MM2-9X5W Wireless Data Transceivers

(For Restricted Use)

Covering Firmware v10.6.7

User Manual and Reference Guide

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2. If Product is used outside of FreeWave specifications as stated in the Product's data sheet.

3. If Product has been modified, repaired, or altered by Customer unless FreeWave specifically authorized such alterations in each instance in writing. This includes the addition of conformal coating.

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Warning! The MM2-9X5W is sold as a two-board solution, connected at the FreeWave factory, and is not intended for separate applications. Separation of the MM2-T and the power amplifier voids the FreeWave warranty.

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Preface

This document includes the following regarding the FreeWave MM2-9X5W:

- A basic introduction to the transceiver and how to determine the mode you want to run it in.
- Examples of how FreeWave transceivers can exist in a network with other transceivers.
- How to access the setup parameters available on the transceiver.
- Basic transceiver programming and setup information that applies to all network types.
- Considerations and quick starts for your network design, including charts of LED displays.
- Details about defining a MultiPoint network including the use of subnet IDs to route information through the network.
- Steps to view statistics about a transceiver's performance.
- Pinouts and mechanical drawings.

For information about the firmware releases that apply to the transceiver, see Appendix A.

The contents of this document assumes that you have a basic understanding of Tool Suite and its components. For more information about using Tool Suite, see the *Tool Suite User Manual* available on the *User Manual and System Tools* CD or by selecting **File > Help** in the Tool Suite software.

Notational Conventions

This document uses the following notational conventions:

- **Bold** - Indicates items that you select, parameter settings, and parameter names.

- ⚠ **Warning!** - Indicates a situation that may cause damage to the transceiver, data, or network.

- 🌟 - Provides time saving or informative suggestions about using the product.

The term "radio" and "transceiver" are used throughout this manual to refer to the MM2-9X5W.

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Contacting FreeWave Technical Support

For up-to-date troubleshooting information, check the Support page at www.FreeWave.com.

FreeWave provides technical support Monday through Friday, 7:30 AM to 5:30 PM Mountain Time (GMT -7). Call toll-free at 1.866.923.6168, within Colorado call 303.381.9200, or contact us through email at moreinfo@freewave.com.

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Chapter 1: Introduction

FreeWave serial transceivers are DCE (Data Communications Equipment) transceivers that operate in virtually any environment where data communications occur. The transceivers act as data transmission devices, duplicating data in either Point-to-Point or Point-To-MultiPoint mode.

The MM2-9X5W consists of an MM2-T (the top board) and a power amplifier (bottom board) and is for restricted use only. The MM2-9X5W is for applications that permit the operation within the 902 to 928 MHz frequency band while transmitting 5 Watts RF.

> ⚠️ **Warning!** The MM2-9X5W is sold as a two board solution, connected at the FreeWave factory, and is not intended for separate applications. Separation of the MM2-T and the power amplifier voids the FreeWave warranty.

Choosing a Location for the Transceiver

Placement of the FreeWave transceiver is likely to have a significant impact on its performance. The key to the overall robustness of the RF link is the height of the antenna. When using an external antenna, placement

of that antenna is critical to a solid data link. Other antennas in close proximity are a potential source of interference; use the Radio Statistics to help identify potential problems. In general, FreeWave units with a higher antenna placement will have a better communications link. In practice, the transceiver should be placed away from computers, telephones, answering machines, and other similar devices. FreeWave Technologies, Inc. offers directional and Omni directional antennas with cable lengths ranging from 3 to 200 feet.

The Show Radio Statistics page is found in option 4 in the main terminal menu or in the Diagnostic information in Tool Suite. An adjustment as little as 2 feet in antenna placement may resolve some noise issues.

Choosing Point-to-Point or Point-to-MultiPoint Operation

A Point-to-Point network is best suited when your network consists of one Master and one Slave transceiver. You can add up to four Repeaters to extend the reach of the network.

> **Important:** Adding a Repeater to a network cuts the network throughput by 50%.

In a Point-to-MultiPoint network (also referred to as MultiPoint network) the Master transceiver is able to simultaneously communicate with numerous Slave transceivers. In its simplest form, a MultiPoint network functions with the Master broadcasting its messages to all Slave transceivers. If requested by the Master, the Slave transceivers respond to the Master when given data by the device connected to the data port. This response depends on your setup. You can extend the reach of the network with as many Repeaters as is required. Adding Repeaters to a network cuts the throughput by half.

It is important to note the differences between Point-to-Point and MultiPoint networks. In a Point-to-Point network all packets are acknowledged, whether sent from the Master to the Slave or from the Slave to the Master. In a MultiPoint network, you determine the number of times outbound packets from the Master or Repeater to the Slave or other Repeaters are sent. The receiving transceiver, Slave or Repeater, accepts the first packet received that passes the 32 bit CRC. However, the packet is not acknowledged. On the return trip to the Master, all packets sent are acknowledged or retransmitted until they are acknowledged. Therefore, the return link in a MultiPoint network is generally very robust.

Traditionally, a MultiPoint network is used in applications where data is collected from many instruments and reported back to one central site. The architecture of such a network is different from Point-to-Point applications. The following parameters influence the number of transceivers that can exist in a MultiPoint network:

1. Data block size. The longer the data blocks, the fewer number of deployed Slave transceivers can exist in the network.

2. Baud rate. The data rate between the transceiver and the device to which it is connected could limit the amount of data and the number of transceivers that can exist in a network

3. The amount of contention between Slave transceivers. Polled Slave transceivers versus timed Slave transceivers.

4. Repeater Use. Using the **Repeater** setting in a Point-to-Point or MultiPoint network decreases overall network capacity by 50%.

For example, if the network polls once a day to retrieve sparse data, several hundred Slave transceivers could be configured to a single Master. However, if each Slave transmits larger amounts of data or data more frequently, fewer Slave transceivers can link to the Master while receiving the same network performance. When larger amounts of data are sent more frequently, the overall network bandwidth is closer to capacity with fewer Slave transceivers.

Data Communication Link Examples

FreeWave transceivers' versatility allows data links to be established using a variety of different configurations.

The example below shows the most common and straight forward link; a Master communicating to a Slave in a Point-to-Point link.
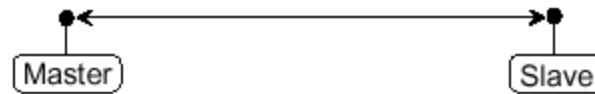
The example below shows how a link using a Repeater. The Repeater may be located on a hilltop or other elevated structure enhancing the link from the Master to the Slave. In this configuration, it may be desirable to use an external Omni directional antenna at the Repeater. A Yagi antenna may be used at both the Master and Slave transceivers.

Adding a Repeater to a network cuts the network throughput by 50%.
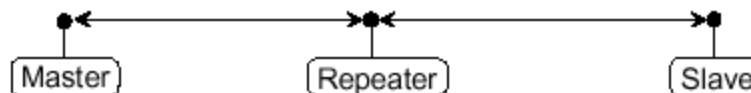
The example below shows a link with two Repeaters between the Master and Slave. With two Repeaters there is more flexibility in getting around obstacles and greater total range is possible. Again, it may be desirable to use external Omni-directional antennas with the Repeaters, and attaching a Yagi antenna to the Master and Slave transceiver to increase the range of the link.

When two Repeaters are used no further degradation in the RF throughput of the link is experienced.
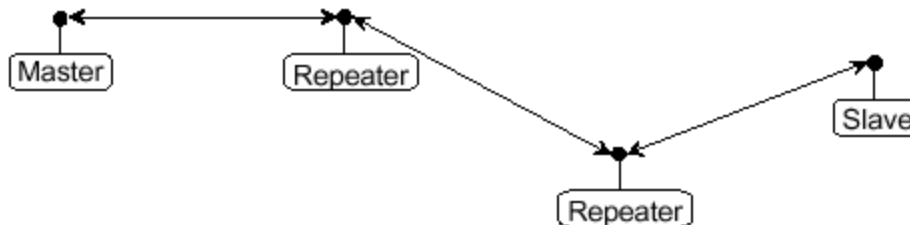
The example below shows a configuration where a Master transceiver routinely calls a number of Slave transceivers at different times. The Master transceiver is communicating with a transceiver designated as a Slave/Repeater that is connected to a remote device. Since this device is placed in an elevated location, the transceiver may also be used as a Repeater when it is not used as a Slave. At any time the Master may call any of the Slave transceivers, establish a connection, and send and receive data.
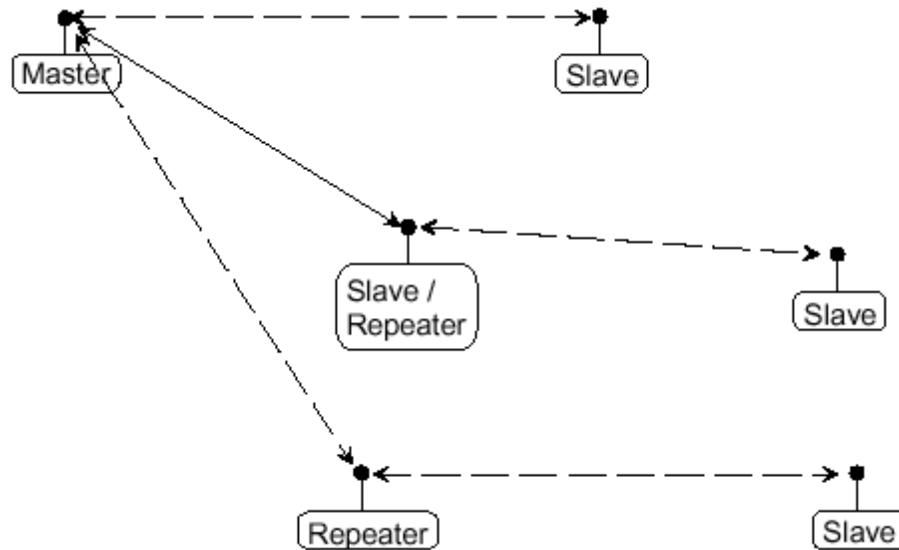
The next example illustrates a standard Point-to-Multipoint network. From the Master, any data is broadcast to all three Slave transceivers, one of which receives it through a Multipoint Repeater. The data is in turn sent out of the serial port of each of the three Slave transceivers. The end device should be configured to interpret the serial message and act on it if necessary.
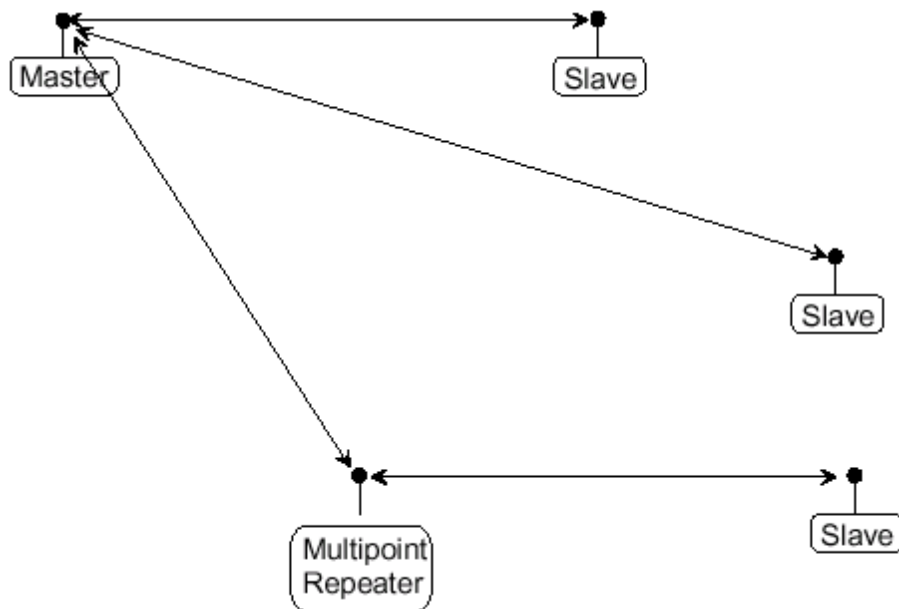
The last example is a Point-to-Multipoint network that uses one of the sites as a Slave/Repeater. This network functions in the same manner as a standard Multipoint network with Repeaters. However, the number of transceivers may be reduced with the use of the Multipoint Slave/Repeater feature.
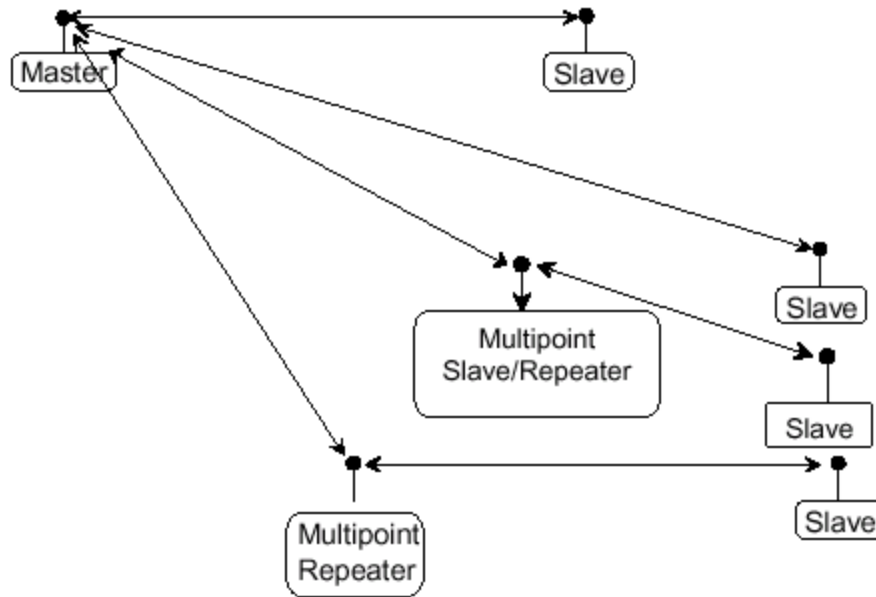
Finding the Product Serial Number

Each FreeWave transceiver is assigned a unique serial number. If you need to contact FreeWave Technical Support, you will be asked for the serial number on the transceiver you are calling about.

The serial number is three digits, followed by a hyphen and four digits, for example 111-1111, and is printed on a label on the smaller of the two boards that comprise the MM2-9X5W.
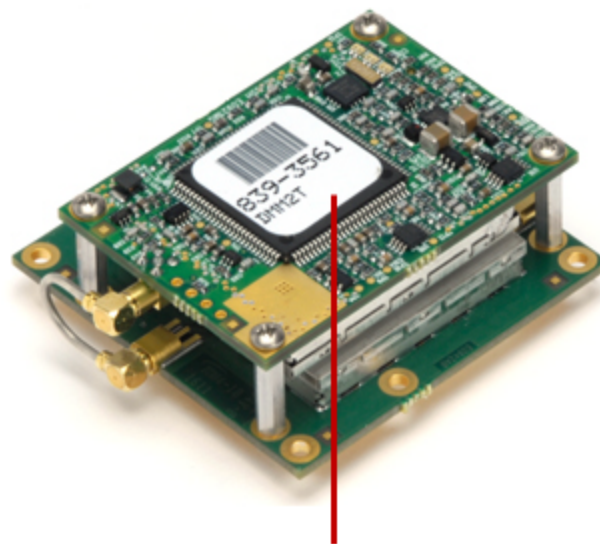
Product Serial
Number

Powering the Transceiver

Pin 2 on the J4 connector powers the amplifier portion of the MM2-9X5W. Connect it to a positive supply with +12.0 VDC ± 5%.

> ⚠️ **Warning!** Applying a supply voltage to the amplifier that is above or below +12.0 VDC ± 5% may render the product inoperable or cause permanent damage to the product and voids the warranty.

Pin 3 on the J4 powers the radio portion of the MM2-9X5W. Connect it to a positive supply with +4.9 to +5.5 VDC.

If the power supply line runs outside the enclosure, use electrostatic discharge (ESD) protectors to protect the transceiver from electric shock, and transient voltage suppressors (TVS) to protect from an over-voltage situation. Using both helps enhances reliable operation and can be purchased at most electronic supply stores.

In addition, due to the amplified power, ensure that you place the transceiver on an appropriate heat sink to transfer its heat, and connect the RF port to a device with more than 6 dB and rated to 5 W to protect any surrounding components.

> **Note:** If the input power decreases, the amplified power out also decreases. For more information about output power, see "Transmit Power" on page 29.

Output Protection

The MM2-9X5W attempts to transmit its data, even if the antenna is damaged or broken off during use. If there is no load on the antenna port, it shuts off the amplifier. The MM2-9X5W attempts to transmit again at its next transmit interval. If there still is no load, it shuts down the output. This behavior continues until there is a load or no data to transmit.

Configuration Tool Options

> **Note:** The terms modem and transceiver are used interchangeably in this document and in the text within the setup tools. While the words have different meanings, the two terms should be treated as one and the same when referring to FreeWave products.

When the transceiver is in Setup mode, you can use the following setup tools to configure the settings on the transceiver:

- **Tool Suite** - Tool Suite is the newest configuration software and replaces EZConfig, and is the recommended method for programming your transceivers.

  It provides a group of tools for configuring the devices in your network and for monitoring your network's performance. Using the Configuration application within Tool Suite, you can program changes to your transceiver's settings. Tool Suite is available on the *User Manual and System Tools* CD and is also available for download from www.FreeWave.com.

  For more information about using Tool Suite, see the *Tool Suite User Manual* available on the *User Manual and System Tools* CD or by selecting **File > Help** in the Tool Suite software.

- **Terminal Emulator** - A terminal emulator program, such as HyperTerminal or Tera Term, offers many of the same configuration options that are available in the Configuration application in Tool Suite. Terminal emulators vary in cost, and several are downloadable free of charge. If you run versions of the Windows operating system prior to Windows 7, HyperTerminal is included in the operating system installation. However, if you are running Windows 7 or newer, HyperTerminal is no longer available.

  You can use the terminal emulator program of your choice to program the transceiver. The Setup Terminal application within Tool Suite provides the same interface that is available using a terminal emulator.

For OEMs and engineering firms that want to integrate the MM2-9X5W into their product, the above approaches can be used for programming the MM2-9X5W. In addition to this approach, FreeWave offers a more "machine friendly" method that allows specific commands to be sent directly to the MM2-9X5W without using the menu system. FreeWave requires a Non Disclosure Agreement (NDA) prior to providing information about how to program transceivers in this manner. Contact your FreeWave sales representative for further details.

Tool Suite and Terminal Emulators

If you are using a terminal emulator, the tabs for a device in Tool Suite mirror the Setup main menu selections. For example, option **0** from the Setup main menu in the terminal menu setup is **Set Operation Mode**. The corresponding configuration tab for the device in Tool Suite is **(0) Operation Mode**.
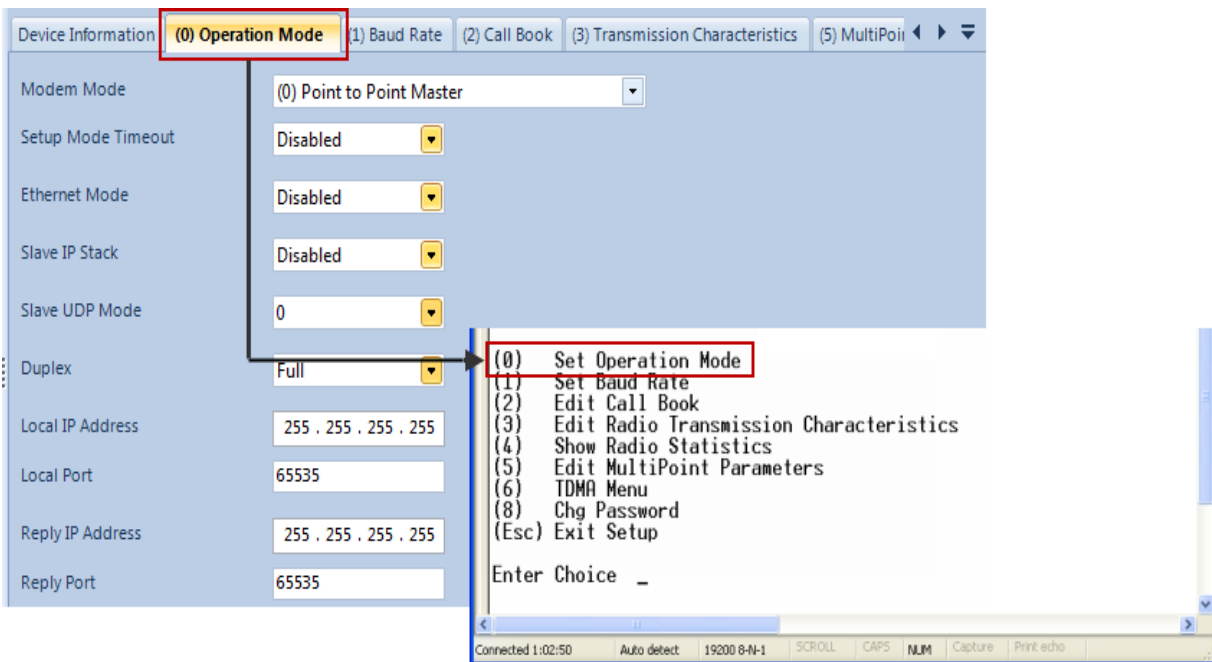
You can also use the Setup Terminal application within Tool Suite to use and view the terminal menus. It displays the same menus and provides the same programming settings as you see using a terminal emulator.

Throughout this document, if the setup procedure in the terminal emulator is different than the procedure in Tool Suite, the terminal instructions are also included.

Transceiver Setup Mode

To read the current settings from or to program a transceiver, the transceiver must be in Setup mode. When a transceiver is in Setup mode, all three LEDs display solid green ▪ ▪ ▪ . See the sections below for details about how to access the transceiver's Setup mode using Tool Suite or the terminal interface.

> **Note:** OEM boards may also enter Setup when Pin 2 on a 10-pin connector or Pin 8 on a 24-pin connector is grounded, or using a break command. For more information about the break command, see "Use Break to Access Setup" on page 19.

The **Setup Port** parameter in the Baud Rate tab determines whether the main data port or the diagnostics port is used to access the setup parameters for the transceiver. For more information, see "Setup Port" on page 18.

Using the **Setup Mode Timeout** parameter in the Operation Mode tab, you can set the transceiver to exit Setup Mode automatically. When the setting is enabled, if the transceiver has not received any menu selections or programming information within 5 seconds, it exits Setup and resumes its previous mode.

For Setup mode troubleshooting information, see "Troubleshooting " on page 71.

Using Tool Suite to Connect to and Program Transceivers

To read and program a transceiver using Tool Suite, you need to connect the transceiver to a computer that runs the Tool Suite software. You can also use Tool Suite to set up a template version of a transceiver. Templates include settings that apply to more than one transceiver in your network. For more information about using templates, see the *Tool Suite User Manual* available from the **File > Help** menu within the application.

1. Connect a serial or diagnostic cable between the computer or laptop and the transceiver.

   Using a diagnostic cable and the diagnostic port is recommended.

2. Connect the power supply to the transceiver and the power source and turn on the transceiver.

3. With the transceiver connected to the computer in Tool Suite, click **Configuration** in the Application pane to display the Configuration application.

4. Ensure the correct port is selected in the **Com Port** field in the Configuration ribbon.

5. Short Pin 4 to place the transceiver into Setup mode.
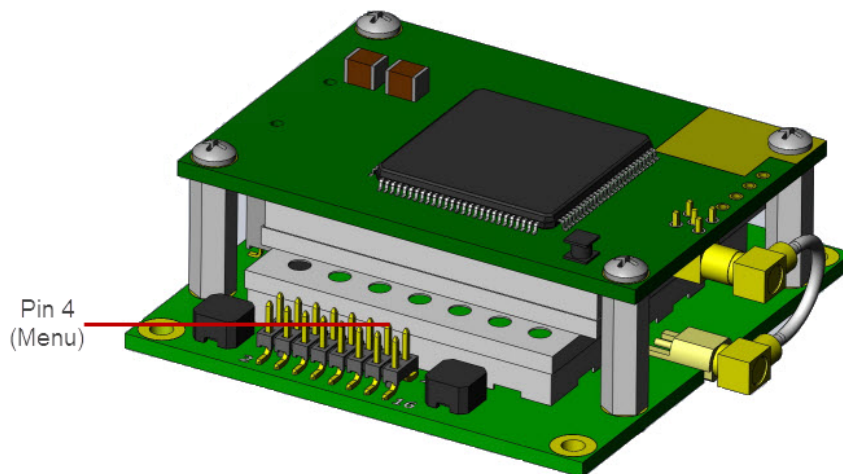
6. Click **Read Radio** in the Configuration ribbon to read the transceiver's current settings.

7. Make the necessary parameter changes and do one of the following to send the changes to the transceiver:

   - To send only the parameters you have changed, within the Configuration application in the Network Title ribbon, click **Quick**. This option is only available if you clicked **Read Radio** and are not sending parameter settings from a template to the transceiver.

   - To send all the settings for all parameters, within the Configuration application in the Network Title ribbon, click **All**.

   - To set a device back to its factory default settings, within the Configuration application in the Network Title ribbon, click **Default**.

For more information about using Tool Suite, see the *Tool Suite User Manual* available on the *User Manual and System Tools* CD or by selecting **File > Help** in the Tool Suite software.

Accessing the Setup Menu Using a Terminal Emulator

Use a terminal emulator of your choice to access the Setup menu. For any terminal emulator application, plug the serial cable into a COM port on the transceiver, open a session, and ensure that the port settings are set to the following for a proper connection to the transceiver:

Port Setting	Select
Bits per second	19200
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None

The following instructions describe how to access the transceiver's Setup menu using the Setup Terminal application within Tool Suite. Setup Terminal contains the port settings above, by default. For more information about using Tool Suite, see the *Tool Suite User Manual* available on the *User Manual and System Tools* CD or by selecting **File > Help** in the Tool Suite software.

1. Plug a serial cable into the COM 1 port on the transceiver, connect the cable to a COM port on the computer running Tool Suite, and connect the transceiver to a power source.

2. Open Tool Suite and select Setup Terminal in the Applications pane.

3. From the drop-down list at the top left of the window, select the COM port on the computer to which the transceiver is connected.
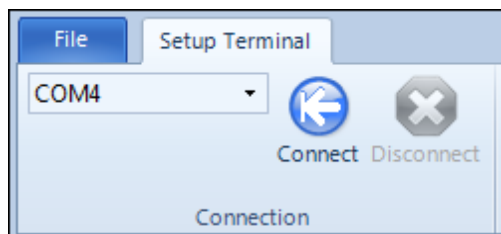
4. Click **Connect**.

5. Short Pin 4 (Menu) to place the Transceiver in Setup Mode.
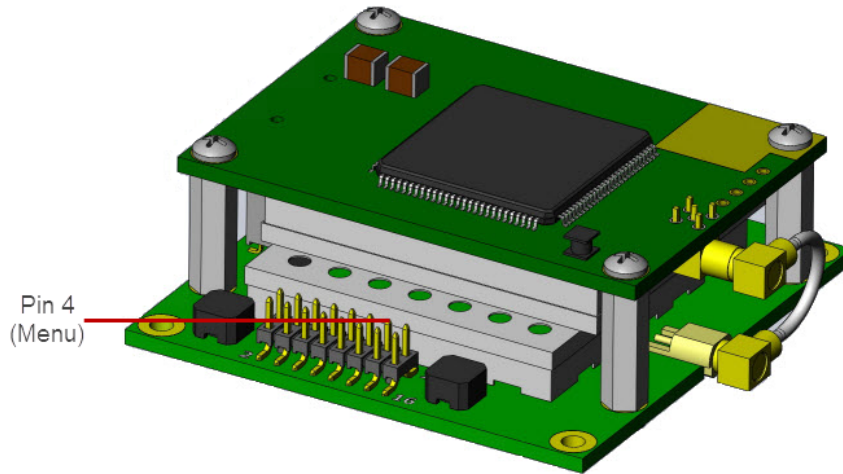
As you navigate through the Setup menu and make changes to the parameters, the parameters are sent to the transceiver *immediately*.

Connecting and Disconnecting from HyperTerminal

The HyperTerminal dialog box displays several icons in the toolbar. To reconnect to HyperTerminal, you need to disconnect your current session. Click the **Disconnect** icon, and then click the **Call** icon to reconnect. If the settings have not been saved they must be re-selected when HyperTerminal reconnects to the transceiver.

Troubleshooting HyperTerminal

The following are some common issues encountered while using HyperTerminal as the terminal emulator. The steps to resolve the issue are specific to the HyperTerminal interface, however, you can use similar steps when troubleshooting other terminal emulators.

> **Important:** When a change is made to the HyperTerminal settings in an open terminal session, the connection must be disconnected then reconnected before the settings take effect.

This error usually indicates one of two things; either the wrong COM port is selected or a null modem cable is being used. Follow the steps below to change the COM port.

1. Click the **Disconnect** icon.
2. From the **File** menu, select **Properties**.
3. Click the **Connect To** tab and verify that the correct COM port is selected.
4. Click **OK** to close the Properties dialog box.
5. Click the **Call** icon.
6. Return the transceiver to Setup mode. The Setup menu screen displays.

In addition, if the transceiver has been previously configured, you could be using the wrong port to access the Setup menu. For more information, see "Setup Port" on page 18.Try connecting to the other port.

Unrecognizable characters usually indicates a Baud Rate problem. Follow the steps below to change the Baud Rate.

1. Click the **Disconnect** icon.

2. From the **File** menu, select **Properties**.

3. Click **Configure**, change the following and click **OK**:

   - **Baud Rate** to **19200**
   - **Data Bits** to **8**
   - **Parity** to **None**
   - **Stop Bits** to **1**
   - **Flow Control** to **1**

4. Click **OK** to close the Properties dialog box.

5. Click the **Call** icon.

6. Return the transceiver to Setup mode. The Setup menu screen displays.

The Setup menu displays on the screen, but nothing happens when keys on the keyboard are pressed.

This error usually indicates flow control is turned on in a three-wire connection (Rx, Tx, and Gnd). Follow the steps below if the connection uses a three-wire connection.

1. Click the **Disconnect** icon.

2. From the **File** menu, select **Properties**.

3. Click **Configure**, change the **Flow Control** to **None**, and click **OK**.

4. Click **OK** to close the Properties dialog box.

5. Click the **Call** icon.

6. Return the transceiver to Setup mode. The Setup menu screen displays.

A connection exists, the terminal emulator is receiving data, and some data is correct, but the remaining data is in unrecognizable characters.

This error usually indicates a parity mismatch. To resolve this issue, ensure that the parity of the transceiver and the parity of HyperTerminal are set the same. HyperTerminal's parity settings are under the Properties menu. The FreeWave transceiver parity is found under the Baud Rate menu in the Setup menu.

1. Within HyperTerminal, click the **Disconnect** icon.

2. From the **File** menu, select **Properties**.

3. Click **Configure**, change the **Parity** to **None**, and click **OK**.

4. Click **OK** button to close the Properties dialog box.

5. Click the **Call** icon.

6. Return the transceiver to Setup mode. The Setup menu screen displays.

Upgrading Transceivers to the Latest Firmware

If Tool Suite is connected to a transceiver, and a new version of the firmware is available for that transceiver model, an indication displays within the Configuration application's Device Information tab. You can use Tool Suite to upgrade firmware on a serial transceiver that is connected directly to the computer using the diagnostic cable. You cannot complete an over-the-air upgrade using Tool Suite.

> **Note:** If you are using a USB-to-serial converter cable, a firmware upgrade can take a long time to complete. FreeWave recommends using USB-to-serial cables that include the FTDI Chip Set to shorten the upgrade time. This inclusion is listed on the cable's packaging.

For more information about using Tool Suite, see the *Tool Suite User Manual* available on the *User Manual and System Tools* CD or by selecting **File > Help** in the Tool Suite software.

Use the steps below to upgrade a transceiver to the latest firmware:

1. With the transceiver connected to your computer through the COM port, open Tool Suite and click **Configuration** in the Applications pane to display the Configuration application.

2. Click **Upgrade Radio** in the Firmware section of the Configuration ribbon.

3. Click **Yes** at the prompt to proceed or **No** to cancel without installing the new firmware.

   Tool Suite identifies and displays the firmware version that is loaded on the connected device and displays the latest version of firmware available for that model.

4. Click **Yes** to proceed with the upgrade, or **No** to exit.

   The system displays the progress of the firmware upgrade. After the firmware upgrade is complete, a message displays that the firmware upgrade was successful.

Chapter 2: Basic Transceiver Programming and Setup

As you set up your network, whether it be a Point-to-MultiPoint network or a Point-to-Point network, the process for setting up and programming a transceiver is the same. This chapter describes the following aspects of programming and setting up a transceiver:

- Setting the transceiver's role in the network and the network type. .
- Entering parameters that establish communication with the instrument or computer to which the transceiver is connected.
- Establishing communication with other transceivers in the network.
- Setting RF transmission characteristics.

Setting the Transceiver's Role in the Network and the Network Type

Networks consist of a Master transceiver and any number of other components including Repeaters, Slave transceivers, and transceiver's that act as both a Slave and a Repeater. The first parameter to set in a transceiver is its Operation Mode or Modem Mode. The mode tells the transceiver what network type it is in (Point-to-Point or Point-to-MultiPoint) and what role it plays, Master, Slave, or Repeater, in that network.

> **Note:** The network type must match for all transceivers in a network. For example, if you are configuring a Point-to-MultiPoint network, ensure the **Modem Mode** selection for transceivers in the network starts with Point-to-MultiPoint.

In a Point-to-Point configuration, Master or Slave mode may be used on either end of the link without performance degradation. When setting up the transceiver, remember that the settings on the Master control a

number of parameters. Therefore, deploying the Master on the communications end where it is easier to access is advised, but not necessary.

Set the Modem Mode in the Operation Mode tab, using the **Modem Mode** field. These settings are available in the Operation Mode menu in the terminal interface. Select from the following options:

Operation Mode	Description
Point-to-Point Master (0)	This mode designates the transceiver as the Master in Point-to-Point mode. The Master may call any or all Slaves designated in its Call Book. In Point-to-Point mode the Master determines the setting used for most of the transmission characteristics, regardless of the settings in the Slave and/or Repeaters. The settings not determined by the Master are: • **Transmit Power** • **Slave Security** • **Retry Time Out** • **Hop Table settings** A quick method of identifying a Master is to power the transceiver. Prior to establishing a link with a Slave, all three of the LEDs on the Master are solid red.
Point-to-Point Slave (1)	This mode designates the transceiver as a Slave in Point-to-Point mode. The Slave communicates with any Master in its Call Book—either directly or through up to four Repeaters. When functioning as a Slave, the Entry to Call feature in the transceiver's Call Book is not operational. Set the **Slave Security** parameter to **1** to bypass the Call Book in the Slave. For more information, see "Slave Security" on page 29.
Point–to-MultiPoint Master (2)	This mode designates the transceiver as a Master in MultiPoint mode. This mode allows one Master transceiver to communicate simultaneously with numerous Slaves and Repeaters. A Point-to-MultiPoint Master communicates only with other transceivers designated as Point-to-MultiPoint Slaves or Point-to-MultiPoint Repeaters.
Point-to-MultiPoint Slave (3)	This mode designates the transceiver as a Slave in MultiPoint mode. This mode allows the Slave to communicate with a MultiPoint Master. The Slave may communicate with its Master through one or more Repeaters.

Operation Mode	Description
Point-to-Point Slave/Repeater (4)	This mode designates the transceiver to act as *either* a Slave or Repeater—depending on the instructions from the Master. The transceiver cannot act as both a Slave and a Repeater at the same time. True Slave/Repeater functionality is only available in a MultiPoint mode. Adding a Repeater to a network cuts the network throughput by 50%. **Note:** Point-to-Point Slave/Repeaters have no security features. When a transceiver is designated a Point-to-Point Slave/Repeater, it allows any Master to use it as a Repeater.
Point-to-Point Repeater (5)	FreeWave allows the use of up to four Repeaters in a Point-to-Point communications link, significantly extending the operating range. When designated as a Repeater, a transceiver behaves as a pass-through link. All settings for the Call Book, baud rates, and transmission characteristics are disabled. A Repeater connects with any Master that calls it. The Repeater must be set up properly in the Master's Call Book. Adding a Repeater to a network cuts the network throughput by 50%.
Point-to-Point Slave/Master Switchable (6)	Mode 6 allows the transceiver to be controlled entirely through software commands. A number of key parameters in the FreeWave user interface may be changed either directly with a program such as Windows Terminal or through the use of script files. Additionally, when the **Point-to-Point Slave/Master Switchable** option is selected and the transceiver is not calling a Slave, it functions as a Slave and accepts any appropriate calls from other transceivers. For more information, see application note #5476, *Mode 6*.
Point-to-MultiPoint Repeater (7)	This option allows the transceiver to operate as a Repeater in a MultiPoint network. You can have as many Repeaters as necessary in a MultiPoint network. If the Repeater is to act as a Slave/Repeater, also set the **Slave Repeater** parameter in the MultiPoint Parameters tab to **Enabled**. Adding a Repeater to a network cuts the network throughput by 50%.
Mirrorbit Master (A) **Mirrorbit Slave (B)**	Mirrorbit Master and Mirrorbit Slave mode are currently not supported.

Establishing Communication with Instrumentation and Computers

The settings in the Baud Rate tab are the communications settings between the transceiver and the instrument or computer to which it is connected (transceiver serial port to the device). These settings are unique to each transceiver, and do not need to match across the network.

For example, a pair of transceivers may be used in an application to send data from remote process instrumentation to an engineer's computer. In this application, the baud rate for the transceiver on the instrumentation might be set to 9600, and the transceiver on the polling host might be set to 57,600.

Set the following parameters in the Baud Rate tab. These settings are available in the Baud Rate menu in the terminal interface, and apply to both Point-to-Point and Point-to-MultiPoint networks.

Baud Rate

Default Setting:	115200
Options:	600, 1200, 2400, 4800, 9600, 19200, 38400, 57600, 76800, 115200, 230400
Setup Terminal Menu:	(1) Set Baud Rate
Description:	The communication rate between the transceiver's data port and the instrument to which it is connected. This setting is independent from the baud rate for the other transceivers in the network. Set the baud rate to the highest level supported by the device to which it is connected. With a poor RF link, this may actually result in slower data communications.

With a **Baud Rate** setting of 38,400 or higher, FreeWave recommends that you use the Flow Control lines.

Note: The Setup port baud rate always defaults to **19,200** no matter how the data port Baud Rate is set. The only exception is Mode 6. For more information, see application note #5476, *Mode 6*.

Data Parity

Default Setting:	0 (8, N, 1)
Options:	See table below.
Setup Terminal Menu:	(1) Set Baud Rate > (A) Data Parity
Description:	Six data word length and parity configurations are available for use with FreeWave transceivers. The default setting is **8-None-1** and is the most commonly used serial communications protocol.

The following table describes each option:

Option	Data Bits	Parity	Stop Bits
0	8	None	1
1	7	Even	1
2	7	Odd	1
3	8	None	2
4	8	Even	1
5	8	Odd	1

Flow Control

Default Setting:	(0) None
Options:	• **(0) None** - No flow control CTS is active and de-asserts when buffering is 98% full. Can pass XON/XOFF data but does not use it in any way.
	• **(1) RTS** - Uses RTS/CTS (Request to Send/Clear to Send) for flow control..
	• **(2) DTR** - Uses DTR/DSR (Data Terminal Ready/Data Set Ready) for flow control..
	• **(3) DOT** - Half Duplex
Setup Terminal Menu:	(2) Set Baud Rate > (F) FlowControl
Description:	Specifies the hardware flow control for the data port on the transceiver. Flow control is the process of managing the speed at which data is transmitted so as not to overwhelm the device receiving the transmission. FreeWave recommends using **Flow Control** if you are using a baud rate higher than 38,400.

Modbus RTU

Note: When using the transceiver in **Modbus RTU** mode, the **Master Packet Repeat** parameter setting in the MultiPoint Parameters tab must match in every transceiver.

Default Setting:	0 (Disabled)
Options:	0 to 9
Setup Terminal Menu:	(1) Set Baud Rate > (B) Modbus RTU
Description:	A setting other than **0** in this parameter causes the transceiver to wait for an amount of time "gathering" data before sending out the RF link.

- **0 (Disabled)** - The transceiver sends data out through its RF link as soon as the data is received into the serial port. This is the default setting.
- **1** - The transceiver waits for a number of slots equal to two times the **Master Packet Repeat** setting before sending the received data out the RF link. For example, if the **Master Packet Repeat** parameter is set to **3**, the transceiver waits for 6 slots, gathering data up the whole time. At the end of the 6 slots, the transceiver sends all received data in one "burst." This is the appropriate setting for most Modbus RTU devices.
- **2 or higher** - The transceiver waits for a number of slots calculated using the following formula:

    (Modbus RTU setting + Master Packet Repeat setting + 1) x 2

    For example, in a transceiver where the **Modbus RTU** setting is **2** and the **Master Packet Repeat** setting is **3**, the transceiver waits for (2 + 3 + 1) x 2, or 12 slots.

Serial Interface

Default Setting:	(0) RS232
Options:	In all MM2-9X5W models, this must be set to **(0) RS232**.
Setup Terminal Menu:	(1) Set Baud Rate > (C) RS232/485
Description:	Use this option to set the protocol of the data port for connection to an external device.

Setup Port

> **Important:** Do not change this setting unless the correct programming cable is available for the new setting.

Default Setting:	(3) Both
Options:	• **(1) Main Only** - Programming and reading a transceiver's setup information is done through the data port. • **(2) Diagnostics Only** - Programming and reading a transceiver's setup information is done through the diagnostic port. • **(3) Both** - Programming and reading a transceiver's setup information is done through either the data port or the diagnostic port .
Setup Terminal Menu:	(1) Set Baud Rate > (D) Setup Port
Description:	Determines which port on the transceiver, Main or Diagnostics, is used to access the parameter settings in Tool Suite or enter the Setup main menu in the terminal interface.

Turn Off Delay

> **Note:** The MM2-9X5W transceivers do not use the **Turn Off Delay** parameter.

Turn On Delay

Default Setting:	0 ms
Options:	Any number between 0 and 9 ms
Setup Terminal Menu:	(1) Set Baud Rate > (E) Turn On Delay
Description:	Sets the delay between when the line drivers are turned on and when the data leaves the data port.

Use Break to Access Setup

> **Note:** This setting is typically only used in OEM scenarios.

Default Setting:	Disabled
Options:	• (0) - Disabled - The break command is disabled.
	• (1) - Enabled - The Setup menu is sent at 19,200 bps.
	• (2) - Enabled - The Setup menu is sent at the transceiver's current baud rate. This setting is only available through the terminal interface.
Setup Terminal Menu:	(2) Set Baud Rate > (G) Use break to access setup
Description:	Enables a break command to put the transceiver into Setup mode over the data port. To send a break character the end device must hold the Tx data line in the space voltage level for longer than 1 character time. If a character is defined as having 1 start bit, 8 data bits, and 1 stop bit, the character time is 10 bits, thus the transmit data line must be held in the space voltage level for a period of time longer than 10 bits.

Establishing Communication with Other Transceivers in the Network

For the transceivers in your network to communicate successfully, you need to tell the transceivers what other devices are available for them to communicate with. Use one of the following options:

- **Network ID** - Used in MultiPoint Networks, the **Network ID** parameter is available in the MultiPoint Parameters tab. Each transceiver in a single network should be assigned the same ID. A Slave links with the first Master or Repeater that it hears that has a matching **Network ID**.

  Because the **Network ID** does not use serial numbers, MultiPoint Masters and Repeaters may be replaced without reprogramming all of the Slaves in the network. The **Network ID** function should be used in conjunction with the **Subnet ID** feature (if necessary) to route data through the transceiver network.

  Without having the serial numbers in the Call Book, Slaves may establish communications with different Masters that match the transceiver's golden settings described below, though not at the same time. This is very useful in mobile MultiPoint applications.

  For information about setting the **Network ID** parameter in a MultiPoint Network, see "Using the Network ID in MultiPoint Networks" on page 36.

- **Call Book** - The Call Book is *required* in Point-to-Point networks. The Call Book stores serial numbers of other transceivers in the network that are allowed to talk to a transceiver. Using the Call Book offers both security and flexibility in determining how FreeWave transceivers communicate with each other.

> **Important:** While the Call Book is an option in Point-to-MultiPoint networks, FreeWave strongly recommends using the **Network ID** feature in most applications. If a large MultiPoint network is implemented using the Call Book and you want to add a transceiver to the network, or need to replace a transceiver, you must physically reprogram each transceiver in the network and enter the new serial number in the transceiver's Call Book. This can be a time consuming process and can cause a delay in getting your network back up and running.

For more information about defining the Call Book in a Point-to-Point network, see "Using the Call Book in Point-to-Point Networks" on page 54. For more information about defining the Call Book in a Point-to-MultiPoint network, see "Using the Call Book in MultiPoint Networks" on page 36.

"Golden Settings"

A standard network requires that the following parameters are set the same on all transceivers in the network. FreeWave refers to these as the "golden" settings.

- **Frequency Key**
- **Min Packet Size**
- **Max Packet Size**
- **Network ID**
- **RF Data Rate**

Transceivers that contain the same settings in all these parameters can communicate with each other. If you choose to use the Call Book instead of the **Network ID**, or are running a Point-to-Point network, the appropriate serial numbers must be listed in the Call Book for each transceiver. If you are working with parallel Repeaters, the **Frequency Key** setting may differ.

Setting RF Transmission Characteristics

The Transmission Characteristics parameters allow you to modify settings that determine how data is sent between transceivers in your network. Many of these parameters must be maintained throughout the network for proper functionality.

> **Important:** The parameters in the Transmission Characteristics tab are only for the advanced user who has a good understanding of the principles of RF transmission.

Several settings on a Slave or Repeater transceiver come from the Master, and are therefore set *only* at the Master. Settings that you must set on each *Slave or Repeater* include the following:

- **Transmit Power**
- **Slave Security**
- **Retry Time Out**
- **Hop Table Size**
- **Hop Table Version**
- **Hop Table Offset**

You can leave most parameters in the Transmission Characteristics tab set to their default settings when completing basic setup. However, you must set the following parameters, and they *must be the same* for all transceivers in your network:

- **Frequency Key**
- **Hop Table properties (Size, Version, and Offset)**
- **Max Packet Size**

- **Min Packet Size**
- **RF Data Rate**

Set the following parameters in the Transmission Characteristics tab. These settings are available in the Edit Radio Transmission Characteristics menu in the terminal interface, and apply to both Point-to-Point and Point-to-MultiPoint networks, unless indicated otherwise in their description.

Frequency Key (Golden Setting)

Note: In MultiPoint networks, the **Frequency Key** must be set identically in all transceivers. Any transceiver with a **Frequency Key** different from the Master transceiver will not establish a link. There are exceptions if the network contains parallel repeaters. For more information, see "Working with Parallel Repeaters" on page 59. In Point-to-Point networks the Master transceiver's settings take precedence over the Slave transceiver.

Default Setting:	5
Options:	0 to 9 and A to E
	Note: Do not use **Frequency Key E** with the 915 to 928 MHz, 916 to 920 MHz, and 921 to 928 MHz hop tables.
Setup Terminal Menu:	(3) Edit Radio Transmission Characteristics > (0) FreqKey
Description:	Fifteen choices are available for the **Frequency Key** (0 to 9 and A to E) setting, representing 15 different pseudo-random hop patterns. Hopping patterns minimize the interference with other FreeWave transceivers operating in the area.
	For example, if 10 pairs of FreeWave transceivers are operating on different networks in close proximity, setting a different **Frequency Key** value reduces the chance that the transceivers hop to the same frequency at the same time. If two networks were to hop to the same frequency, the next hop would be to a different frequency for both networks.
	You can gain additional network separation by adjusting the **Max Packet Size** and **Minimum Packet Size** parameters.
	Use the **Hop Table Version**, **Hop Table Size**, and **Frequency Zone** parameters to define more network differentiation by way of limiting the number and location of frequencies the transceivers may hop on in the 902 to 928 MHz band.
	Note: 900 MHz transceivers do not use the **Hop Frequency Offset** setting.

Frequency Zones

Note: In MultiPoint networks, this setting only needs to be set on the Master. In a Point-to-Point network, the Master and the Slave must have matching **Frequency Zone** settings.

Default Setting:	All zones selected

Options:	See below.
Setup Terminal Menu:	(3) Edit Radio Transmission Characteristics > (0) FreqKey > F > (3) Frequency Zone
Description:	Divides the available band (902 MHz to 928 MHz) into smaller bands, in this case 16 smaller bands each consisting of 5, 7, and 8 frequency channels depending on the frequency zone. These 16 zones are stored in a binary word, which is made up of 16 bits numbered 0 to 15. Displayed in LSB to MSB, these bits directly represent the zones that the transceiver operates on from lowest frequency to highest.

A value of **1** in the bit sequence instructs the transceiver to operate within the represented band. A value of **0** bypasses the represented band. This feature should only be used with the standard hop table.

Note: You must set the **Hop Table Version** to **902 to 928 MHz** when using frequency zones. If you select another **Hop Table Version**, the limitations of that selection would be applied to the hopping pattern as well. For example, if you select **916 to 920** as the **Hop Table Version**, only the middle of the band would be available in the pattern. Then, if frequency zones 5, 6, 7, 8, and 9 were set to **0**, no allowable frequencies would be available for the transceiver to use.

Warning! FCC regulations require a minimum of 50 separate channels be used within a hop pattern. Use the table below to determine the number of frequency zones required for legal FCC use.

EXAMPLE:
1. Using zones 1 to 7 is equal to 49 channels; this is not legal according to the FCC.

2. Using zones 0 to 6 is equal to 50 channels; this is legal according to the FCC.

Binary Zone Number (LSB First)	Beginning Freq. (MHz)	Ending Freq. (MHz)	Number Of Channels
1	902.2464	903.8592	8
2	904.0896	905.4720	7
3	905.7024	907.0848	7
4	907.3152	908.6976	7
5	908.9280	910.3104	7
6	910.5408	911.9232	7
7	912.1536	913.5360	7
8	913.7664	915.1488	7
9	915.3792	916.7616	7
10	916.9920	918.6048	8

Binary Zone Number (LSB First)	Beginning Freq. (MHz)	Ending Freq. (MHz)	Number Of Channels
11	918.8352	920.2176	7
12	920.4480	921.8304	7
13	922.0608	923.4432	7
14	923.6736	925.0560	7
15	925.2864	926.6688	7
16	926.8992	927.8208	5

To enable Frequency Zones in Tool Suite:

1. In the Tool Suite Configuration application, select the device to program and click the (3) Transmission Characteristics tab.

2. Click **Frequency Zones** to display the frequency zones available.

3. Select the check boxes next to the Frequency Zones to enable.

To enable Frequency Zones in the terminal interface:

1. From the main Setup menu, select **3 Edit Radio Transmission Characteristics**.

2. Select option **0 FreqKey**.

3. Select **F** for More.

4. Select option **3 Frequency Zone**.

5. Enter **1** to enable a frequency zone and **0** to disable a frequency zone. Frequency Zone entries begin with **1** (LSB) and continue through **16** (MSB).
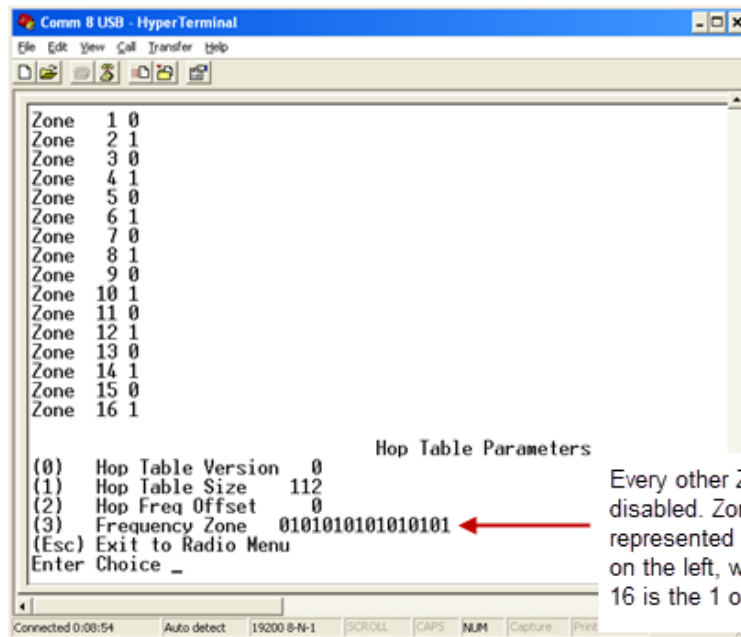
High Noise

> **Note:** This feature is not supported in the MM2-9X5W transceivers.

Hop Table Size

> **Note:** All transceivers in a network must have identical **Hop Table** settings.

Default Setting:	112
Options:	50 to 111
Setup Terminal Menu:	(3) Edit Radio Transmission Characteristics > (0) FreqKey > F > (1) Hop Table Size
Description:	Defines how many separate channels a given network uses.
	FreeWave recommends using **Frequency Zones** instead of the **Hop Table Size** setting.

> **Warning!** FCC regulations require a minimum of 50 separate frequency channels be used within a hop pattern. Using the Standard hop table, a minimum of 5 frequency zones are required for legal FCC use.

Hop Table Version

> **Note:** All transceivers in a network must have identical **Hop Table** settings to function properly.

Default Setting:	902-928 MHz
Options:	• 902-928 MHz, full band
	• 915-928 MHz
	• 903.744-926.3232 MHz
	• 916-920 MHz
	• 921-928 MHz
	• 902-911_919-928 MHz, uses 902-928 MHz with center frequencies of 911-919 MHz notched out
	• 902-915 MHz
	If using a **Hop Table Version** setting of **915-928 MHz**, **916-920 MHz**, or **921-928 MHz**, do not set the **Frequency Key** parameter setting to **E** (916-920 MHz).
Setup Terminal Menu:	(3) Edit Radio Transmission Characteristics > (0) FreqKey > F > (0) Hop Table Version
Description:	Determines the section of the 900 MHz band the transceiver uses.
	In the terminal interface, enter the number that corresponds to the frequency band:

Number to Enter	Frequency Band
0	902-928 MHz, uses the full band
1	915-928 MHz
2	903.744-926.3232 MHz
3	916-920 MHz
4	921-928 MHz
5	902-911_919.928 MHz, uses 902-928 MHz with center frequencies of 911-919 MHz notched out
6	902-915 MHz

Max Packet Size and Min Packet Size (Golden Setting)

Note: In MultiPoint networks, the **Max Packet Size** and **Min Packet Size** must be set identically in all transceivers. In Point-to-Point networks the Master transceiver's settings take precedence over the Slave transceiver.

Default Setting: Max Packet Size = 8
Min Packet Size = 9

Options: Any number between 0 and 9.

Setup Terminal Menu: (3) Edit Transmission Characteristics > (1) Max Packet Size and (2) Min Packet Size

Description: The **Max** and **Min Packet Size** parameter settings and the **RF Data Rate** parameter determine the number of bytes in the packets. Throughput can be enhanced when packet sizes are optimized. In Point-to-Point mode, the **Max** and **Min Packet Size** settings do not have material impact on throughput unless 115.2 kbps is desired. However, this may have an impact on latency. For example, if small amounts of data are sent and large packet sizes are selected, a certain amount of time "wasted" between each packet would be seen.

Within each over-the-air frame, both the Master and Slave are guaranteed the number of bytes specified in the **Minimum Packet Size** parameter. In the Master, this is used for maintaining the RF link whether the Gateway has data to transmit or not. The **Maximum Packet Size** parameter is used to allocate the maximum number of bytes for each Master transmission. The **Minimum Packet Size** is used to allocate the minimum number of bytes for each Slave transmission. If the Gateway does not use all the bytes allocated in the **Maximum Packet Size** setting minus the **Minimum Packet Size** setting, then the remaining bytes are available for the Endpoint.

The following table defines the minimum and maximum packet size in bytes when the **RF Data Rate** parameter is set to **2** (153.6 kbps). Using the default settings, the actual minimum packet size, in bytes, is 63, and the maximum packet size is 233.

RF Data Rate = 2 (153.6 kbps)											
max		Max Packet Total (Data and Overhead)									
	min	0	1	2	3	4	5	6	7	8	9
0		15 / 15	36 / 15	58 / 15	79 / 15	100 / 15	121 / 15	143 / 15	164 / 15	185 / 15	206 / 15
1		20 / 20	42 / 20	63 / 20	84 / 20	105 / 20	127 / 20	148 / 20	169 / 20	190 / 20	212 / 20
2		26 / 26	47 / 26	68 / 26	90 / 26	111 / 26	132 / 26	153 / 26	175 / 26	196 / 26	217 / 26
3		31 / 31	52 / 31	74 / 31	95 / 31	116 / 31	137 / 31	159 / 31	180 / 31	201 / 31	222 / 31
4		36 / 36	58 / 36	79 / 36	100 / 36	121 / 36	143 / 36	164 / 36	185 / 36	206 / 36	228 / 36
5		42 / 42	63 / 42	84 / 42	105 / 42	127 / 42	148 / 42	169 / 42	190 / 42	212 / 42	233 / 42
6		47 / 47	68 / 47	90 / 47	111 / 47	132 / 47	153 / 47	175 / 47	196 / 47	217 / 47	238 / 47
7		52 / 52	74 / 52	95 / 52	116 / 52	137 / 52	159 / 52	180 / 52	201 / 52	222 / 52	244 / 52
8		58 / 58	79 / 58	100 / 58	121 / 58	143 / 58	164 / 58	185 / 58	206 / 58	228 / 58	249 / 58
9		63 / 63	84 / 63	105 / 63	127 / 63	148 / 63	169 / 63	190 / 63	212 / 63	233 / 63	254 / 63

(Left axis label: Min Packet (Date and Overhead))

The table below defines the minimum and maximum packet size in bytes when the **RF Data Rate** parameter is set **3** (115.2 kbps). Using the default settings, the actual minimum packet size, in bytes, is 44, and the maximum packet size is 172.

	min	RF Data Rate = 3 (115.2 kbps) Max Packet Total (Data and Overhead)									
max		0	1	2	3	4	5	6	7	8	9
Min Packet (Date and Overhead)	0	8 / 8	24 / 8	40 / 8	56 / 8	72 / 8	88 / 8	104 / 8	120 / 8	136 / 8	152 / 8
	1	12 / 12	28 / 12	44 / 12	60 / 12	76 / 12	92 / 12	108 / 12	124 / 12	140 / 12	156 / 12
	2	16 / 16	32 / 16	48 / 16	64 / 16	80 / 16	96 / 16	112 / 16	128 / 16	144 / 16	160 / 16
	3	20 / 20	36 / 20	52 / 20	68 / 20	84 / 20	100 / 20	116 / 20	132 / 20	148 / 20	164 / 20
	4	24 / 24	40 / 24	56 / 24	72 / 24	88 / 24	104 / 24	120 / 24	136 / 24	152 / 24	168 / 24
	5	28 / 28	44 / 28	60 / 28	76 / 28	92 / 28	108 / 28	124 / 28	140 / 28	156 / 28	172 / 28
	6	32 / 32	48 / 32	64 / 32	80 / 32	96 / 32	112 / 32	128 / 32	144 / 32	160 / 32	176 / 32
	7	36 / 36	52 / 36	68 / 36	84 / 36	100 / 36	116 / 36	132 / 36	148 / 36	164 / 36	180 / 36
	8	40 / 40	56 / 40	72 / 40	88 / 40	104 / 40	120 / 40	136 / 40	152 / 40	168 / 40	184 / 40
	9	44 / 44	60 / 44	76 / 44	92 / 44	108 / 44	124 / 44	140 / 44	156 / 44	172 / 44	188 / 44

Max Packet Size and Min Packet Size Example

Using a **Minimum Packet Size** setting of **9** and a **Maximum Packet Size** setting of **9** and an **RF Data Rate** of **3**, using the the table above, you can see that the number of min bytes available for the Slave is **44** and the number of max bytes available for the Master is **188**.

If the Master has no traffic to transmit, then it uses 44 bytes (the **Minimum Packet Size** setting) leaving 188 bytes (188 - 44 + 44) for the Slave. The Slave does not get the total of the max and min bytes or in this example 232 bytes (188 + 44).

If the Master uses 100 bytes in a frame, then the Slave would have 132 bytes available to use within that frame.

(188 total available for the Master - 100 the Master uses + 44 bytes available to the Slave)

MCU Speed

Default Setting: (0) Normal

Options:
- (0) Normal (low speed) - Reduces current consumption.
- (1) Fast (high speed) - Required for 230 KBaud and greater data port rate.

If the transceiver is AES enabled and you are using the encryption functionality, set this parameter to **3** using the terminal interface. The value is accepted even though it is not viewable as an option and applies only when using AES encryption. For more information about setting up AES encryption, see "Enabling and Setting Up AES Encryption" on page 62.

Setup Terminal Menu: (3) Edit Radio Transmission Characteristics > (B) MCU Speed

Description: Controls the speed of the Micro Controller Unit (MCU) in the transceiver.

Remote LED

Note: This feature is not supported in the MM2-9X5W transceivers.

Retry Time Out

Default Setting: 255

Options: Any number between 0 and 255 in MultiPoint networks.

Any number between 151 and 255 in Point-to-Point networks.

Setup Terminal Menu: (3) Edit Transmission Characteristics > (8) Retry Time Out

Description: The **Retry Time Out** parameter in a Slave or Repeater sets the delay the unit waits before dropping the connection to a Master or Repeater. The factory default is set at the maximum of **255**. The maximum setting means that if 1 packet in 255 is sent successfully from the Master to the Slave or Repeater, the link is maintained. The minimum recommended setting is **8**. This allows a Slave or Repeater to drop a connection if less than 1 in 8 consecutive packets is successfully received from the Master. The function in the Master is effectively the same. With a setting of **255**, the Master allows a Slave or Repeater to stay connected as long as 1 packet in 255 is successfully received at the Master.

The **Retry Time Out** parameter is useful when a MultiPoint network has a roving Master or Slave. As the link gets weaker, a lower setting allows a poor link to break in search of a stronger one.

Note: Setting the **Retry Time Out** parameter to **20** in the MultiPoint Master is recommended in areas where several FreeWave networks exist. This recommended setting allows Slaves and Repeaters to drop the connection if the link becomes too weak, while at the same time prevent errant disconnects due to interference from neighboring networks.

While intended primarily for MultiPoint networks, the **Retry Time Out** parameter may also be modified in Point-to-Point networks. However, the value in Point-to-Point mode should not be set to less than 151.

RF Data Rate (Golden Setting)

Note: In MultiPoint networks, the **RF Data Rate** parameter must be set identically in all transceivers. Any transceiver with an **RF Data Rate** setting different from the Master will not establish a link. In Point-to-Point networks the Master setting takes precedence over the Slave.

Default Setting: (3) Normal

Options:
- (2) High - 153.6 kbps
- (3) Normal - 115.2 kbps

Setup Terminal Menu:	(3) Edit Transmission Characteristics > (4) RF Data Rate
Description:	FreeWave transceivers have two **RF Data Rate** settings; **2** (High) and **3** (Normal). **RF Data Rate** should not be confused with the serial port **Baud Rate**. Use setting **2** (RF Speed of 153.6 kbps) when the transceivers are close together and you need to optimize data throughput. Use setting **3** (RF Speed of 115.2 kbps) when the transceivers are farther away and a solid data link is preferred over data throughput.

RTS to CTS

> **Note:** For MM2-9X5W transceivers, ensure this setting remains at (0) Disabled, as the MM2-9X5W is TTL only.

Slave Security

> **Note:** The **Slave Security** parameter has no effect in Point-to-MultiPoint networks where the **Network ID** is used.

Default Setting:	(0) On
Options:	(0) On
	(1) Off
Setup Terminal Menu:	(3) Edit Transmission Characteristics > (6) Slave Security
Description:	**Slave Security** allows Slave transceivers to accept transmissions from a Master not included in the Call Book. The default setting of **0** (On) means only Masters in the Slave transceiver's Call Book may link to that Slave.

The **Slave Security** parameter may be disabled (setting of **1**) allowing any Master to call the Slave.

The **Slave Security** parameter must be set to **1** when the unit is operating in Mode 6, Slave/Master Switchable or a Point-to-Point network where the Slave may need to accept calls from more than 10 different Masters. When the **Slave Security** parameter is set to **1**, the transceiver accepts calls from any other FreeWave transceiver. Additional network security measures may be taken to prevent unauthorized access, such as changing default settings for **Frequency Key**, **Hop Table**, or **Frequency Zones**.

Transmit Power

> **Note:** The **Transmit Power** setting applies to the Master only.

Default Setting:	
Options:	Any number between 0 and 10
Setup Terminal Menu:	(3) Edit Transmission Characteristics > (5) RF Xmit Power
Description:	Sets the output power of the transceiver in dBm. In MM2-9X5W transceivers, a setting of 10 is approximately 5 W of output power.

If the input power decreases, the amplified power out also decreases. Therefore, if the Transmit Power setting is set to 10, it is possible that the transmit power will be below 5 W if there is not ample input power.

Note: When testing transceivers at your facility and they are in close proximity to one another, set the **Transmit Power** parameter to a low number. When you deploy transceivers to the field, raise the **Transmit Power** number accordingly.

Transmit Rate

Default Setting:	(1) Normal
Options:	(0) Diagnostics
	(1) Normal
Setup Terminal Menu:	(3) Edit Transmission Characteristics > (3) Xmit Rate
Description:	FreeWave transceivers have two available **Transmit Rate** settings. The setting for normal operation of the transceiver is **1**. When set to **0**, the transceivers transmit back and forth continuously regardless if they have any actual data. **0** should be used only as a diagnostic tool and not for normal operation. The strength of the signal may be gauged by the Clear to Send (CTS) LED. A solid red CTS LED indicates a strong signal; a blinking CTS LED indicates a weaker signal.
	0 is useful to qualitatively gauge signal strength in Point-to-Point mode.

Chapter 3: Configuring Point-to-MultiPoint Networks

When installing MultiPoint networks it is important to do some up front planning around the devices you are going to implement and the route your data is going to take back to the Master. A MultiPoint network can contain the following devices:

- Only one Master. All communications are from and to the Master.

- An unlimited number of Slave transceivers (remote sites).

- An unlimited number of Repeaters between any Slave and the Master.

- Serial Repeaters can be Slave transceivers and Repeaters at the same time.

This chapter builds on the settings described in the previous chapters and provides details about the following setup that applies specifically to a MultiPoint network:

- Point-to-MultiPoint network characteristics.

- Using the Network ID or the Call Book to establish which transceivers in the network can communicate with each other.

- Using subnet IDs to route traffic through the network, back to the Master.

- Settings and recommendations for additional parameters that apply to a MultiPoint network.

- Conserving power in devices within the network.

- Running network diagnostics.

Point-to-MultiPoint Network Characteristics

A Point-to-MultiPoint network has the following unique characteristics.

Golden Settings

A Point-to-MultiPoint network requires that the golden settings, as described on page 20, are set the same on all transceivers in the network.

If several independent MultiPoint networks are to be located in close proximity the planning becomes more critical. In such cases, it becomes very important to include as much frequency and time diversity as possible through use of different **Min and Max Packet Size**. In some instances the use of the **MultiMaster Sync** option may be required. For more information, about the **MultiMaster Sync** setting, see application note #5412, *Synchronizing Collocated Masters*, or contact FreeWave Technical Support.

In almost all MultiPoint networks, the **Frequency Key** is the same for all transceivers. In other networks, where parallel Repeaters are introduced, the **Frequency Key** value needs to change.

Master-to-Slave Communications

Master-to-Slave communications within a MultiPoint network have the following characteristics:

- Data packets sent from the Master include a 32-bit CRC.
- The Master repeats its data broadcast between 0 to 9 times, depending on the setting in the **Master Packet Repeat** setting. For more information, see "Master Packet Repeat" on page 43.
- A Slave or Repeater does not send acknowledgements to the Master when it receives data. When any Slave in the network receives the data packet from the Master with the 32-bit CRC, that Slave ignores any additional repeats of the data, and passes the data to its data port.
- Repeaters in the network send data to Slave transceivers and other Repeaters.

Slave-to-Master Communications

Slave-to-Master communications within a MultiPoint network have the following characteristics:

- Data packets sent from the Slave to the Master include a 32-bit CRC.
- When the Master successfully receives data, it sends an acknowledgement to the Slave and passes the data to its data port.

Point-to-MultiPoint Network Quick Start

The following is a quick start guide for setting up two transceivers in Point-to-MultiPoint mode. This mode allows for a Master to communicate with several Repeaters and Slaves simultaneously.

Point-to-MultiPoint Network Quick Start (Tool Suite):

1. Connect the transceiver to a TTL-to-RS232 converter then connect to the serial port of a computer either through the data pins or diagnostics pins. Make sure to connect the transceiver to a power source.

   Ensure the power supply is a positive supply with +12.0 VDC ± 5%.

2. Open a Tool Suite session, select the **Configuration** application, and ensure the correct port is selected in the **Com Port** field in the upper left of the Configuration ribbon.

3. From the Networks section of the Configuration ribbon, select the network in which the transceiver resides or click **Add Network** to create a new network in Tool Suite.

4. Click **Read Radio** in the Configuration ribbon to read the transceiver's current settings.

   - If you are using a diagnostics cable to connect to the transceiver, the transceiver automatically goes into Setup mode.

   - If you are using a data cable to connect to the transceiver, you are prompted to press the transceiver's Setup button to put it in Setup mode or short Pin 4 to ground.

   - When in Setup mode, all three LEDs on the transceiver display solid green.

5. Select the Operation Mode tab.

   In the **Modem Mode** field, select **2** to set the transceiver as a Point-to-MultiPoint Master or select **3** to set the transceiver as a Point-to-MultiPoint Slave.

   Note: A MultiPoint network can have only one Master, unless running in Multi-Master Synch mode. For more information, see "Multi-Master Synch" on page 65.

6. Select the Baud Rate tab.

   Change the **Baud Rate**, **Data Parity**, and **Modbus RTU** to match the device that the transceiver is to be connected to.

7. Select the Transmission Characteristics tab.

   Set the following parameters so they are identical on all transceivers in the network:

   - **Frequency Key**

   - **Max Packet Size**

   - **Min Packet Size**

   - **RF Data Rate**

   If several independent MultiPoint networks are located in close proximity, it becomes very important to include as much frequency and time diversity as possible through use of different **Frequency Key**, **Min and Max Packet Size**, and **Hop Table** settings.

   Changing these settings from the factory defaults may help to eliminate interference from other FreeWave networks.

8. Select the MultiPoint Parameters tab.

   In the **Network ID** field, set the value to any value between **1** and **4095**. FreeWave recommends setting the **Network ID** to the last three or four digits of the Master transceiver's serial number if it is below 4095. This value must be the same in all transceivers in the network.

   Note: A setting of **255** disables the **Network ID** feature and enables the Call Book feature.

9. Do one of the following to send the changes to the transceiver:

   - To send all the settings for all parameters, within the Configuration application in the Network Title ribbon, click **All**.

- To send only the parameters you have changed, within the Configuration application in the Network Title ribbon, click **Quick**. This option is only available if you clicked **Read Radio** and are not sending parameter settings from a template to the transceiver.

Point-to-MultiPoint Network Quick Start (Terminal Interface):

1. For board level configuration, connect the transceiver to a TTL-to-RS232 converter then connect to the serial port of a computer either through the data pins or diagnostics pins. Make sure to connect the transceiver to a power source.

   Ensure the power supply is a positive supply with +12.0 VDC ± 5%.

2. Open a terminal emulator session and use the following settings when connecting the transceiver. You can also use the Setup Terminal application within Tool Suite if a terminal emulator is unavailable:

   - Connect to COMx (where 'x' is the number of the COM port being connected).
   - Set the following:
     - **Data Rate** - 19,200
     - **Data Bits** - 8
     - **Parity** - none
     - **Stop bits** - 1
     - **Flow control** - none

3. Press the Setup button or short Pin 4 to ground. If using the diagnostics cable, press **Shift-U** (uppercase U).

   - The three LEDs on the transceiver should all turn green, indicating Setup mode.
   - The Main menu displays on the screen.

4. Press **0** to access the Operation Mode menu.

   - Press **2** to set the transceiver as a Point-to-MultiPoint Master or press **3** to set the transceiver as a Point-to-MultiPoint Slave.
   - Press **Esc** to return to the Main menu.

   Note: A MultiPoint network can have only one Master, unless running in Multi-Master Synch mode. For more information, see "Multi-Master Synch" on page 65.

5. Press **1** in the Main menu.

   - Change the **Baud Rate**, **Data Parity**, and **Modbus RTU** to match the device that the transceiver is to be attached to.
   - Press **Esc** to return to the Main menu.

6. Press **3** in the Main menu.

   - Set the following parameters so they are the same on all transceivers in the network:
     - **FreqKey**
     - **Max Packet Size**

- **Min Packet Size**
- **RF Data Rate**

The Frequency Key option is located in the **F** submenu after you press **0** to access the Frequency Key menu in Main menu **3**.

Changing these values may help to eliminate interference from other FreeWave networks.

- Press **Esc** to return to the Main menu.

7. Press **5** in the Main menu.

In the **Network ID** field, set the value to any value between **1** and **4095**. FreeWave recommends setting the **Network ID** to the last three or four digits of the Master transceiver's serial number if it is below 4095. This value must be the same in all transceivers in the network.

Note: A setting of **255** disables the **Network ID** feature and enables the Call Book feature.

8. Press **Esc** to exit the Setup menu and resume normal transceiver operation.

Point-to-MultiPoint Operation LEDs

	Master			Slave			Repeater		
Condition	Carrier Detect (CD)	Transmit (Tx)	Clear to Send (CTS)	Carrier Detect (CD)	Transmit (Tx)	Clear to Send (CTS)	Carrier Detect (CD)	Transmit (Tx)	Clear to Send (CTS)
Powered, not linked	Solid red bright	Solid red dim	Off	Solid red bright	Off	Blinking red	Solid red bright	Off	Blinking red
Repeater and Slave linked to Master, no data	Solid red bright	Solid red dim	Off	Solid green	Off	Solid red bright	Solid green	Solid red dim	Solid red bright
Repeater and Slave linked to Master, Master sending data to Slave	Solid red bright	Solid red dim	Off	Solid green	Off	Solid red bright	Solid green	Solid red dim	Solid red bright
Repeater and Slave linked to Master, Slave sending data to Master	Solid green RCV data or Solid red bright	Solid red dim	Inter-mittent flash red	Solid green	Inter-mittent flash red	Solid red bright	Solid green	Solid red bright	Solid red bright
Master with diagnostics program running	Solid red bright	Solid red dim	Inter-mittent flash red	Solid green	Intermittent flash red	Solid red bright	Solid green	Solid red bright	Solid red bright

* in an idle condition, the CTS LED is solid red with a solid link, as the link weakens the CTS LED on the Repeater and Slave begins to blink

Overlapping MultiPoint Networks

Overlapping MultiPoint networks may be set up effectively with FreeWave transceivers when several key parameters are set correctly. Overlapping MultiPoint networks are defined as networks using different Master transceivers, which share or overlap in a specific geographic area. It may also include collocated transceivers

configured into different networks. For more information, see application note #5412, *Synchronizing Collocated Masters (Multi-Master Sync Mode)*.

Collocated MultiPoint networks require the following parameters be unique for each network:

- **Network ID**, unless using the Call Book
- **Frequency Key** (in conjunction with Repeater Frequency)
- **Max Packet Size**
- **Min Packet Size**

For more information about the installation of Point-to-MultiPoint networks, contact FreeWave Technical Support.

Establishing Communication with Other Transceivers in a MultiPoint Network

For the transceivers in your network to communicate successfully, you need to tell the transceiver what other devices are available for them to communicate with. You can use the **Network ID** or the Call Book. FreeWave recommends using the **Network ID** option instead of the Call Book in MultiPoint networks. Because the **Network ID** does not use serial numbers, MultiPoint Master transceivers and Repeaters may be added or replaced without reprogramming each Slave transceiver in the network.

Using the Network ID in MultiPoint Networks

The **Network ID** parameter is located in the MultiPoint Parameters tab. Assign each transceiver in a single network the same **Network ID**. Slave transceivers link with the first Master or Repeater it hears that has a matching **Network ID**.

Keep the following in mind when setting the **Network ID**:

- The value can be any value between 1 and 4095, except 255, which enables the Call Book.
- To help ensure your ID is unique to your network, avoid using numbers that coincide with nearby landmarks or highways.
- FreeWave recommends a **Network ID** of four characters. For example, the last four digits of the Master serial number if it is below 4095, which is ensured to be unique and does not overlap with other nearby FreeWave networks.
- Use the **Network ID** function in conjunction with the **Subnet ID** feature (if necessary) to route data through the transceiver network.

Using the Call Book in MultiPoint Networks

Although not recommended, the Call Book is an option in MultiPoint networks. If the **Network ID** feature is used in a MultiPoint network, no entries are needed in the Call Book of any of the transceivers.

> **Important:** FreeWave recommends using the **Network ID** feature in a MultiPoint network. Using the Call Book in a MultiPoint network can cause delay in resuming communications if a Master is damaged.

For information about setting the Call Book, see "Using the Call Book in Point-to-Point Networks" on page 54.

In a MultiPoint network, the Slave transceivers and Repeaters are not listed in the Master transceiver's Call Book. Slave transceivers must have the Master and any Repeater it is going to use in *its* Call Book.

The following examples show the Call Books of a MultiPoint network comprised of a Master, Repeater, and Slave in which the Slave can communicate either through the Repeater or directly to the Master:

MultiPoint Master Call Book (Unit Serial Number 900-0001)

Entry	Number	Repeater 1	Repeater 2
(0)	000-0000		
(1)	000-0000		

No serial number entries are necessary in the Master's Call Book.

MultiPoint Repeater Call Book (Unit Serial Number 900-0002)

Entry	Number	Repeater 1	Repeater 2
(0)	900-0001		
(1)	000-0000		

MultiPoint Slave Call Book (Unit Serial Number 900-0003)

Entry	Number	Repeater 1	Repeater 2
(0)	900-0001		
(1)	900-0002		
(2)	000-0000		

At times, you may want to force Slave transceivers to go through a specific MultiPoint Repeater. In this scenario, the Slave transceiver's Call Book should contain only the serial number for that Repeater as the entry on line 0.

Programming Point-to-MultiPoint Extended Call Book

In a MultiPoint network, Slave transceivers can be programmed to roam between Master transceivers and Repeaters using the MultiPoint Extended Call Book function. Slave transceivers with Call Books configured as described below communicate with any transceiver whose serial number appears in any of the three columns. Do the following to enable this functionality:

1. Set the **Network ID** to **255**.

2. In the Call Book, enter **999-9999** as the last entry in the first and second columns.

3. In the Call Book, set **Entry to Call** to **All**.
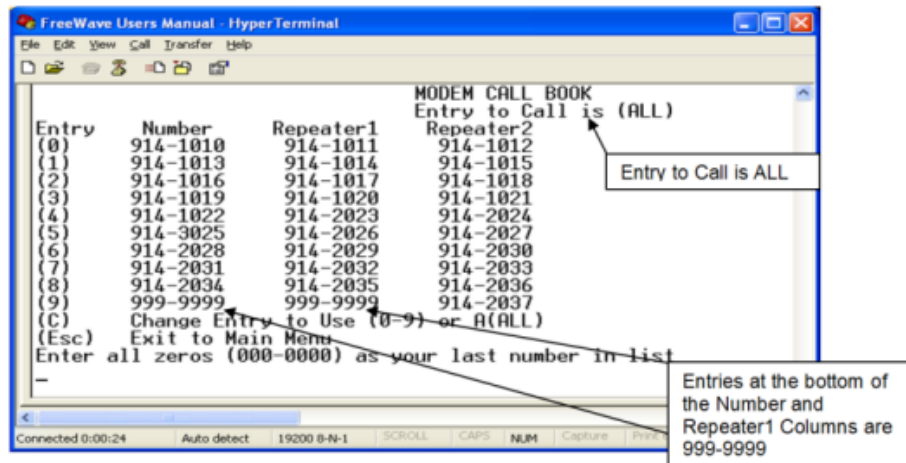
Routing Communications Through the Network

When using the **Network ID** feature, a Repeater or Slave links to the first Repeater or Master it hears with the same ID. Using subnet IDs, you can determine the path a Repeater or Slave uses to communicate back to the Master. Subnet IDs are particularly helpful to force two Repeaters in the same network to operate in series rather than in parallel, or if desired, to force Slave transceivers to communicate to a specific Repeater for load balancing purposes.

By forcing the communications path, you can optimize performance of the network by ensuring the Repeater or Slave links to a Repeater or Master with robust RF communications. Subnet IDs can help to minimize latency.

Assigning Subnet ID Values

Subnet IDs consist of two parts, both available in the Multipoint Parameters tab:

- **Rx** - This setting identifies which transceiver a Repeater or Slave listens to. In the terminal interface, this is the **Rcv Subnet ID**.

- **Tx** - This setting identifies the ID on which this device transmits, and in turn which devices listen to it. The **Tx Subnet ID** parameter is relevant for Multipoint Master transceivers and Repeaters *only*. In the terminal interface, this is the **Xmt Subnet ID**.

The default (disable) setting for both **Rx** and **Tx** is **F**, which is a visual way to indicate that the device is the final in the line of communication and does not use a subnet ID. A Multipoint Slave with a **Subnet ID** of **F**,**F** does not roam from one Repeater or network to the next, it only links to a Master or Repeater that has either a **Tx** setting of **0** or an **F**,**F Subnet ID**.

Setting both **Rx** and **Tx Subnet ID** to **0** allows a mobile Slave to roam from subnet to subnet, and possibly from network to network, provided the **Network ID**, **Max and Min Packet Size**, and **RF Data Rates** are the same between networks.

The examples in this section show the subnet definitions from the Master transceiver through the network to the Slave transceivers. When the subnet path is defined, the Slave transceivers can follow the route back to the Master.

The following illustration depicts a network in which subnet IDs are used to force communications along a specific path. The subnet settings follow.

Subnet ID Settings for This Example

Transceiver	Rx	Tx	Additional Information
Master	0	0	The default settings (F, F) actually use 0, 0. The **Rx Subnet** on the Master has no effect on the network.
Repeater1	0	1	A **0** forces the transceiver to link only to the Master.
Repeater2	1	2	**Rx Subnet = 1** forces communication through Repeater 1. Repeater 1 transmits on subnet **2**.
Slave	2	F	**Rx Subnet = 2** forces communication through Repeater 2. The Slave is the end of the network, so its **Tx Subnet** is **F**.

In the following example, Repeater 2 must communicate through Repeater 1, the Slave connected to Repeater 1 must route through Repeater 1. The other two Slave transceivers must route through Slave/Repeater 2.
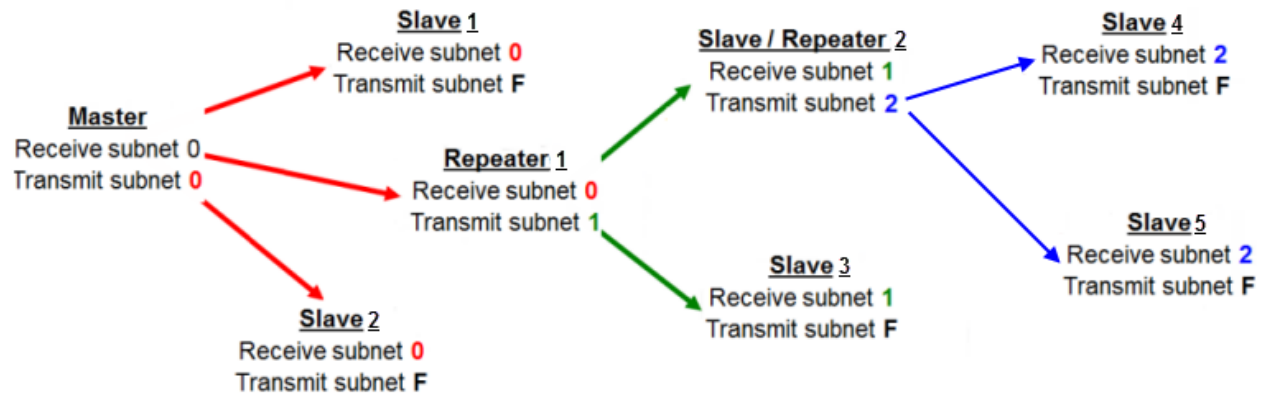
Subnet ID Settings for This Example

Transceiver	Rx	Tx	Additional Information
Master	0	0	The default settings (F, F) actually use 0, 0. The **Rx Subnet** on the Master has no effect on the network.
Slave 1	0	F	**Rx Subnet = 0** forces the transceiver to link only to the Master. The Slave does not transmit to any device except the Master, so its **Tx Subnet** is **F**.
Repeater1	0	1	**Rx Subnet = 0** forces the transceiver to link only to the Master. Transmits on subnet **1**.

Transceiver	Rx	Tx	Additional Information
Slave 2	0	F	**Rx Subnet = 0** forces the transceiver to link only to the Master.
Slave/Repeater 2	1	2	**Rx Subnet = 1** forces the transceiver to link only to Repeater 1. It transmits on **Tx Subnet 2** to Slave 4 and 5.
Slave 3	1	F	**Rx Subnet = 1** forces the transceiver to link only to Repeater 1. The Slave does not transmit to any device except Repeater 1, so its **Tx Subnet** is **F**.
Slave 4	2	F	**Rx Subnet = 2** forces the transceiver to link with Slave/Repeater 2.
Slave 5	2	F	**Rx Subnet = 2** forces the transceiver to link with Slave/Repeater 2.

In the following example, Repeater 1 must talk directly to the Master; Repeater 2 must talk directly to Repeater 1. Slave 1, 2, and 3 are forced along the direction of the solid lines. Slave 4 may link to the first Master or Repeater it hears in the network.
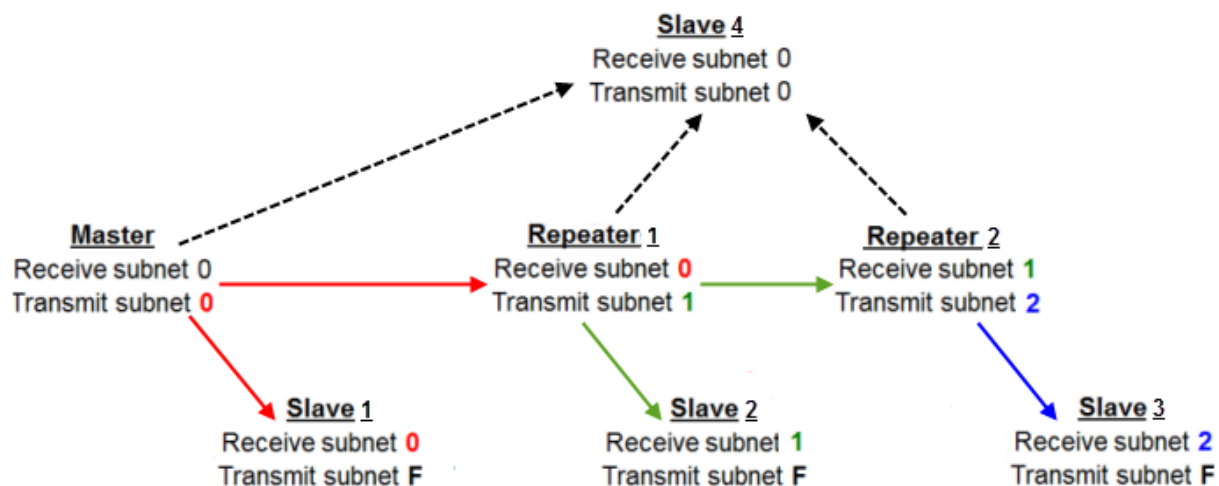
Subnet ID Settings for this Example

Transceiver	Rx	Tx	Other Information
Master	0-F	0-F	The default settings (F, F) actually use 0, 0. The **Rx Subnet** on the Master has no effect on the network.
Repeater 1	0	1	A **0** forces the transceiver to link only to the Master.
Repeater 2	1	2	**Rx Subnet = 1** forces communication through Repeater 1. Repeater 1 transmits on SubnetID 1.
Slave 1	0	0 or F	**Rx Subnet = 0** forces communication through the Master.
Slave 2	1	0 or F	**Rx Subnet = 1** forces communication through Repeater 1.
Slave 3	2	0 or F	**Rx Subnet = 2** forces communication through Repeater 2.
Slave 4	0	0	The **0,0** setting allows the Slave to link with the first Master or Repeater it hears with the same **Network ID**.

Setting Other MultiPoint Parameters

The other MultiPoint Parameters options allow you to modify several different parameters in the transceiver that determine the characteristics of a MultiPoint network.

Set the following parameters in the MultiPoint Parameters tab. These settings are available in the MultiPoint Parameters menu in the terminal interface.

1 PPS Enable Delay

Default Setting:	255
Options:	255 to disable 1 PPS
	0 to 254 to enter the delay
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (9) 1 PPS Enable/Delay
Description:	The **1 PPS Enable/Delay** setting allows a 1PPS signal to propagate from the Master to all Slaves in a MultiPoint network. When this parameter is enabled a properly generated pulse applied on the DTR line of the Master provides a 1 PPS pulse on the CD line of any Slave in the network.
	Follow the steps below to use the **1 PPS Enable/Delay** feature.

To setup 1PPS Enable/Delay:

1. Set the **1 PPS Enable/Delay** parameter to **0** in the Master transceiver.

   The Master must have a 1 PPS pulse on the DTR pin.

2. Enable the **1 PPS Enable/Delay** parameter on the Slave transceivers. Slave transceivers are calibrated at the factory.

To calibrate a Slave transceiver in 1PPS Enable/Delay mode:

1. Trigger an oscilloscope on the 1 PPS pulse on the DTR line of the Master transceiver.

2. Monitor the CD line of the Slave transceiver.

3. If the timing on the Slave transceiver differs from the Master it may be adjusted via the value in the Slave transceiver's **1 PPS Enable/Delay** parameter. The difference in time between each incremental integer value is 542.534 nanoseconds (ns). Changing the parameter to higher values decreases the Slave transceiver time delay and changing the parameter to lower values increases the time delay.

When properly calibrated, the CD line Slave transceiver outputs a pulse that goes high for about 2 ms in synch with the 1 PPS pulse on the Master transceiver. The output on the Slave transceiver occurs within 20 microseconds of the input to the Master.

> **Important:** When **1 PPS** is enabled, the Master transceiver must have a 1 PPS pulse on its DTR pin, otherwise the RF network does not function.

Diagnostics

Default Setting:	0 (Disabled)
Options:	Any number between 0 and 128
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (B) Diagnostics
Description:	Allows diagnostics data in the Network Diagnostics application within Tool Suite to be viewed at the Master transceiver in parallel with application data. The setting in this parameter determines how many slots out of 128 are dedicated to diagnostics. For example, if set to **10**, 1 out of every 10 data slots is for diagnostics data; if set to **100**, 1 out of every 100 data slots is for diagnostics data.
	Diagnostics is always secondary to actual transmitted data.
	For more information, see "Reading Diagnostics in Tool Suite" on page 48.

DTR Connect

Default Setting:	(0) Off
Options:	• **(0) Off** - When set to off in the Slave transceiver, the transceiver transmits when the data is received.
	• **(1) DTR Sensing** - Forms a Point-to-Point link with the Master transceiver when the DTR line is high to send data.
	• **(2) Burst Mode** - The transceiver transmits data in bursts.
Setup Terminal Menu:	(5) MultiPoint parameters > (4) DTR Connect
Description:	Determines how the transceiver sends its data. This mode is valuable when a network has many low data rate devices and you want to increase overall network capacity.
	If **DTR Connect** is set to **1** and the **RTS to CTS** function is enabled on the transceiver, then **RTS to CTS** takes precedence over **DTR Connect**.
	If **DTR Connect** is set to **2** and **RTS to CTS** is enabled, then **RTS to CTS** is ignored. The transceiver has two separate transmit and receive user data buffers. These buffers are 2 Kbytes each. In case of a buffer overflow, the transceiver outputs unpredictable data.

Local Mode

Default Setting:	(0) Disabled
Options:	(0) Disabled, (1) Enabled
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (E) Local Access
Description:	Enable **Local Mode** to access a Slave transceiver with a local Master transceiver. This Master does not take the place of the network Master. For more information, see application note #5457, *Local Mode*.

Master Packet Repeat

Note: When using the transceiver in **Modbus RTU** mode, the **Master Packet Repeat** setting must match in every transceiver, regardless of whether the network is in Point-to-Point or MultiPoint mode.

Default Setting:	3
Options:	Any number between 0 and 9.
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (1) Master Packet Repeat
Description:	In a Point-to-MultiPoint network, Slave transceivers do not acknowledge transmissions from the Master. If Slave transceivers did acknowledge all data transmissions, in a large network, the Master would soon become overwhelmed with acknowledgments from the Slaves. Without acknowledgments, 100% confidence every Slave transceiver has received every packet cannot be met.

To address this issue, you can modify the **Master Packet Repeat** parameter, assigning a value between **0** (the packet is transmitted once) to **9** (the packet is transmitted 10 times).

For networks with solid RF links, this parameter should be set to a low value such as **1** or **2**. If a network has some weak or marginal links it should be set with higher values. If a Slave transceiver receives a good packet from a Master more than once it discards the repeated packets. Similarly, after a MultiPoint Repeater receives a good packet from the Master, it discards any further repeated packets. In turn, the Repeater sends the packet out to the next Repeater or Slaves the number of times corresponding to its own **Master Packet Repeat** setting.

Increasing the **Master Packet Repeat** setting increases the probability of a packet getting through, but also increases latency in the network because each packet from the Master or Repeater is being sent multiple times. Therefore, it is important to find the optimal mix between network robustness, throughput, and latency. In general, a setting of **2** to **3** works well for most well designed networks.

Note: The **Master Packet Repeat** parameter may be set to **0** if the user software is capable of, or requires acknowledgment. In this case, if the Master sends a packet that the Slave transceiver does not receive, the user software controls the retries as needed.

Master Packet Repeat in MultiPoint Networks with Repeaters

The **Master Packet Repeat** parameter must also be set in MultiPoint Repeaters because a Repeater appears as a Master to a Slave transceiver. Therefore, the Repeater sends the packet out the number of times corresponding to its own **Master Packet Repeat** parameter setting. If this parameter is set improperly the reliability of the overall network may be diminished.

For example, if a Master's **Master Packet Repeat** parameter setting is **3**, the link between the Master and Repeater should be robust. If the Repeater's **Master Packet Repeat** parameter setting is **0**, this could cause marginal links between the Repeater and the Slaves. The Slaves communicating through this Repeater only

receive the initial packet from the Master with no repeats. Therefore, if the packet is not received on the first try, the Slave transceiver does not respond as expected.

> Note: The **Master Packet Repeat** parameter setting in any MultiPoint Repeater must be *less than or equal* to the Master's setting.

Max Slave Retry

Default Setting:	9
Options:	Any number between 1 and 9.
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (2) Max Slave Retry
Description:	Defines how many times the Slave transceiver attempts to retransmit a packet to the Master before beginning to use a back-off algorithm (defined by the **Retry Odds** parameter). The Slave transceiver retries stop when the Slave receives an acknowledgement from the Master.

Radio ID

Default Setting:	Blank
Options:	Any 4 digit, user-defined number.
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (D) Radio ID
Description:	Use this option to designate a transceiver with an arbitrary, user-defined, 4-digit number that identifies the transceiver in Diagnostics mode.

Radio Name

Default Setting:	Blank
Options:	Any combination of letters or numbers up to 20 characters
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (G) Radio Name
Description:	Use this parameter to give a transceiver a name, such as its location. Naming transceivers can be helpful to identify a transceiver when in Diagnostics mode.

Repeater Frequency

Default Setting:	(0) Disabled
Options:	(0) Disabled
	(1) Enabled
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (5) Repeater Frequency
Description:	Enable this parameter when you need a **Frequency Key** other than that of the Master. This condition occurs when parallel Repeaters in a network may have overlapping areas of responsibility. The default setting of **0**

(Disabled) causes the Repeater to use the key set in the **Frequency Key** parameter in the Transmission Characteristics tab.

Note: When the **Repeater Frequency** parameter is disabled and **Subnets** are not configured, the **Frequency Key** parameter setting in each Slave transceiver must match the Master or Repeater acting as the Master for the transceiver.

Repeaters

Note: This parameter needs to be set in the MultiPoint Master only. The setting has no effect if set in a MultiPoint Slave.

Default Setting:	(1) Enabled
Options:	(0) Disabled
	(1) Enabled
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (0) Number Repeaters
Description:	Indicates if any number of Repeaters exist in the network.

Retry Odds

Default Setting:	0
Options:	Any number between 0 and 9.
Setup Terminal Menu:	(5) Edit MultiPoint Parameters > (3) Retry Odds
Description:	While packets transmitted from the Master to the Slave transceivers in a MultiPoint network are not acknowledged, packets transmitted from Slaves to the Master are acknowledged. It is possible that more than one Slave attempts to transmit to the Master at the same time. Therefore, it is important that a protocol exists to resolve contention for the Master between Slaves in the network. This is addressed through the **Max Slave Retry** and **Retry Odds** parameters. After the Slave has unsuccessfully attempted to transmit the packet the number of times specified in the **Max Slave Retry** parameter, it attempts to transmit to the Master on a random basis. The **Retry Odds** parameter determines the probability that the Slave attempts to retransmit the packet to the Master; a low setting assigns low odds to the Slave attempting to transmit. Conversely, a high setting assigns higher odds.

Consider two different Slave transceivers in a MultiPoint network, one with a strong RF link and the other with a weak RF link to the Master. If a Slave has a weak or poor link, set the **Retry Odds** parameter to **0** as it may become a "chatty" Slave and lockup the network, causing a loss of communication.

When the **Retry Odds** parameter is set to **0**, after the Slave has exhausted the number of retries set in the **Max Slave Retry** parameter and still not gained the Master's attention, the Slave's data buffer is purged. A **Retry Odds** parameter set to **0** is recommended for most networks.

Slave/Repeater

Default Setting:	(0) Disabled
Options:	(0) Disabled
	(1) Enabled
Setup Terminal Menu:	(5) MultiPoint Parameters > (A) Slave/Repeater
Description:	The **Slave/Repeater** mode allows a transceiver in a MultiPoint network to switch between Slave and Repeater functions. When in this mode, a transceiver repeats any packets sent across the network as well as uses the data port. Thus, where one Repeater and one Slave may be required in another vendor's network, FreeWave networks require only one transceiver.

To operate a transceiver as a MultiPoint Slave/Repeater, the following must be set:

- The **Modem Mode** parameter in the Operation Mode tab must be set to **MultiPoint Repeater**.
- The **Slave/Repeater** parameter in the MultiPoint Parameters tab must be enabled.

Conserving Power

Power consumption can be essential, especially for remote sites that are difficult to access. You can conserve power using the settings below available in the Transmission Characteristics tab. These settings are available in the Radio Transmission Characteristics menu in the terminal interface.

Low Power Mode

> **Note:** This setting applies only to MultiPoint Slave transceivers using the RS232 protocol. **Low Power Mode** does not work with MultiPoint Repeaters because they are constantly transmitting.

Default Setting:	0
Options:	Any number between 0 and 31. The higher the number, the greater the power consumption decrease.
Setup Terminal Menu:	(3) Edit Radio Transmission Characteristics > (9) Low Power Mode
Description:	Allows a MultiPoint Slave transceiver to consume less power, primarily by dimming the transceiver's LEDs.

When set to **2** through **31**, the transceiver sleeps between slots. For example, at a setting of **2** the transceiver sleeps 1 out of 2 slots; at a setting of **3** the transceiver sleeps 2 out of 3 slots, and so on.

When the transceiver is asleep, it hears nothing from the Master.

The following table shows the changes at different **Low Power Mode** settings. The actual current draw depends on many factors. The table

below gives only a qualitative indication of supply current savings. A low number reduces latency and a high number reduces current consumption.

Current Draw

More

Less

Setting	Description
0	Low power, disabled.
1	LEDs dimmed, transceiver remains awake, transceiver is listening to the Master's transmissions on every slot, and transceiver's data port is shut down if the RTS line is de-asserted (low). In this case, the transceiver needs to be awakened before it is able to send data to the Master.
2	LEDs dimmed, transceiver sleeps every other slot.
3	LEDs dimmed, transceiver sleeps 2 of 3 slots.
4-31	LEDs dimmed, transceiver sleeps the number of slots corresponding to the setting. For example, with a setting of 31 the transceiver sleeps 30 of 31 slots.

Note the following about the **Low Power Mode** parameter:

- Power savings occur only when the Slave transceiver is linked. No power savings occur when the Slave transceiver is transmitting data. **Low Power Mode** is of little value when a Slave has a constant, high throughput. The **MCU Speed** parameter must be set to **0** and the **RF Data Rate** parameter must be set to **3** for **Low Power Mode** to operate properly.

- To communicate to an RS232 port of a transceiver that is in **Low Power Mode**, the RTS line must be held high to wake it up. The transceiver wakes up within approximately 20 milliseconds of when RTS goes high.

- If the Request to Send (RTS) line on the Slave transceiver is held high, the transceiver remains in normal operation regardless of the **Low Power Mode** setting. After RTS is dropped the transceiver reverts to the **Low Power Mode**.

- If the transceiver has the **DTR Connect** parameter in the MultiPoint Parameters tab set to **1** or **2** and if the **Low Power Mode** is enabled (set to **1 to 31**), the RTS line on the transceiver must be asserted for the **DTR Connect** feature to operate properly.

- The diagnostic pins must be disabled or terminated to a cable for the sleep current in **Lower Power Mode** to match the specifications. To disable the diagnostic pins, ensure the following are set:

  - In the Baud Rate tab, the **Setup Port** parameter is set to **1 (Main Only)**.

- In the MultiPoint Parameters tab, the **Diagnostics** parameter is set to **0** (Off).

- To realize full power savings in **Low Power Mode**, the serial port must be deactivated between operation. To do that the RTS line must be asserted. However, because RS485/422 operation uses the RTS line as part of the data bus, it cannot be asserted to wake-up the transceiver. Therefore, FreeWave recommends that all transceivers set to RS485 or RS422, use a **Low Power Mode** setting of **0**.

Reading Diagnostics in Tool Suite

The Network Diagnostics application provides a place to view diagnostic data for all the devices connected to the Master in your network in real time. This application is *not* meant to replicate the functionality of a Network Management System, but rather it is a tool that can be used for diagnostics and troubleshooting in the field.

> **Important:** The Network Diagnostics application is intended for occasional network monitoring or troubleshooting, not for continuous, long-term collection of diagnostic data.

This section provides basic steps for reading diagnostics using Tool Suite. Tool Suite stores the diagnostic data in the database and you can import or export a diagnostic file. For information regarding the data available, recommended best practices, and importing and exporting files using the Network Diagnostics application, see the *Tool Suite User Manual* available on the *User Manual and System Tools* CD or by selecting **File > Help** in the Tool Suite software.

> **Note:** To help identify the transceivers in your network when running Network Diagnostics, set the **Radio Name** and **Radio ID** fields in the Multipoint Parameters tab.

The diagnostic program *must* be run from the Master transceiver. Diagnostics requires the following:

- A setting between 1 and 128 in the **Diagnostics** parameter available in the MultiPoint Parameters menu on the Master.

- A second computer or serial connection to run the diagnostics software.

- A diagnostics cable. (Available from FreeWave.)

- Diagnostics software. (Available on the *User Manual and System Tools* CD and on www.FreeWave.com.)

For more information about Diagnostics, contact FreeWave Technical Support.

To run diagnostics using Tool Suite:

1. Connect the Master to the computer running Tool Suite.

2. Open Tool Suite and click **Network Diagnostics** in the Applications pane.

3. From the drop-down menu in the Networks section of the ribbon, select the serial network for which you want to run diagnostics.

   If you do not have a network defined, click **Add** and follow the instructions in the wizard. For more information, see the *Tool Suite User's Manual*.

4. From the ribbon, click **Start**.

5. To stop running diagnostics, click **Stop**.

   If you move away from the Network Diagnostics application without selecting **Stop**, the program continues to poll for diagnostic data.

   Important: Tool Suite is not optimized for the collection and management of large amounts of diagnostic data from continuous polling. Collection of excessive amounts of data results in overall performance degradation in Tool Suite and network throughput degradation.

Chapter 4: Configuring Point-to-Point Networks

Point-to-Point networks are the most basic type of network, and do not require much more than setting up the basic network, as described in the basic programming and setup chapter.

This chapter provides:

- A brief quick start to setup a Point-to-Point network.
- An LED chart for LED function within a Point-to-Point network.
- Information about programming the Call Book.

Point-to-Point Network Quick Start

To establish a link between a pair of FreeWave transceivers just received from the factory, complete the steps described below for each transceiver.

Point-to-Point Network Quick Start (Tool Suite):

1. For board level configuration, connect the transceiver to a TTL-to-RS232 converter then connect to the serial port of a computer either through the data pins or diagnostics pins. Make sure to connect the transceiver to a power source.

   Ensure the power supply is a positive supply with +12.0 VDC ± 5%.

2. Open a Tool Suite session, select the Configuration application, and ensure the correct port is selected in the **Com Port** field in the Configuration ribbon.

3. From the Networks section of the Configuration ribbon, select the network in which the transceiver resides or click **Add Network** to create a new network in Tool Suite.

4. Click **Read Radio** in the Configuration ribbon to read the transceiver's current settings.

   - If you are using a diagnostics cable to connect to the transceiver, the transceiver automatically goes into Setup mode.

   - If you are using a data cable to connect to the transceiver, you are prompted to press the transceiver's Setup button to enter Setup mode.

   - When in Setup mode, all three LEDs on the transceiver display solid green.

5. Select the Operation Mode tab.

   In the **Modem Mode** field, select to set the transceiver to Point-to-Point mode. For example, set one transceiver as a Point-to-Point Master (Mode 0) and the other as a Point-to-Point Slave (Mode 1). For more information about modem modes, see "Setting the Transceiver's Role in the Network and the Network Type" on page 13.

   Note: A Point-to-Point network can have only one Master.

6. Select the Baud Rate tab.

   Change the **Baud Rate**, **Data Parity**, and **Modbus RTU** to match the device that the transceiver is to be attached to.

7. Select the Transmission Characteristics tab.

   Set the following parameters so they are identical on all transceivers in the network:

   - **Frequency Key**

   - **Max Packet Size**

   - **Min Packet Size**

   - **RF Data Rate**

   If several independent networks are located in close proximity, it becomes very important to include as much frequency and time diversity as possible through use of different **Frequency Key**, **Min and Max Packet Size**, and **Hop Table** parameter settings.

   Changing these settings from the factory defaults may help to eliminate interference from other FreeWave networks.

8. Select the Call Book tab.

   Enter the Slave serial number in the Master's Call Book. Enter the Master's Serial number in the Slave's Call Book, or disable the **Slave Security** parameter in the Slave. For more information about setting up the Call Book see "Using the Call Book in Point-to-Point Networks" on page 54.

   Shortly after both transceivers are plugged in, they should establish a link with each other and the connection is complete. Using the LED table below, verify that the transceivers are operating as expected.

9. Do one of the following to send the changes to the transceiver:

   - To send all the settings for all parameters, within the Configuration application in the Network Title ribbon, click **All**.

   - To send only the parameters you have changed, within the Configuration application in the Network Title ribbon, click **Quick**. This option is only available if you clicked **Read Radio** and are not sending parameter settings from a template to the transceiver.

Point-to-Point Network Quick Start (Terminal Interface):

1. For board level configuration, connect the transceiver to a TTL-to-RS232 converter then connect to the serial port of a computer either through the data pins or diagnostics pins. Make sure to connect the transceiver to a power source.

   Ensure the power supply is a positive supply with +12.0 VDC ± 5%.

2. Open a terminal emulator session and use the following settings when connecting to the transceiver. You can also use the Setup Terminal application within Tool Suite if a terminal emulator is unavailable.

   - Connect to COMx (where 'x' is the number of the COM port being connected).
   - Set the following:
     - **Data Rate** - 19,200
     - **Data Bits** - 8
     - **Parity** - none
     - **Stop bits** - 1
     - **Flow control** - none

3. Press the **Setup** button on the transceiver. If using the diagnostics cable, press **Shift-U** (capital U).

   - The three LEDs on transceiver should all turn green, indicating Setup mode.
   - The Main menu displays on the screen.

4. Press **0** to access the Operation Mode menu.

   - Press **0** to set the transceiver as a Point-to-Point Master or press **1** to set the transceiver as Point-to-Point Slave. For more information about modem modes, see "Setting the Transceiver's Role in the Network and the Network Type" on page 13.
   - Press **Esc** to return to the Main menu.

5. Press **1** in the Main menu.

   - Change the **Baud Rate**, **Data Parity**, and **Modbus RTU** to match the device that the transceiver is to be attached to.
   - Press **Esc** to return to the Main menu.

6. Press **2** in the Main menu to update the Call Book.

   Enter the Slave serial number in the Master's Call Book. Enter the Master's Serial number in the Slave's Call Book, or disable the **Slave Security** parameter in the Slave. For more information about setting up the Call Book, see "Using the Call Book in Point-to-Point Networks" on page 54.

7. Press **3** in the Main menu.

   - Set the following parameters so they are the same on all transceivers in the network:
     - **FreqKey**
     - **Max Packet Size**
     - **Min Packet Size**
     - **RF Data Rate**

The **Frequency Key** option is located in the **F** submenu after you press **0** to access the Frequency Key menu in Main menu **3**.

Changing these values may help to eliminate interference from other FreeWave networks.

- Press **Esc** to return to the Main menu.

Shortly after both transceivers are plugged in, they should establish a link with each other and the connection is complete. Using the LED table below, verify that the transceivers are operating as expected.

8. Press **Esc** to exit the Setup menu and resume normal transceiver operation.

Point-to-Point Operation LEDs

	Master			Slave			Repeater		
Condition	Carrier Detect (CD)	Transmit (Tx)	Clear to Send (CTS)	Carrier Detect (CD)	Transmit (Tx)	Clear to Send (CTS)	Carrier Detect (CD)	Transmit (Tx)	Clear to Send (CTS)
Powered, no link	Solid red bright	Solid red bright	Solid red bright	Solid red bright	Off	Blinking red	Solid red bright	Off	Blinking red
Linked, no Repeater, sending sparse data	Solid green	Intermittent flash red	Intermittent flash red	Solid green	Intermittent flash red	Intermittent flash red	n/a	n/a	n/a
Master calling Slave through Repeater	Solid red bright	Solid red dim	Solid red bright	Solid red bright	Off	Blinking red	Solid red bright	Off	Blinking red
Master linked to Repeater, not to Slave	Flashing orange	Solid red dim	Solid red bright	Solid red bright	Off	Blinking red	Solid Red bright	Solid red dim	Solid red bright
Repeater linked to Slave	Solid green	Intermittent flash red	Intermittent flash red	Solid green	Intermittent flash red	Intermittent flash red	Solid green	Intermittent flash red	Intermittent flash red
Mode 6 - waiting for ATD command	Solid red bright	Off	Blinking red	Solid red bright	Off	Blinking red	n/a	n/a	n/a
Setup Mode	Solid green	Solid green	Solid green	Solid green	Solid green	Solid green	Solid green	Solid green	Solid green

Using the Call Book in Point-to-Point Networks

The Call Book is required in Point-to-Point networks. While the Call Book is an option in Point-to-MultiPoint networks, FreeWave strongly recommends using the **Network ID** feature in most applications. If a large MultiPoint network is implemented using the Call Book and you want to add a transceiver to the network, or need to replace a transceiver, you must physically travel to all transceivers in the network and enter the new serial number in the transceiver's Call Book.

Using the Call Book offers both security and flexibility in determining how FreeWave transceivers communicate with each other.

You must set the following for two FreeWave transceivers to communicate in Point-to-Point mode:

1. The Master transceiver' serial number must be listed in the Slave transceiver's Call Book or **Slave Security** is turned off in the Slave.

2. The Slave serial number must be listed in the Master Call Book .

3. The Master must be programmed to call the Slave (**Entry to Call** option).

The Call Book allows you to incorporate up to 10 FreeWave transceivers, designate 1 to 4 Repeaters to use with each transceiver, and designate which Slave the Master calls. To set the **Entry to Call** option, select the number in the **Entry to Call** field, select **All** to direct the Master to call all Slave transceivers.

> **Note:** To set the **Entry to Call** option in the terminal interface, enter **C** at the Call Book menu, followed by the menu number corresponding to that Slave. To call any available Slave in the list, enter **C** then enter **A** to direct the Master to **Call All**.

It is important that the Call Book slots (0-9) are filled sequentially starting with slot 0. When a Master is instructed to **Call All**, it calls all Slave transceivers listed until it reaches the first serial number of 000-0000 (or a blank slot). If a serial number is entered after the all zero number or as a Repeater, the Master does not recognize it as a valid number.
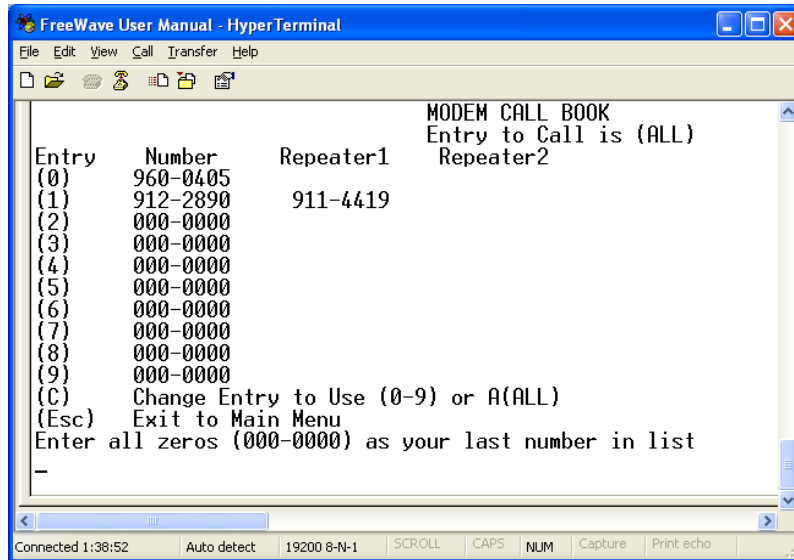
> **Note:** When entering numbers into the Call Book, you need only define Repeaters in the Master Call Book. The Slave Call Book only requires the Master serial number. A Repeater need not have anything listed in its Call Book.

To set the Call Book in Tool Suite:

1. In the Tool Suite Configuration application, select the device to program and click the **(2) Call Book** tab.

2. In the **Number** column in **Row 0**, enter the seven-digit serial number of the transceiver being called.

3. In the **Repeater 1** column, enter the first Repeater's seven-digit number. If no Repeaters are being used, leave the column empty.

4. In the **Repeater 2** column, enter the second Repeater's 7-digit number. If only one Repeater is being used, leave the column empty.

5. If Repeaters are being used, select the appropriate **Entry to Call** option in the Master Call Book.

   To apply the changes, select either the **Quick** or **All** icon. Tool Suite applies the changes to the transceiver.

To set the Call Book in the terminal interface:

1. Select **C(2) Edit all Book** from the main Setup menu to display the following window:

```
FreeWave User Manual - HyperTerminal
File  Edit  View  Call  Transfer  Help

                           MODEM CALL BOOK
                           Entry to Call is (ALL)
  Entry    Number     Repeater1    Repeater2
  (0)    960-0405
  (1)    912-2890     911-4419
  (2)    000-0000
  (3)    000-0000
  (4)    000-0000
  (5)    000-0000
  (6)    000-0000
  (7)    000-0000
  (8)    000-0000
  (9)    000-0000
  (C)    Change Entry to Use (0-9) or A(ALL)
  (Esc)  Exit to Main Menu
  Enter all zeros (000-0000) as your last number in list
  _

Connected 1:38:52    Auto detect    19200 8-N-1    SCROLL   CAPS   NUM   Capture   Print echo
```

2. Enter the number or letter associated with the option you want to select.

3. At the Enter New Number prompt, enter the seven-digit serial number of the transceiver being called.

4. The system prompts for the first Repeater's serial number. If no Repeaters are being used, press **Esc** and continue with step 6. Otherwise, enter the 7-digit serial number of the Repeater.

5. The system prompts for the second Repeater's serial number. Enter the 7-digit serial number of the second Repeater. If only one Repeater is being used, press **Esc**.

    The system refreshes the transceiver's Call Book menu with the new changes.

6. Repeat steps 2 to 5 for additional transceivers in the network.

7. Press **Esc** to return to the Main menu.

Programming Point-To-Point Extended Call Book to Use Three or Four Repeaters

In a Point-to-Point configuration, FreeWave transceivers can use up to four Repeaters. To use three or four Repeaters, program the Call Book with the Slave serial number, followed by the first two Repeaters. On the next line enter 999-9999 as the transceiver to call. When prompted for the Repeaters enter the third and fourth Repeaters in the link.

The illustration below shows a Point-to-Point link where a Slave is called through four Repeaters. In this example the Master is calling the Slave, 571-3872, through Repeater 1, 901-1234, then Repeater 2,910-0234, then Repeater 3, 571-3456, and finally Repeater 4, 571-4567. Entering the serial number 999-9999 in line 1 instructs the Master to continue calling through the Repeaters programmed on that line.

| Entry	Number	Repeater 1	Repeater 2
0	571-3872	901-1234	910-0234
1	999-9999	571-3456	571-4567
2			
3			
4			
5			
6			
7			
8			
9			

To call a Slave transceiver through one or more Repeaters, that Slave must be called individually. With **Call All** selected, the Master will not connect with any Slave transceivers through Repeaters. The Master calls every Slave in the list and connects with the first Slave that responds. When calling through a Repeater, the Master must first call that Repeater and establish a communications link with it prior to making contact with the Slave.

Chapter 5: Advanced Programming

The settings and scenarios covered in this chapter are considered advanced programming, and are settings and scenarios that you are not as likely to use in your network.
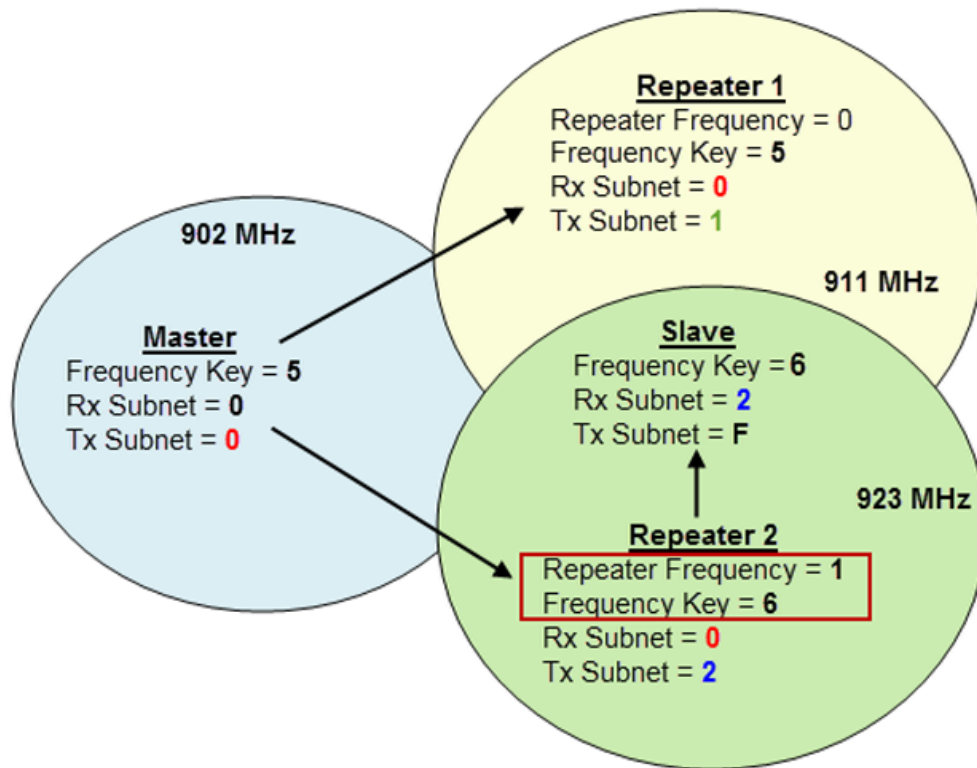
Working with Parallel Repeaters

As you add Repeaters to a network, plan accordingly to avoid creating a parallel Repeater scenario. A parallel Repeater is defined as two or more Repeaters linked to the same point in the network.
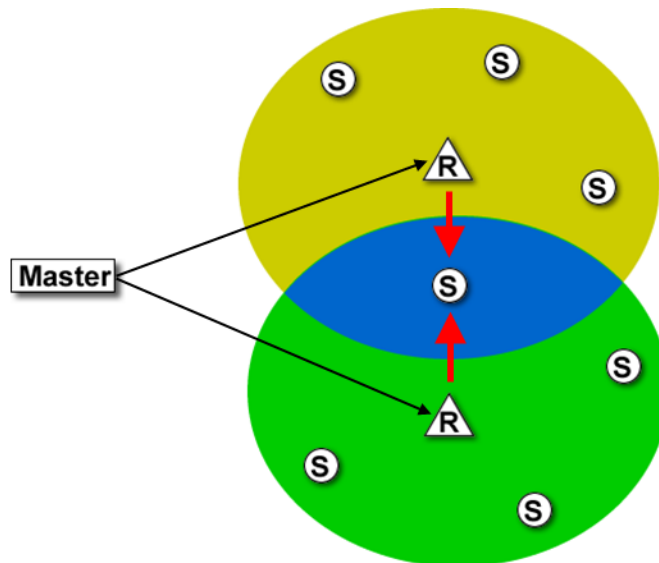
In the diagram above, the Slave transceiver in the middle has overlapping coverage from both the Repeaters (parallel Repeaters). Data from the Repeaters is transmitted on the same **Frequency Key** in the same time slot, which creates message collisions.

To resolve this scenario, change the following settings on one or more of the Repeaters in conflict:

- **Repeater Frequency** - Set the **Repeater Frequency** parameter in the MultiPoint Parameters tab to any number other than **0**. If set to a number other than **0**, the transceiver uses the frequency key set in the **Frequency Key** parameter in the Transmission Characteristics tab, instead of the frequency key assigned to the Master.

- **Frequency Key** - Set the **Frequency Key** parameter in the Transmission Characteristics tab to a key other than that of the conflicting Repeater.

If you need to add a Repeater to your network, use the following steps to help ensure that you resolve any parallel Repeater issues up front, before deploying the Repeater in the network.

1. From within Tool Suite, run a network diagnostics file. You can also gather the settings from all the Repeaters that are currently in your network.

2. Review the network diagnostics file, paying special attention to the following settings on each Repeater and the Master

   - **Frequency Key**

   - **Repeater Frequency**

   - **Rx** and **Tx Subnet IDs**

3. On a piece of paper, draw your network, noting the above settings for each Repeater, ensuring there are no duplicates.

   If there are duplicates, change the **Repeater Frequency** and the **Frequency Key** parameters as described above.

If the Repeater you are adding is the only Repeater in the network, set the **Frequency Key** parameter to match the Master, the **Rx Subnet ID** parameter to match the Master's **Tx Subnet ID** parameter setting, and the **Tx Subnet ID** parameter to **1**. In the Master, set the **Repeaters** parameter to **Enabled**.

Setting Transceiver Passwords

Use passwords to prevent access to or changing of any of the transceiver's parameters. This option is useful if you want to prevent unauthorized personnel from gaining access to the transceiver settings.

If the **Setup Port** option in the Baud Rate tab is set to **(1) Main Only** or **(3) Both**, the password is only accepted if the option is accessed from the main data port. To use the Password function using the diagnostics port, the **Setup Port** option must be set to **(2) Diagnostics Only**.

> **Warning!** If the password feature is enabled and the password is forgotten, you need to return the transceiver to FreeWave to have the password disabled.

To set a password:

1. From the Setup main menu in the terminal interface, select **(8) Chg Password** to display the following prompt:

   New PW? (<esc> to exit)

2. To back out of the process and not enable the password press **Esc**. To set a password, type exactly four characters. Passwords are case sensitive.

   Press **Esc** to cancel the process at any point.

3. After you enter the four characters the following prompt displays:

   <Enter> to accept,<esc> to quit.

4. To accept the password as entered and enable the feature, press **Enter**. To quit the process and not enable the password, press **Esc**.

   If you press **Enter**, the password displays on the line above. The password is case sensitive and every keystroke is a character.

To change a password:

After the password feature has been enabled, it is possible to change to a new password.

1. From the Setup main menu in the terminal interface, select **(8) Chg Password**.

2. At the Enter Security Code prompt enter the current four character, case sensitive password.

   After entering the password correctly, the prompt to enter the new password displays. Enter the new four character, case sensitive password.

   Press **Esc** to cancel this process at any point.

3. To accept the password as entered and enable the feature, press **Enter**. To quit the process and not enable the password, press **Esc**.

   If you press **Enter**, the password displays on the line above. The password is case sensitive and every keystroke is a character.

To disable a password:

After the password features has been enabled, it is possible to disable the password if you know the current password.

> **Important:** You can only disable a password using the prompt when you read the transceiver in Tool Suite, or through a terminal emulator. You cannot disable the password using Setup Terminal application within Tool Suite.

1. From the Setup main menu in the terminal interface, select **(8) Chg Password**.

2. Hold down the **Alt** key and type **0255** using the number pad on your keyboard and release the **Alt** key.

3. Repeat this step three more times (hold **Alt** and type **0255** a total of 4 times).

> **Important:** You must type the **0255** using the NUM Pad on your computer, not the top row of numerals.

After the fourth entry, the password is disabled.

Enabling and Setting Up AES Encryption

Protecting the confidentiality, integrity, and authenticity of your data communications is essential to maintaining a robust, reliable, and secure wireless infrastructure. FreeWave has incorporated a number of mechanisms to achieve these critical security objectives, including the use of AES encryption. When available and enabled, AES encryption adds a layer of 128-bit, 192-bit, or 256-bit encryption strength to the data before it is sent over the RF link.

To use AES encryption, you must set the encryption strength, provide an encryption key, and provide an encryption channel key. These settings are available in the (3) Edit Radio Transmission Characteristics > (E) Encryption menu in the terminal interface, and are not available in Tool Suite. For more information about the settings, see the descriptions below. For information about accessing the Setup menu using the terminal interface, see "Accessing the Setup Menu Using a Terminal Emulator " on page 9.

> **Important:** When AES is enabled, every transceiver in the network must have matching encryption strengths, encryption keys, and encryption channel keys, and the **MCU Speed** parameter set to **3** for successful communication and data transmission.

Encryption (Strength)

> **Note:** AES encryption settings are available only through the Setup menu in the terminal interface. If the transceiver does not have **Encryption** enabled, menu option **E** in the (3) Edit Radio Transmission Characteristics menu is blank and has no function.

> **Important:** This setting must match across all transceivers in the network.

Default Setting: (0) Off

Options:

- **(0) Off** - Turns off AES encryption.
- **(2) AES 128** - Enables AES encryption, 128-bit strength.

- **(3) AES 192** - Enables AES encryption, 192-bit strength.
- **(4) AES 256** - Enables AES encryption, 256-bit strength.

The options available for selection are based on the encryption strength set at the factory, or within the upgrade to use AES completed with FreeWave technical support's assistance. For example, if the transceiver is factory set to include AES 256, then each strength option is available; however, if the transceiver is factory set to include AES 192, then only **Off**, **AES 128**, and **AES 192** are available.

Selecting any option other than **0** enables AES encryption and you must also set the encryption key and the channel key for successful communication.

Setup Terminal Menu: (3) Edit Radio Transmission Characteristics > (E) Encryption

Description: AES encryption is available in various strengths. Your network, and the data you are sending determines the encryption strength you should use. The higher the encryption strength, the stronger the encryption; however, it can also take longer for the encryption and de-encryption to take place.

Encryption Key

Note: AES encryption settings are available only through the Setup menu in the terminal interface. If the transceiver does not have **Encryption** enabled, menu option **E** in the (3) Edit Radio Transmission Characteristics menu is blank and has no function.

Important: This setting must match across all transceivers in the network.

Default Setting: Blank

Options: Any set of hexadecimal pairs as described below.

Setup Terminal Menu: (3) Edit Radio Transmission Characteristics > (E) Encryption > (5) Enter Key

Description: The encryption key is the piece of information used to encrypt and de-encrypt the data sent through your network. Even with encryption, your data is only as secure as the strength of the encryption key you use. Keys should be random in nature and entered as hexadecimal values (0 to F in two-character pairs). You can use any combination of characters for your key. For example, a combination of numbers that you know, or a sentence or phrase converted into hexadecimal format. Various string-to-hexadecimal converters are available on the Internet.

Enter the encryption key in 2-character hexadecimal combinations in the lines provided:

```
Enter Choice  e
0=Off, 2=AES128, 3=AES192, 4=AES256, 5=Enter Key 6=Channel Key
00 34
01 a5
02 6d
03 45
04 76
05 23
06 1a
07 0e
08 87
09 43
0A 11
0B 0b
0C 22
0D 19
0E 90
0F 75
10 61
11 07
12 56
13 a3
14
```

The **Enter Key** option always asks for all 32 lines of the encryption key. However, the encryption strength you select determines how many of the lines are required:

- **128-bit encryption** - Enter key information in rows 00 to 0F. The last 16 lines (10 to 1F) are ignored.

- **192-bit encryption** - Enter key information in rows 00 to 17. The last 8 entries (18 to 1F) are ignored.

- **256-bit encryption** - Enter key information in rows 00 to 1F. All lines are used.

Encryption Channel Key

Note: AES encryption settings are available only through the Setup menu in the terminal interface. If your transceiver does not have **Encryption** enabled, menu option **E** in the (3) Edit Radio Transmission Characteristics menu is blank and has no function.

Important: This setting must match across all transceivers in the network.

Default Setting:	Blank
Options:	Any set of hexadecimal pairs as described below.
Setup Terminal Menu:	(3) Edit Radio Transmission Characteristics > (E) Encryption > (6) Channel Key
Description:	The channel key is required when AES encryption is enabled for transceivers in the network to link when AES encryption is enabled. This setting differs from the **Encryption Key** parameter in that it does not encrypt the actual data but is required, along with the other "golden settings" described in a network, for the communication to take place.

Channel keys should be random in nature and entered as hexadecimal values (0 to F in two-character pairs). You can use any combination of characters for your key. For example, a combination of numbers that you know, or a sentence or phrase converted into hexadecimal format. Various string-to-hexadecimal converters are available on the Internet.

Enter the encryption key in 2-character hexadecimal combinations in lines 00 to 07 in the lines provided.

```
Enter Choice  e
0=Off, 2=AES128, 3=AES192, 4=AES256, 5=Enter Key 6=Channel Key
00 12
01 af
02 21
03 43
04 51
05 ab
06 Ac
07 cD
```

Troubleshooting AES Setup

The transceivers link, transmit data, and then unlink.

Verify that the **MCU Speed** parameter is not set to **3** in the terminal interface.

The transceivers link, transmit data, but the data is in unrecognizable characters.

Verify that the **Encryption Key** on each transceiver is set exactly the same. If the keys do not match, the transceivers can still transmit data, but cannot decrypt the data.

The transceivers do not link and the golden settings are all set the same.

Verify that the **Channel Key** in the Encryption menu is set the same across the transceivers in the network. If the keys do not match, the transceivers will not link when AES is enabled, even if the golden settings match.

Low Baud Rates

The transceiver's baud rate may be set to 300, 600, or 900. For more information about using a low baud rate, contact FreeWave Technical Support.

Multi-Master Synch

The **Multi-Master Synch** setting is reserved for applications in both Point-to-Point and MultiPoint modes with concentrations of Master units where it is necessary to reduce interference between the Master transceivers. For more information about using **Multi-Master Synch** in non-TDMA mode, see application note #5412, *Synchronizing Collocated Masters*, or contact FreeWave Technical Support. For more information about using **Multi-Master Synch** while in TDMA mode, contact FreeWave Technical Support.

Time Divisible Multiple Access (TDMA)

Available as an optional, add-on feature in some transceiver models, the FreeWave Time Division Multiple Access (TDMA) protocol is an enhanced and sophisticated version of Point-to-MultiPoint communications. The TDMA protocol provides timing and other parameters, which in turn allow large transceiver networks to work in a non-polled environment. This option is only used for peer-to-peer communications or when applications are very time specific. If you purchase TDMA as an option, additional information is provided to you about implementing and using the feature.

For additional information about TDMA, contact FreeWave Technical Support.

Chapter 6: Viewing Transceiver Statistics

When you read a transceiver the system displays data transmission statistics the transceiver has gathered during the most recent session. This information is valuable when you need to know the signal strength and noise levels of the link. Statistics are gathered during each time the Master and Slave link and are reset when the next link begins.

In addition, you can view more data transmission characteristics, including averages gathered over time, in the Network Diagnostics application. For information about running network diagnostics using Tool Suite, see the *Tool Suite User Manual*.

To display statistics in Tool Suite:

1. In the Tool Suite Configuration application, click **Read Radio**, and then click the Device Information tab.

2. Review the statistics. Each statistic is described in detail in the sections below.

    You can also view the same statistics using the Setup Terminal option in Tool Suite.

To display the Radio Transmission Characteristics in the terminal interface:

1. Select **(4) Show Radio Statistics** from the Setup main menu to display the following window:

    Review the radio statistics. Each statistic is described in detail in the sections below.

Antenna Reflected Power

This statistic is not valid in the MM2-9X5W transceivers.

Noise Level

The **Noise Level** indicates the level of background noise and interference at this transceiver and at each of the Repeaters in the link. The number is an average of the noise levels measured at each frequency in the

transceiver's frequency hop table.

> **Tip** The individual measurement values at each frequency hop channel are shown in the frequency table. If you are viewing statistics in the terminal interface, press **Enter** when the Radio Statistics menu displays to view the frequency table.

Ideally, the difference between the average signal level and average noise level should be **15** or more. Margins that are significantly higher than this are an indication of a high level of interference that may degrade the performance of the link.

Number of Disconnects

The value in this statistic indicates the total number of times the link between the Master and the Slave has been lost and the transceivers lose Carrier Detect from the time the transceiver is powered on until the transceiver is put into Setup mode. Under ideal operating conditions, the number of disconnects should be **0**. One or more disconnects may indicate a weak link, the presence of severe interference problems, or loss of power to any of the transceivers in the link.

> **Note:** In Tool Suite, the disconnect information is available in the Summary View in the Network Diagnostics application.

Radio Temperature

The **Radio Temperature** value is the current operating temperature of the transceiver in degrees Celsius.

Rate % (Receive Percentage Rate)

The **Rate %** measures the percentage of data packets that were successfully transmitted from the Master and received by the upstream transceiver on the first attempt. The rate percentage represents only what the upstream transceiver received.

A number of 75 or higher indicates a robust link that provides very good performance even at high data transmission rates. A number of 15 or lower indicates a weak or marginal link that provides lower data throughput. Throughput is reduced by 50 percent if the network contains a Repeater.

> **Note:** Many settings can impact actual throughput, including **Master Packet Repeat** and **Max Slave Retry**. In addition, if the link is asymmetrical, the percentage reported in this statistic can be very high, and the uplink can still be poor.

Signal Level

The **Signal Level** indicates the level of received signal at the transceiver and at each of the Repeaters in the link. The source of the signal is the transceiver that transmits to the transceiver from which you are reading this statistic. The number is an average of the received signal levels measured at each frequency in the transceiver's frequency hop table.

> **Tip** The individual measurement values at each frequency hop channel are shown in the frequency table. If you are viewing statistics in the terminal interface, press **Enter** when the Radio Statistics menu displays to view the frequency table.

For a reliable link, the margin should be at least 15 dB. Low average signal levels can often be corrected with higher gain antennas, better antenna placement and/or additional Repeaters.

Transmit Current

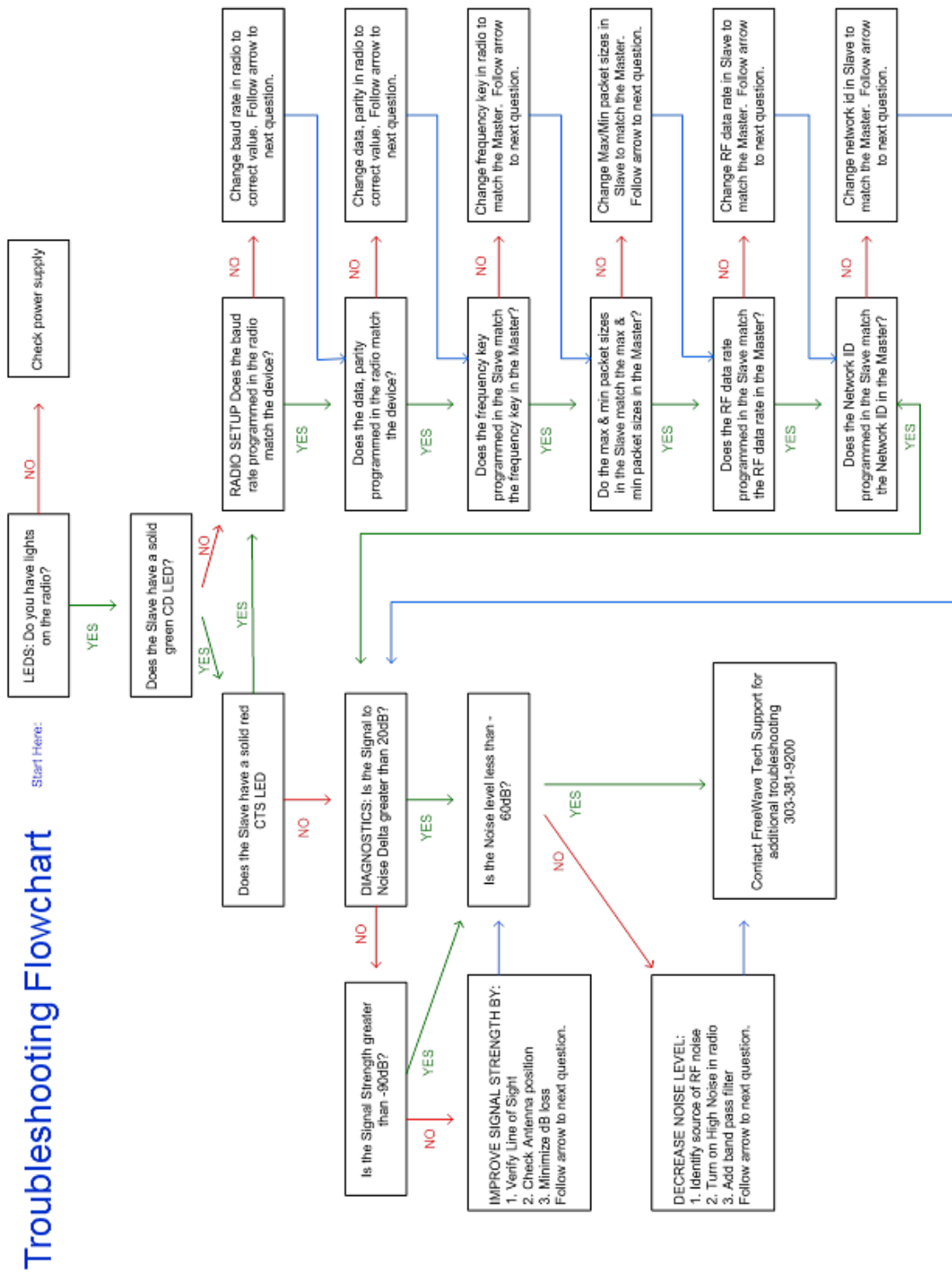This statistic is not valid in the MM2-9X5W transceivers.

Chapter 7: Troubleshooting

If you are experiencing trouble with your network, use the following to initially troubleshoot and help identify the problem with the network or a transceiver within it:

- Settings
- RF Quality

Use the following flow chart and the troubleshooting list in this chapter to walk through basic checks to help diagnose the issue. If you need assistance, contact FreeWave Technical Support.

Troubleshooting Flowchart

Troubleshooting Flowchart

Start Here:

LEDS: Do you have lights on the radio?

NO → Check power supply

YES → Does the Slave have a solid green CD LED?

NO → RADIO SETUP Does the baud rate programmed in the radio match the device?

YES → Does the Slave have a solid red CTS LED

Does the Slave have a solid red CTS LED — NO → DIAGNOSTICS: Is the Signal to Noise Delta greater than 20dB?

RADIO SETUP Does the baud rate programmed in the radio match the device?
- NO → Change baud rate in radio to correct value. Follow arrow to next question.
- YES → Does the data, parity programmed in the radio match the device?

Does the data, parity programmed in the radio match the device?
- NO → Change data, parity in radio to correct value. Follow arrow to next question.
- YES → Does the frequency key programmed in the Slave match the frequency key in the Master?

Does the frequency key programmed in the Slave match the frequency key in the Master?
- NO → Change frequency key in radio to match the Master. Follow arrow to next question.
- YES → Do the max & min packet sizes in the Slave match the max & min packet sizes in the Master?

Do the max & min packet sizes in the Slave match the max & min packet sizes in the Master?
- NO → Change Max/Min packet sizes in Slave to match the Master. Follow arrow to next question.
- YES → Does the RF data rate programmed in the Slave match the RF data rate in the Master?

Does the RF data rate programmed in the Slave match the RF data rate in the Master?
- NO → Change RF data rate in Slave to match the Master. Follow arrow to next question.
- YES → Does the Network ID programmed in the Slave match the Network ID in the Master?

Does the Network ID programmed in the Slave match the Network ID in the Master?
- NO → Change network id in Slave to match the Master. Follow arrow to next question.
- YES →

DIAGNOSTICS: Is the Signal to Noise Delta greater than 20dB?
- NO → Is the Signal Strength greater than -90dB?
- YES → Is the Noise level less than -60dB?

Is the Signal Strength greater than -90dB?
- NO → IMPROVE SIGNAL STRENGTH BY:
  1. Verify Line of Sight
  2. Check Antenna position
  3. Minimize dB loss
  Follow arrow to next question.
- YES →

Is the Noise level less than -60dB?
- NO → DECREASE NOISE LEVEL:
  1. Identify source of RF noise
  2. Turn on High Noise in radio
  3. Add band pass filter
  Follow arrow to next question.
- YES → Contact FreeWave Tech Support for additional troubleshooting 303-381-9200

Chapter 8: Additional Transceiver Information

This section contains additional important information about the FreeWave transceivers described in this manual.

- Connector pin assignments
- Factory default settings
- Specifications
- Mechanical drawings

MM2-9X5W 16-Pin Connector Pinout

J4 - 16 pin, 2.00 mm centers, Samtec TMM series, TMM-108-01-*G-D-SM-option*

> **Note:** See the drawing below for identification of pin numbers.

Pin	Input/Output	Description
1	-	Ground
2	Input	+12 VDC power for the amplifier
3	Input	+4.9 to +5.5 VDC power for the MM2-T
4	-	Menu
5	Input	Data Terminal Ready
6	-	Ground
7	Output	Transmit
8	Output	RSSI - Not currently supported.
9	Input	Receive

Pin	Input/Output	Description
10	Output	Carrier Detect
11	Input	Request to Send
12	Output	Clear to Send
13	Input	Diagnostic Received Data
14	Output	Diagnostic Transmit Data
15	-	Ground
16	-	Not used
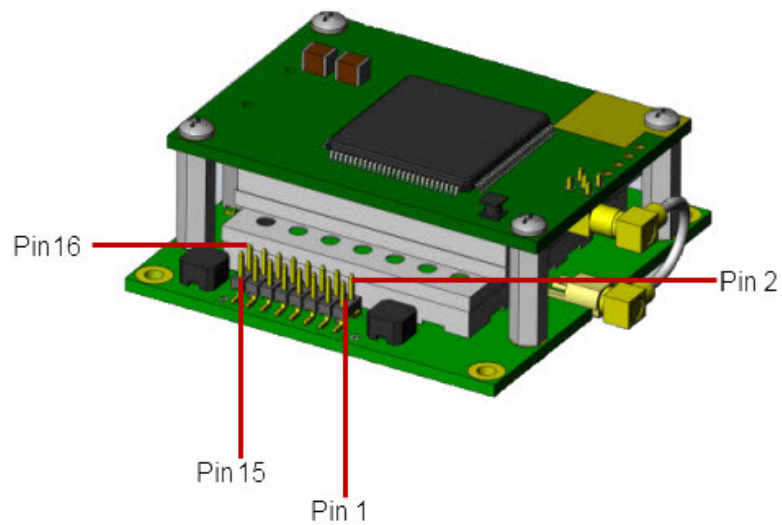
MM2-9X5W Specifications

Specifications may change at any time without notice. For the most up-to-date specifications information, see the product's data sheet available at www.FreeWave.com.

Specification	
Transmitter	
Frequency	902 to 928 MHz
RF Data Rate	1536.6 and 115.2 kbps, user selectable
Output power	5 Watt
Data Link Range	90 miles
Modulation	2 level GFSK
Channel Bandwidth	230 kHz
Hopping Channels	50 to 112, user selectable
Hopping Bands	7, user selectable
Hopping Patterns	15 per Band, 105 total, user selectable
Frequency Zones	16 Zones
RF Connector	MMCX (Straight)
Receiver	
Sensitivity	-108 dBm at 115.2 kbps for BER 10^{-4} -103 dBm at 153.6 kbps for BER 10^{-4}
IF Selectivity	20 dB at fc ± 230 kHz 40 dB at fc ± 460 kHz
RF Selectivity	50 dB at 896 MHz, 935 MHz
Dynamic Range	+10 dBm 3rd Order Intercept Point at Input Connector
Data Transmission	
Error Detection	32 bit CRC, retransmit on error
Data Throughput	80 kbps at RF Data Rate 153.6; 115.2 kbps and RF Data Rate of 115.2
Data Encryption	FHSS Technology, option AES 128/192/256 encryption
Data Interface	1200 bps to 230.4 kbps
Connector	Straight 16-pin dual row header 2.0 mm spacing
Power Requirements	
Operating Voltage	Input 1: +12.0 to +15.0 VDC (amplifier) Input 2: +4.9 to +5.5 VDC (radio)
General Information	

Specification	
Operating Temperature	-40° C to +70° C (-40° F to 158° F)
Humidity	0 to 95% non-condensing
Dimensions	101 mm L x 51 mm W x 13 mm H (4" L x 2 "W x 0.5" H)
Weight	34 g (1.2 oz)

MM2-9X5W Mechanical Drawing
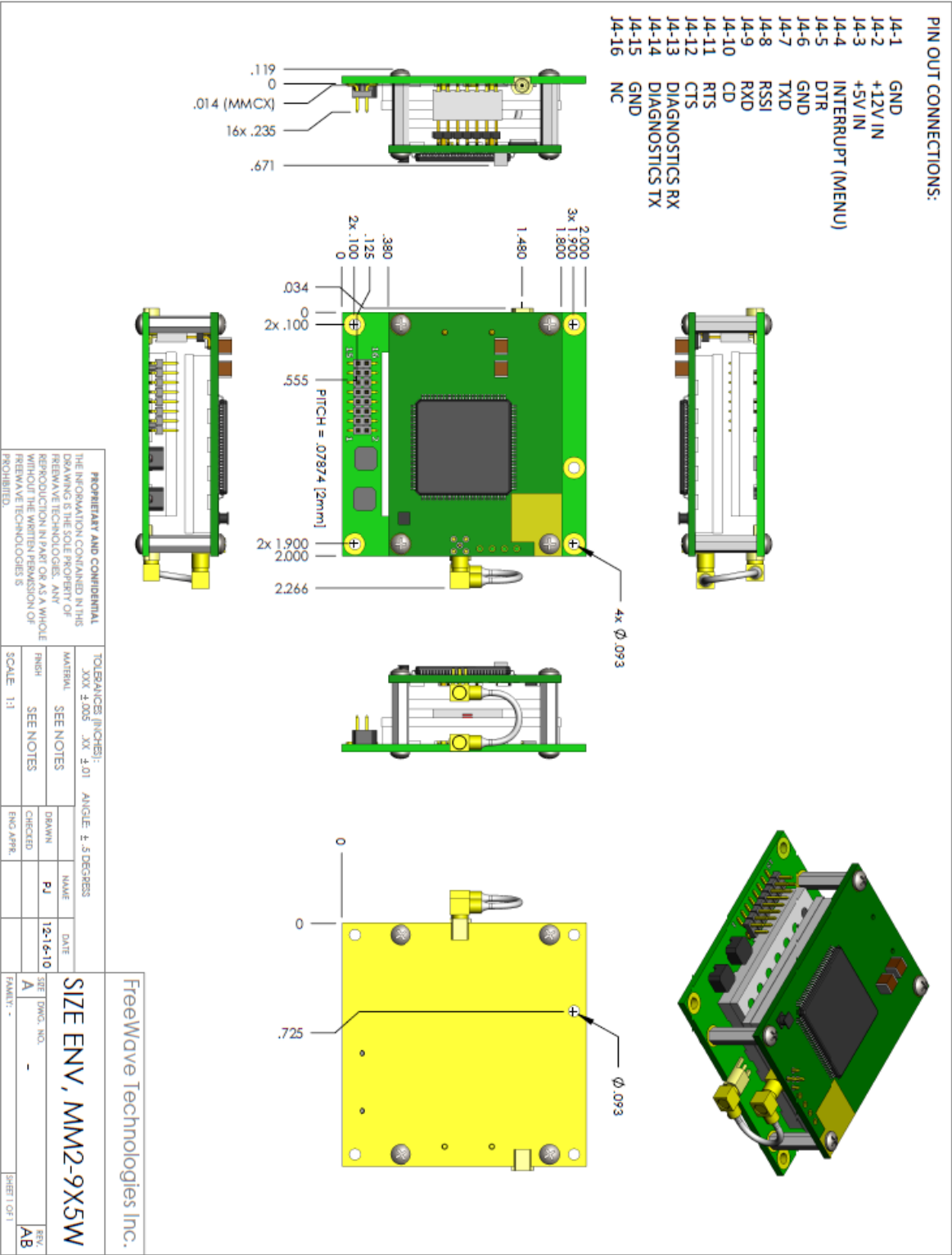
900 MHz Factory Default Settings

FreeWave serial transceivers are shipped from the factory with the following default settings:

Operation Mode	Default		MultiPoint Parameters	Default
Point-to-Point Slave	1		(0) Number of Repeaters	1
Set Baud Rate	**Default**		(1) Master Packet Repeat	2
Baud Rate	115200		(2) Max Slave Retry	9
(A) Data Parity	0		(3) Retry Odds	9
(B) Modbus RTU	0		(4) DTR Connect	0
(C) RS232/485	0		(5) Repeatr Frequency	0
(D) Setup Port	3		(6) Network ID	255
(E) TurnOffDelay/OnDelay	0/0		(7) Reserved	-
(F) Flow Control	0		(8) MultiMaster Sync	0
Radio Parameters	**Default**		(9) 1 PPS Enable Dealy	255
(0) Freq Key	5		(A) Slave/Repeater	0
(0) Hop Table Version	0		(B) Diagnostics	0
(1) Hop Table Size	112		(C) Subnext ID	"Disabled"
	111		Rx ID	F
(2) Hop Freq Offset	0		Tx ID	F
(3) Frequency Zone	All 1s (Enabled)		(D) Radio ID	Not Set
(4) Government Rules	0		(E) Local Access	0
(1) Max Packet Size	8		(G) Radio Name	"blank"
(2) Min Packet Size	9			
(3) Xmit rate	1			
(4) RF Data Rate	3			
(5) RF Xmit Power	10			
(6) Slave Security	0			
(7) RTS to CTS	0			
(8) Retry Timeout	255			
(9) Low Power Mode	0			
(A) High Noise	0			
(B) MCU Speed	0			
(C) Remote LED	0			
(E) Encryption				
Strength	(0) Off			
Enter Key	Blank			
Channel Key	Blank			

Appendix A: Firmware Updates

The sections below describe the updates and known limitations in each firmware version for the MM2-9X5W, as of this document's release. The most recent version is listed first. The latest firmware versions are available on the FreeWave Web site at www.FreeWave.com. You can also view the latest firmware available for most models in Tool Suite.

Version v10.6.7

Release Date: July 2013

> **Note:** If you upgrade from firmware 8.77 or 8.78 to firmware v10.6.7 and experience issues or inconsistent results, contact FreeWave Technical Support at 303.381.9200 or by email at moreinfo@freewave.com.

Additions and Changes:

- Corrected problem with serial radios set to RS485 changing to RS232 operation when no setting change was made. This change only applies to radios that include an RS485 setting for the serial interface.

Known Limitations and Work Arounds:

- In the Network Diagnostics application within Tool Suite, the transceivers report having the incorrect firmware version installed.

- In the Operation Mode tab in Tool Suite (Modem Mode menu in the terminal interface), Ethernet parameters display. These options do not apply to this transceiver.

- Supply voltage readings within Tool Suite can fluctuate and differ from those readings on an external voltage meter.

- In the Transmission Characteristics tab in Tool Suite (Edit Transmission Characteristics menu in the terminal interface), the **Serial Interface** parameter includes RS422, RS485, and RS232. The only valid option is **RS232**.

Version v10.6.6

Release Date: October 2012

> **Note:** If you upgrade from firmware 8.77 or 8.78 to firmware v10.6.6 and experience issues or inconsistent results, contact FreeWave Technical Support at 303.381.9200 or by email at moreinfo@freewave.com.

Additions and Changes:

- Updated firmware version to use the vX.X.X format.

- Added AES 128, 192, and 256 encryption capability. AES functionality is enabled at the factory. To upgrade an existing transceiver to use the AES functionality, contact FreeWave Technical Support.

  You must set AES options using the terminal interface, as Tool Suite versions 2.9.0.0 and before do not include AES.

- Removed the Ultra Low Power Mode feature.

Known Limitations and Work Arounds:

- In the Network Diagnostics application within Tool Suite, the transceivers report having the incorrect firmware version installed.

- In the Operation Mode tab in Tool Suite (Modem Mode menu in the terminal interface), Ethernet parameters display. These options do not apply to this transceiver.

- In the Transmission Characteristics tab in Tool Suite (Edit Transmission Characteristics menu in the terminal interface), the **Serial Interface** parameter includes RS422, RS485, and RS232. The only valid option is **RS232**.

Version 8.78

Release Date: December 2011

Additions and Changes:

- **AES zeroization** - AES capability now supports zeroization, attempting to hold to NAVSO P5239, and various locks and checks against zeroized keys.

- **Clear 8th data bit when set to 7 data bits** - In a case where one radio is programmed with 7 data bits, and parity enabled, the parity bit is transferred by the radios as the 8th data bit, and sent out the port on the other side. This corrupts the data. Now if the radio is set to 7 data bits, it clears the 8th data bit on serial receive.

- **Repeater un-shifts timing in OTA slot** - Repeaters shift half of their timing to ensure their transmissions lineup exactly in time with the masters (2nd layer deep). During an over the air firmware upgrade, the repeater shifted half of it's timing, but did not unshift the timing. This could build into a timing problem causing drop of link on sufficient missed packets.

- **Ultra Low Power Mode** - **ULPM Enable** and **ULPM Sleep** parameters now available in the Transmission Characteristics settings. For more information about **Ultra Low Power Mode**, see the Parameter Reference chapter in this manual.

Version 8.77

Release Date: May 2011 (Initial Release for MM2-9X5W)

Known Limitations and Work Arounds:

- You can now select Mirrored Bit Master or Mirrored Bit Slave as an operation mode.

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