FreeWave Technologies

LRS400S

Data Transceiver

Version 1.0

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LICENSED BAND WIRELESS DATA TRANSCEIVER USER MANUAL

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2. If Product is used outside of FreeWave specifications.
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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A special rate replacement option is offered to non-warranty returns or upgrades. The option to purchase the replacement unit at this special rate is only valid for that RMA. The special replacement rate option expires if not exercised within 30 days of final disposition of RMA.

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FreeWave's Wireless Data Transceivers are designed and manufactured in the United States of America.

Printed in the United States of America.

CAUTION: The LRS400S series transceiver have maximum transmitted output power of 2W. It is recommended that the transmit antenna be kept at least 71 cm away from nearby persons to satisfy FCC RF exposure requirements.

Table of Contents

About FreeWave Transceivers

FreeWave transceivers operate in virtually any environment where RS232 data communications occur. A pair of transceivers function as a 9-pin null modem cable. If the FreeWave transceivers are to be used in an application where a null modem cable is used, such as communication between two computers, then the FreeWave transceivers can be connected directly. If FreeWave transceivers are to be used to replace a straight-through RS232 cable, then a null modem cable must be placed between the transceiver and the DTE instrument to which it is connected.

Choosing a Location for the Transceivers

Placement of the FreeWave transceiver is likely to have a significant impact on its performance. The key to the overall robustness of the radio link is the height of the antenna. In general, FreeWave units with a higher antenna placement will have a better communication link. In practice, the transceiver should be placed away from computers, telephones, answering machines and other similar equipment. The RS232 cable included with the transceiver usually provides ample distance for placement away from other equipment. To improve the data link, FreeWave Technologies offers directional antennas with cable lengths ranging from 3 to 200 feet. 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. The Show Radio Statistics page is found in option 4 in the Main Menu. An adjustment as little as 2 feet in antenna placement can resolve some noise problems. In extreme cases, band pass filter may reduce the out-of-band noise.

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

A Point-to-Point network is limited to one Master and one Slave transceiver.

In a Point-to-MultiPoint network (also referred to as MultiPoint network) the transceiver, designated as a Master, is able to simultaneously communicate with numerous Slaves. In its simplest form, a MultiPoint network functions with the Master broadcasting its messages to all Slaves and the Slaves responding to the Master when given data by the device connected to the data port.

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, outbound packets from the Master to Slaves are sent a set number of times determined by the user. The receiving transceiver will accept 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 by the Slave are acknowledged or retransmitted until they are acknowledged. Therefore, the return link in a MultiPoint network is generally very robust.

> **Note:** In licensed band operation it is suggested to set the repeated master packets at 0 due to the spectrum being quiet. This will maximize throughput and leverage the advantages of licensed band operation.

Traditionally, a MultiPoint network is used in applications where data is collected from many instruments and reported back to one central site. As such, the architecture of such a network is different from Point-to-Point applications. The number of radios in a MultiPoint network is influenced by the following parameters:

1. Size of the blocks of data. The longer the data blocks, the smaller the network capacity.
2. Baud rate.
3. The amount of contention between Slaves. Polled Slaves vs. timed Slaves.

For example, if the network will be polling Slaves once a day to retrieve sparse data, several hundred Slaves could be configured to a single Master. However, if each Slave will be transmitting data at greater levels, then fewer Slaves should be linked to the Master. The overall network will be closer to capacity with fewer Slaves.

For examples and additional information on data communication links, see the section Examples of Data Communication Links later in this document.

Quick Start on a Point-to-MultiPoint Network

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 Slaves simultaneously.

1. Connect the transceiver to the serial port of a computer either through a serial cable or via the diagnostics cable. Make sure to connect the radio to a power source (typically, 6 to 30 VDC).

2. Open up a HyperTerminal session.
   - Use the following settings in connecting with HyperTerminal
   - Connect to COMx (where 'x' is the number of the com port being connected to)
   - Set data rate to - **19,200**, data bits - **8,** Parity- **none**, Stop bits – **1**, Flow control – **none**.

3. Press the **Setup** button on the radio. If using the diagnostics cable, press *Shift-U* (capital U).
   - The three lights on the board should all turn green, indicating Setup mode.
   - The main menu will appear on the screen.

4. Press **0** to get into the Operation Mode menu.
   - Press **2** to set the radio as a point to ***MultiPoint Master*.**
   - OR, Press **3** to set the radio as a point to ***MultiPoint Slave.***
   - Press **Esc** to get back to Main menu.

5. Press **1** in the main menu to change the Baud Rate.
   - The baud rate must be changed to match the baud rate of the device that the radio is to be attached to.
   - Press **Esc** to get back to Main menu.

6. At the Main Menu, press **3.**
   - Set FreqKey, Max Packet Size, Min Packet Size, RF Data rate identical on all radios in the network.

   Note: Changing these values may help to eliminate interference from other FreeWave networks.
   - Press **Esc** to get back to Main menu.

7. At the Main Menu, press **5**.
   - Set the Network ID value to any value between 1 and 4095, except 255.
   - Make sure this value is the same on every radio in the network.

Point-to-MultiPoint Operation LEDs.

	Master			Slave		
Condition	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
Slave linked to Master, no data	Solid red bright	Solid red dim	Off	Solid green	Off	* Solid red bright
Slave linked to Master, Master sending data to Slave	Solid red bright	Solid red dim	Off	Solid green	Off	* Solid red bright
Slave linked to Master, Slave sending data to Master	Solid green RCV data or Solid red bright	Solid red dim	Intermittent flash red	Solid green	Intermittent flash red	* Solid red bright
Master with diagnostics program running	Solid red bright	Solid red dim	Intermittent flash red	Solid green	Intermittent flash red	* Solid red bright

* Clear to Send LED will be solid red with a solid link, as the link weakens the Clear to Send LED light on the Slave will begin to flash.

Quick Start on a Point-to-Point Network

When purchased as a pair, the FreeWave® Wireless Data Transceivers are shipped from the factory pre-configured to operate in Point-to-Point applications. To establish communications between a pair of FreeWave Wireless Data Transceivers just received from the factory:

1. Connect antennas to the transceivers. Freewave Technologies recommends that the antenna port be loaded at all times to prevent damage to the LRS400S radios. Noise potential may be reduced on the bench by lowering the Xmit power.

2. Connect the transceiver to the instrument with the RS232 cable and also attach power. The cable supplied with enclosed transceivers (except Waterproof) is a 9-pin male serial; professional board level transceivers will need a separate programming cable (sold separately).

3. Set the Modem mode in each transceiver. One should be set as a Point-to-Point Master (Mode 0) and the other set as a Point-to-Point Slave (Mode 1).

4. Set the baud rate on each transceiver to match the baud rate of the instrument to which it is attached. Please note, when setting the transceiver's baud rate, its RS232 data rate is set. The baud rate does not have to be on the same setting for the two transceivers.

5. Edit 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 Slave Security (in the Slave).

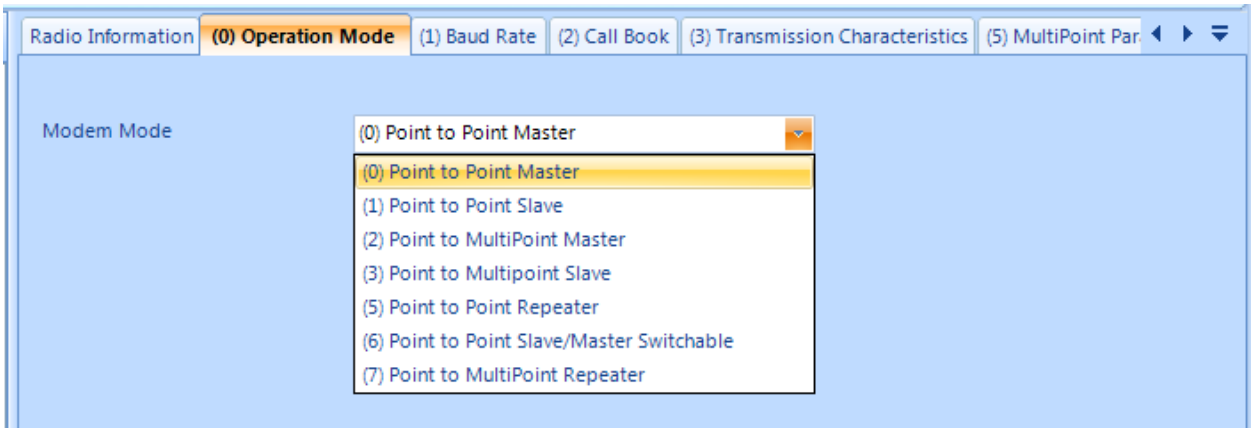
6. Shortly after both transceivers are plugged in, they should establish a communications link with each other and the connection is complete. Using the table below, verify that the radios are operating as expected.

Point-to-Point Operation LEDs

	Master			Slave		
Condition	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
Linked, sending sparse data	Solid green	Intermittent flash red	Intermittent flash red	Solid green	Intermittent flash red	Intermittent flash red
Master calling Slave	Solid red bright	Solid red dim	Solid red bright	Solid red bright	Off	Blinking red
Mode 6 - waiting for ATD command	Solid red bright	Off	Blinking red	Solid red bright	Off	Blinking red
Setup Mode	Solid green	Solid green	Solid green	Solid green	Solid green	Solid green

Setting up a Transceiver

Operation Mode



The Operation Mode option designates the method FreeWave transceivers use to communicate with each other. FreeWave transceivers operate in a Master to Slave configuration. Before the transceivers can operate together, they must be set up to properly communicate.

In a Point-to-Point configuration, Master or Slave Mode may be used on either end of the communication link without performance degradation. When setting up the transceiver, remember that a number of parameters are controlled by the settings in the Master. Therefore, deploying the Master on the communications end where it will be easier to access is advised, but not necessary.

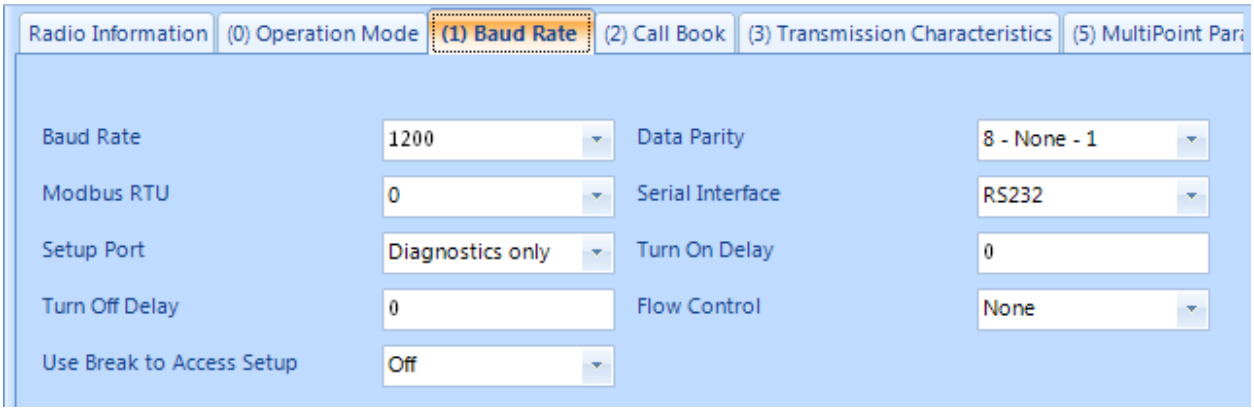
Operation Mode	Description
Point-to-Point Master (0)	This mode designates the transceiver as the Master in Point-to-Point mode. The Master may call any or all Slaves designated in its Call Book. In Point-to-Point mode the Master determines the setting used for most of the radio transmission characteristics, regardless of the settings in the Slave. The settings not determined by the Master are: RF Xmit Power, Slave Security, Retry Time Out, and the Hop Table settings. A quick method of identifying a Master is to power the transceiver. Prior to establishing a communication link with a Slave, all three of the Master's LEDs will be 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. When functioning as a Slave, the **Entry to Call** feature in the transceiver's Call Book is not operational. The Call Book may be bypassed in the Slave by setting Slave Security to 1. See the Slave Security section later in this manual.
Point–to-MultiPoint Master (2)	This mode designates the transceiver as a Master in MultiPoint mode. This mode allows one Master transceiver to simultaneously be in communication with numerous Slaves. A Point-to-MultiPoint Master communicates only with other transceivers designated as Point-to-MultiPoint Slaves.
Point-to-MultiPoint	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

Slave (3)	communicate with its Master.
Point-to-Point Repeater (5)	FreeWave allows the use of one repeater 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 radio transmission characteristics are disabled. A Repeater will connect with any Master that calls it. The Repeater must be set up properly in the Master's call book.
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 FreeWave's 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 will function as a Slave and accept any appropriate calls from other transceivers.
Point-to-MultiPoint Repeater (7)	This option allows the transceiver to operate as a Repeater in a MultiPoint network. See the MultiPoint parameters section for details on enabling MultiPoint Slave/Repeater mode. **Note:** The use of repeaters in Point to Multipoint Networks is restricted to one repeater per network.

Baud Rate

This setting is the communication rate between the transceiver and the instrument to which it is connected. It is important to note that this is independent of the baud rate for the other transceiver(s) in 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 engineer's computer might be set to 57,600.

Set Baud Rate



1. Select the appropriate baud rate to match the attached device.

<table>
<tr><th>Baud Rate</th><th>Description</th></tr>
<tr><td>Actual Baud Rate (selections 0-9)</td><td>The actual baud rate for the transceiver’s data port.
It is desirable to set the baud rate to the highest level supported by the device to which it is connected. In certain circumstances, however, this may actually result in slower data communications.</td></tr>
<tr><td>Data, Parity</td><td>There are six data word length and parity configurations available to be used with FreeWave transceivers. The default setting is 0 (8, N, 1) and is the most commonly used serial communications protocol. Select the appropriate option to communicate with the end device.

Data Bits Parity Stop Bits
8 None 1
7 Even 1
7 Odd 1
8 None 2
8 Even 1
8 Odd 1</td></tr>
<tr><td>Modbus RTU</td><td>Support for Modbus RTU protocol is available. The default setting for Modbus RTU is 0 (Not Enabled).

To enable Modbus capability, set Modbus RTU to 1.

Note: When using the transceiver in Modbus RTU mode, the Master Packet Repeat must be set the same in all radios whether the network is in Point-to-Point or MultiPoint mode. The Modbus RTU mode must be selected when transceivers are configured in RS485 or RS422 mode.</td></tr>
<tr><td>Serial Interface</td><td>In products for which the protocol of the data port is software selectable, use this menu to set the protocol of the data port. In the TTL RF board product this setting must be "0".
Protocol Additional Information
RS232 Also used for TTL transceivers.
RS422 Modbus RTU mode must be enabled. See above.
RS485 Modbus RTU mode must be enabled. See above.
DOT Special for the Department of Transportation.
Note: When DOT mode is enabled, the TimeDelay settings operate the same as in the RS485/422 mode.

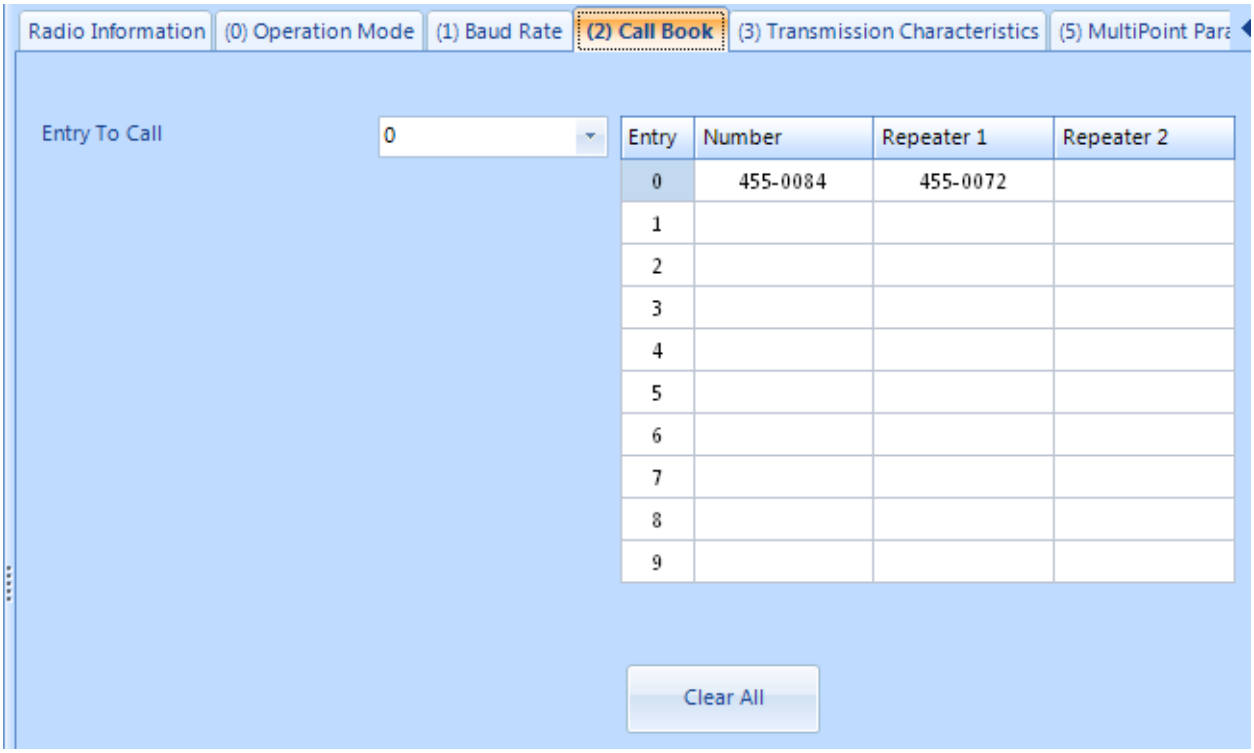
Note: RS4xx mode must have Modbus RTU enabled, and TurnoffDelay set to at least 4.</td></tr>
<tr><td>Setup Port</td><td>Note: DO NOT change this setting unless the correct programming cable is available for the new setting.

This setting determines which port, Main or Diagnostics, is used to enter the Setup Main Menu.

Port Additional Information
Main Only The terminal is connected to the Main Data Port.
Diagnostics Only The terminal is connected to the Diagnostic Port.</td></tr>
</table>

	Both Ports The terminal may be connected to either port. Setup mode is invoked by sending a "U" (capital) to the Diagnostics port or by pressing/toggling the Set-up button/switch, if available. OEM boards may also enter Setup when Pin 2 is grounded. The Main Data Port is the RS232 port. The OEM modules use a 2-row, 2 mm female connector. The diagnostic cable for this port (ASC2009DC) is available from FreeWave.
TurnOn/OffDelay	**TurnOnDelay**- Sets the delay between when the line drivers are turned on and when the data leaves the data port. This setting can be adjusted for a 1-9 mS delay. **TurnOffDelay-** This setting specifies the time after the end of transmission of a character to the RS485 bus that the transceiver stops driving the bus and releases the bus to other devices. The units are ¼ of a character with a range of 0-9. An entry of 4 means a delay equivalent to the duration of a full character. Default is zero delay. For data rates of 1200 bits/S or slower, avoid setting the TurnoffDelay parameter higher than 4. At those rates the functionality of the microprocessor changes so that a TurnoffDelay of 5 will have the same effect as if set to 1, and a setting of 6 will have the same effect as 2, and so on. **Note:** TurnOffDelay must be set to a value of at least 4 for RS4xx operation.
FlowControl	This menu specifies the hardware flow control for the Data port. The options for 0-3 are described below. **Port** **Additional Information** None Default - Uses software control (XON XOFF) RTS DTR DOT

Call Book



The Call Book is required to be used in Point-to-Point networks. The instructions provided in this section are for Point-to-Point mode only.

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

Three settings must be made for two FreeWave transceivers to communicate in Point-to-Point mode:

1. The Master's serial number must be listed in the Slave's Call Book or Slave Security is turned off in the Slave.
2. The Slave's serial number must be listed in the Master's Call Book.
3. The Master must be programmed to call the Slave.

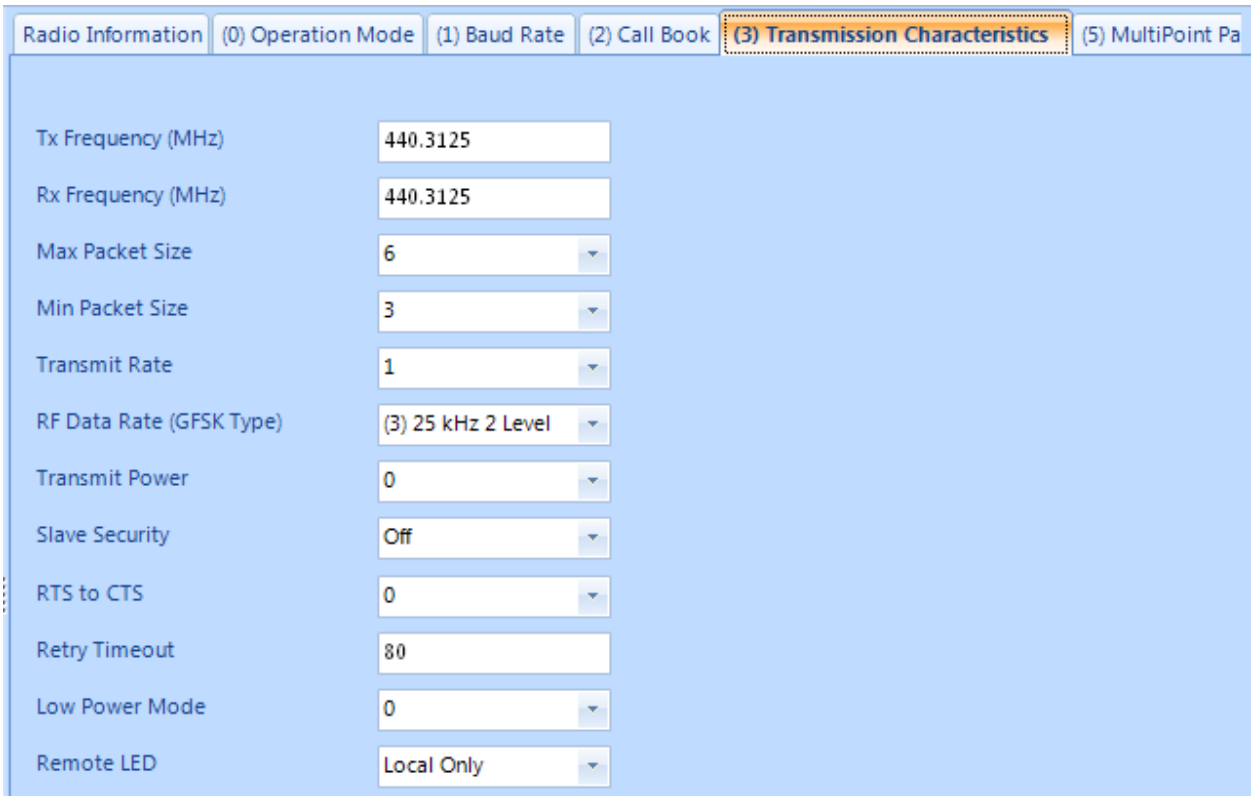
The Call Book allows users to incorporate up to 10 FreeWave transceivers, and designate which Slave the Master will call. To set the **Entry to Call** option, select the appropriate option in the drop down.

Radio Transmission Characteristics

The Edit Radio Transmission Characteristics option allows the user to modify several different parameters in the transceiver. Many of these parameters must be maintained throughout the network for proper functionality.

Note: This menu is **only** for the sophisticated user who has a good understanding of the principles of radio data transmission.

The settings for the Slave(s) not determined by the Master are RF Xmit Power, Slave Security, Retry Time Out and Hop Table Size, Hop Table Version, and Hop Table Offset.



Note: Above image from LRS455. Configuration will be the same.

Edit Radio Transmission Characteristics

Setting Xmit and Rcv Frequencies

The 400MHz Data Transceiver has the option to operate in a Frequency Division Duplex mode by transmitting on one frequency and receiving on another.

The LRS400S transceivers must be programmed to operate on the appropriate frequency. To program the transceiver for single channel operation, enter the frequency, in Megahertz, into the TX and RX Frequency slots.

If the transceivers are to operate in Frequency Division Duplex, the TX and RX Frequency slots will have different frequencies assigned.

(1) AND (2) MAX PACKET SIZE AND MIN PACKET SIZE

The Max and Min Packet Size settings and the RF Data Rate determine the number of bytes in the packets. Throughput can be enhanced when packet sizes are optimized.

The following 3 tables provide the information to determine optimum setting values.

Minimum Packet Size Definition	
Min Setting	**Min Packet Size**
0	0
1	16
2	32
3	48
4	64
5	80
6	96
7	112
8	128
9	144

Maximum Packet Size (2 level FSK)	
Max Setting	**Max Packet Size**
0	32
1	48
2	64
3	80
4	96
5	112
6	128
7	135
8	135
9	135

Maximum Packet Size (4 level FSK)	
Max Setting	**Max Packet Size**
0	32
1	48
2	64
3	80
4	96
5	112
6	128
7	144
8	160
9	176

(3) XMIT RATE

FreeWave transceivers utilize a Master Transmit Beacon to provide low current consumption in the slave radios. The slave radios will turn their receiver off when no data is being passed.

The Xmit Rate setting allows the duty cycle of the Master Transmit Beacon to be changed. A setting of 0 is the highest duty cycle and a setting of 9 is the lowest duty cycle.

(4) RF DATA RATE

FreeWave transceivers have five settings for the RF Data Rate (1, 2, 3, 4, 5). RF Data Rate should not be confused with the serial port Baud Rate.

Setting 2 should be used when the transceivers are close together and data throughput needs to be optimized. Setting 3 should be used when the transceivers are farther away and a solid data link is preferred over data throughput.

Note: In MultiPoint networks, the RF Data Rate must be set identically in all transceivers. Any transceiver with an RF Data Rate different from the Master will not establish a link.

In Point to Point networks the Master's settings take precedence over the Slave.

RF Data Rate Setting	Occupied Bandwidth	Modulation Level
1	50kHz	2-level GFSK
2	25kHz	4-level GFSK
3	25kHz	2-level GFSK
4	12.5kHz	4-level GFSK
5	12.5kHz	2-level GFSK

(5)RF XMIT POWER

The RF Xmit Power parameter allows the user to control the output transmit power up to two watts (+33dBm).

Note: For use in applications requiring greater than 70% transmit duty cycle, the LRS400S series of radios must be attached to an appropriate heat sync.

The following table shows RF TX output versus the RF Xmit Power setting.

RF Xmit Power	RF TX Power (dBm)	RF Xmit Power	RF TX Power (dBm)	RF Xmit Power	RF TX Power (dBm)	RF Xmit Power	RF TX Power (dBm)
10	+33	7	+30	4	+27	1	+24
9	+32	6	+29	3	+26	0	+23
8	+31	5	+28	2	+25		

(6) SLAVE SECURITY

Slave security is a feature which allows Slave transceivers to accept transmissions from a Master not included in the Call Book. The default setting is 0 (Slave Security enabled) which means, only Masters in the Slaves' Call Book may link to that Slave.

Slave Security may be disabled (setting of 1) allowing any Master to call the Slave. Slave Security has no effect in Point-to-MultiPoint networks where the Network ID is not set to 255.

Slave Security 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 Slave Security is set to 1, the transceiver will accept calls from any other FreeWave transceiver. Additional network security measures may be taken to prevent unauthorized access, such as changing default settings for FreqKey, Hop Table or Frequency Zones.

(7) RTS TO CTS

Menu selection RTS to CTS in the Radio Parameters menu provides the option of allowing the RTS line on the Master transceiver to control the CTS line of the Slave. This pass-through control can be enabled in both Point-to-Point and Point-to-MultiPoint. In MultiPoint networks, the Master RTS line will control all Slaves' CTS lines. When enabled, the CTS line ceases to function as flow control. It is not recommended to enable this feature when operating at RS-232 speeds above 38.4kB.

The default setting of 0 disables this function, where as a setting of 1 enables RTS-CTS control.

RTS-CTS setting 2 is described in detail in the application note #5437 DTR to CTS Line Alarm Feature.

With an RTS to CTS setting of 1, the Master senses the RTS line prior to all scheduled packet transmissions. If the state has changed, the Master will then transmit a message to the Slave with the new status. This transmission will occur regardless of data being sent. If data is ready to be sent, the RTS status message will be sent in addition to the data. In Point-to-Point mode, the Master will continue sending the new status message until it receives an acknowledgment from the Slave. In MultiPoint mode, the Master will repeat the message the number of times equal to the Master Packet Repeat value in the MultiPoint Parameters menu.

Master transmit times are completely asynchronous to the occurrence of any change of the RTS line; the latency time from RTS to CTS is variable. The Max and Min Packet Size parameters in the Radio Parameter menu determine this duration. Setting both parameters to their maximum value of 9 will produce a maximum latency time of approximately 21 ms. At the minimum settings for Max and Min Packet Size (0), the time will be approximately 5.9 ms. Please note that this latency can increase significantly if packets are lost between the Master and Slave. In Point-to-MultiPoint mode, there is no absolute guarantee that the state change will be communicated to all Slaves in the unlikely event that all repeated packets from the Master do not get through to all Slaves.

Note: If DTRConnect is enabled and set to 2, the RTS to CTS feature will not work.

Note: If the DTRConnect is enabled and set to 1, RTS to CTS mode takes precedence over the functionality of the CTS line on the Slave relating to the DTRConnect feature.

Note: The RTS to CTS option is only available in RS232 mode.

(8) RETRY TIME OUT

The Retry Time Out parameter in a Slave sets the delay the unit will wait before dropping the connection to a Master in MultiPoint mode. 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, the link will be maintained. The minimum setting is 8. This allows a Slave to drop a connection if less than 1 in 8 consecutive packets is successfully received from the Master.

On the other hand, the function in the Master is effectively the same. With a setting of 255, the Master will allow a Slave 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(s). As the link gets weaker, a lower setting will allow a poor link to break in search of a stronger one.

Note: Setting Retry Time Out to 20 is recommended in areas where several FreeWave networks exist. This setting will allow Slaves 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.

(9) LOWPOWER MODE

The Lowpower Mode feature allows a MultiPoint Slave to consume less power. When set to 2 through 31, the transceiver will sleep 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.

The following table shows the changes at different Lowpower 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.

Setting	Description
0	Lowpower, 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 deasserted (low). In this case, the transceiver needs to be awakened before it will be 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.

IMPORTANT NOTES

1. Lowpower Mode is used only in MultiPoint Slaves using serial protocol. Power savings occur only when the Slave is linked. There are no power savings when the Slave is transmitting data. Lowpower Mode is of little value when a Slave has a constant, high throughput. MCUSpeed must be set to '0' and RF Data Rate must be set to '3' for Lowpower Mode to operate properly.

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

3. If the RTS line on the Slave is held high, the transceiver will remain in normal operation regardless of the Lowpower Mode setting. Once RTS is dropped the transceiver reverts to the Lowpower Mode.

If the transceiver has the DTRConnect option set to 1 or 2 and if the Lowpower Mode enabled (set to 1-31), the RTS line on the transceiver must be asserted for the 'DTRConnect' feature to operate properly.

(C) REMOTE LED

This setting enables the user to connect Remote LED's through the diagnostics port.

Setting	Description	Notes
0	Board LED's	Default. Only on board LEDs are enabled.
1	Board and Remote LED's	Onboard LED's are enabled as well as Remote LED's through the Diagnostic port.
2	Remote LED's	On board LED's are disabled. Remote LED's are enabled through the Diagnostic port.

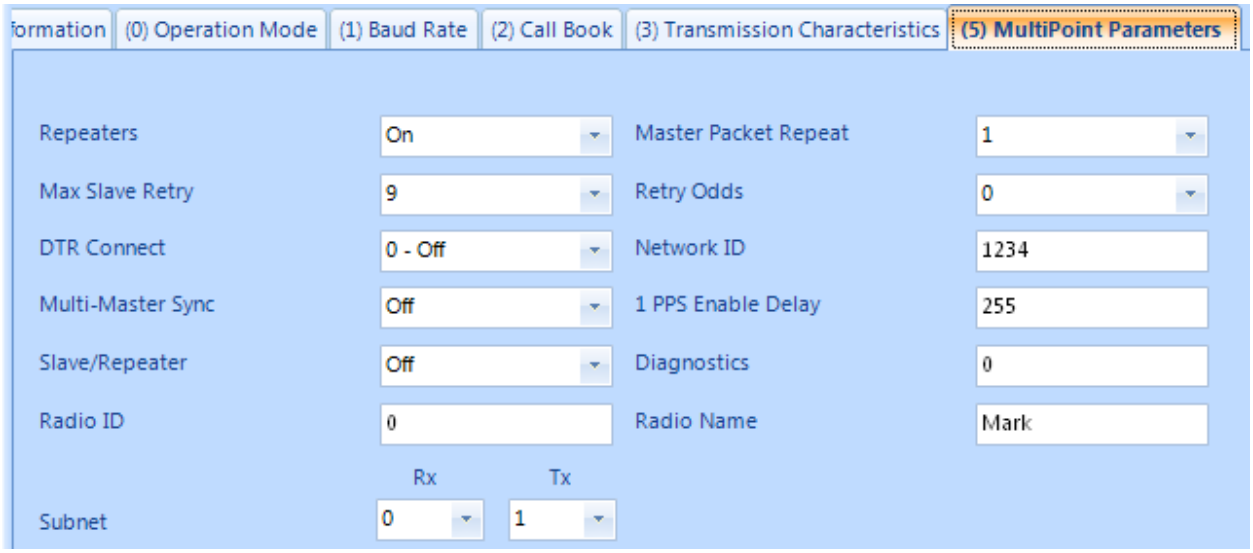
Note: When using Remote LED's the center (TX) LED will not turn Green when in Setup mode. This line is not pinned out.

MultiPoint Parameters

When installing MultiPoint networks it is important to do some up front planning. Unlike Point-to-Point networks, a Point-to-MultiPoint network requires several parameters are set consistently on all transceivers in the network. This includes RF data rate and Min and Max Packet Size.

Note: 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.

Edit MultiPoint Parameters



(0) Repeaters

The Repeaters selection must be set to On if a repeater is to be used in the network. However, if the network will not utilize a repeater, FreeWave recommends setting Repeaters to Off to provide higher throughput.

(1) Master Packet Repeat

In a Point-to-MultiPoint network, Slaves do not acknowledge transmissions from the Master. If Slaves did acknowledge all data transmissions, in a large network, the Master would soon become overwhelmed with acknowledgments from the Slaves. Without acknowledgements, 100% confidence every Slave has received every packet cannot be met. To address this issue, the user may modify the Master Packet Repeat setting, 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 0 or 1. If a network has some weak or marginal links it should be set with higher values. If a Slave receives a good packet from a Master more than once it will discard the repeated packets

Increasing the Master Packet Repeat setting will increase the probability of a packet getting through, but will also increase latency in the network because each packet from the Master 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 0 to 1 will work well for most well designed licensed band networks.

Note: The Master Packet Repeat may be set to 0 if the user software is capable of, or requires acknowledgment. In this case if a packet sent by the Master and not received by the Slave, the user software will control the retries as needed.

(2) MAX SLAVE RETRY

The Max Slave Retry setting defines how many times (0 to 9) the Slave will attempt to retransmit a packet to the Master before beginning to use a back-off algorithm (defined by the Retry Odds setting). Slave retries will stop when an acknowledgement is received from the Master.

(3) RETRY ODDS

While packets transmitted from the Master to the Slaves in a MultiPoint network are not acknowledged, packets transmitted from Slaves to the Master are. It is possible, that more than one Slave will attempt 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. This is addressed through parameters (2) Max Slave Retry and (3) Retry Odds. Once the Slave has unsuccessfully attempted to transmit the packet the number of times specified in Max Slave Retry, it will attempt to transmit to the Master on a random basis. The Retry Odds parameter determines the probability that the Slave will attempt to retransmit the packet to the Master; a low setting will assign low odds to the Slave attempting to transmit. Conversely, a high setting will assign higher odds. An example of how this parameter might be used would be when considering two different Slaves in a MultiPoint network, one with a strong RF link and the other with a weak RF link to the Master. It may be desirable to assign higher Retry Odds to the Slave with the weaker link to give it a better chance of competing with the closer Slave(s) for the Master's attention.

When Retry Odds = 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 will be purged.

(4) DTR CONNECT

With the setting of 0 in the Slave, the transceiver will transmit when RS232 data is received. A setting of 1 will form a Point-to-Point link with the Master when the DTR line is high. With a setting of 2, the transceiver will transmit in bursts. This mode is valuable when a network has many low data rate devices and it is desirable to increase overall network capacity.

Note: If 'DTRConnect' is set to 1 and the 'RTS to CTS' function is enabled on the radio, then 'RTS to CTS' takes precedence over 'DTRConnect'.

Note: If 'DTRConnect' 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 will output unpredictable data.

(6) NETWORK ID

Network ID allows MultiPoint networks to be established without using the Call Book. The default setting of 255 enables the Call Book. To enable Network ID the value must be set between 0 and 4095 (excluding 255). Since Network ID does not use serial numbers, MultiPoint Masters may be replaced without reprogramming all of the Slaves in the network. Slaves will link with the first Master that it hears that has a matching Network ID. The Network ID function should be used in conjunction with the Subnet ID feature (If necessary).

Without having the serial numbers in the Call Book, a Slave may establish communications with different Masters, though not at the same time. This is very useful in mobile MultiPoint applications.

(8) MULTIMASTER SYNC

MultiMaster Sync 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 Masters. Please contact FreeWave Technologies for more information.

(9) 1 PPS ENABLE/DELAY

The 1 PPS Enable/Delay option allows the radio network to propagate a 1PPS signal 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 will provide a 1 PPS pulse on the CD line of any Slave in the network. To use the 1 PPS Enable/Delay feature the steps outlined below must be followed:

1PPS Enable/Delay Setup:

1. The 1 PPS Enable/Delay parameter must be set to 0 in the Master.
2. The Master must have a 1 PPS pulse on the DTR pin.
3. The 1 PPS Enable/Delay parameter on the Slaves must be enabled. Slaves are calibrated at the factory.

Calibrating a Slave in 1PPS Enable/Delay mode

1. Trigger an oscilloscope on the 1 PPS pulse on the DTR line of the Master.
2. Monitor the CD line of the Slave.
3. If the timing on the Slave differs from the Master it may be adjusted via the value in the Slave's 1 PPS Enable/Delay parameter. The difference in time between each incremental integer value is 542.534nS. Changing the parameter to higher values decreases the Slave time delay and changing the parameter to lower values increases the time delay.

When properly calibrated the CD line of a Slave radio will output a pulse that goes high for about 2mS in sync with the 1 PPS pulse on the Master radio. The output on the Slave will occur within 20 microseconds of the input to the Master.

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

(A) SLAVE/REPEATER

Normally a repeater does not have the ability to provide data on the data port. When this capability is necessary Slave/Repeater should be set to On. When using Slave/Repeater, the baud rate and communication protocol must match the end device.

(B) DIAGNOSTICS

This option provides diagnostics data to be viewed at the Master in parallel with application data. The diagnostic program MUST be run from the Master transceiver. Diagnostics requires the following:

1. Diagnostics set to (1 to 128) in the Master.
2. A second computer or serial connection to run the diagnostics software.
3. A diagnostics cable. (Available from FreeWave Technologies.)
4. Diagnostics software. (Available on the User Manual and System Tools CD.)

For more information on Diagnostics, please contact FreeWave Technical Support at (303) 381-9200.

(C) SUBNET ID

The Subnet ID function only works in MultiPoint Networks utilizing the Network ID option. In a MultiPoint Network, a Slave or Repeater will connect with the first Repeater or Master that it hears with the same Network ID. However, where communications need to be forced to follow a specific path the Subnet ID is quite useful. Subnet ID is particularly helpful to force two Repeaters in the same network to operate in series rather than in parallel, or if desired, to force Slaves to communicate to a specific Repeater for load balancing purposes. Two components exist with regard to the Subnet ID:

1. Rcv Subnet ID. This setting identifies which transceiver a Repeater or Slave will listen to.

2. Xmit Subnet ID. This setting identifies the ID on which this device transmits, and in turn which devices will listen to it. *The Xmit Subnet ID parameter is relevant for MultiPoint Repeaters only.*

The default (disable) setting for both Rcv and Xmit is F.

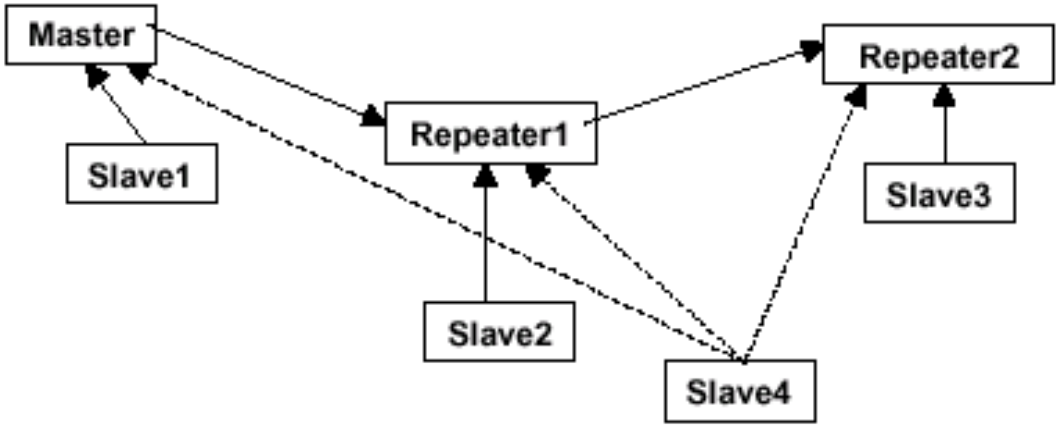
Notes: A Master will always transmit and receive on 0. Changing these settings on the Master is not recommended, under normal circumstances.

In some MultiPoint Networks, the FreqKey will be at the same setting for all transceivers. In other networks, where parallel Repeaters are introduced, the FreqKey value will need to change. See FreqKey and Repeater Frequency sections earlier in this manual for more information.

If both Rcv Subnet ID and Xmit Subnet ID are set to 0 the Subnet ID will show **Roaming** in the menu. This setting will allow a mobile Slave to roam from subnet to subnet and possibly from network to network.

This drawing depicts a Network in which Subnet IDs are used to force communications. In this example, Repeater1 *must* talk directly to the Master; Repeater2 *must* talk directly to Repeater1. Slaves 1, 2, and 3 are forced along the direction of the solid lines. Slave4 may link to the first Master or Repeater it hears.

The respective Subnet ID diagram and settings are shown below.



(D) RADIO ID

Option (D) allows a transceiver to be designated with an arbitrary, user selectable, 4 digit number which identifies the transceiver in diagnostics mode.

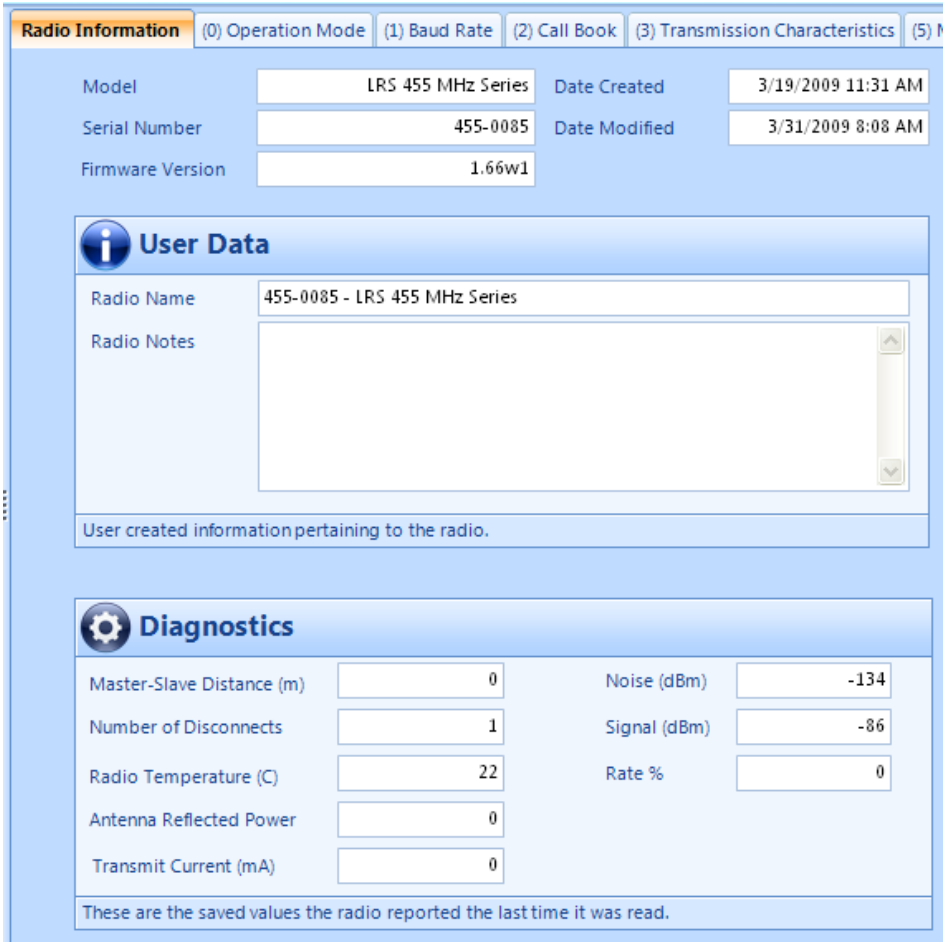
(E) LOCAL ACCESS

Local Access is not to be used at this time.

(G) RADIO NAME

Option (G) allows the user to set a unique 20 character Radio name.

Radio Information



Radio Statistics in the Main Menu allows the user to view data transmission statistics gathered by the transceiver during the most recent session. This is valuable when the user needs to know the signal strength and noise levels of the link. Statistics are gathered during each data link and are reset when the next link begins. See display below.

Number of Disconnects

Any time the link between the Master and the Slave is broken and the radios lose Carrier Detect, it is recorded in the Number of Disconnects value. The value indicates the total number of disconnects that have occurred from the time the transceiver is powered on until the radio 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 radios in the link.

Antenna Reflected Power

This is a measurement of the transmitted power that is reflected back into the transceiver from mismatched antennas or cables, or loose connections between the transceiver and antenna. A reading of 0-5 is good; 5-30 is acceptable; 30+ indicates that the connections should be inspected for loose connections and cable quality.

Average Noise Level

The average noise level indicates the level of background noise and interference at this transceiver. The number is an average of the noise levels measured at each frequency in the transceiver's frequency hop

table. The individual measurement values at each frequency hop channel are shown in the frequency table. Pressing the **Enter** key when the Radio Statistics menu is displayed, accesses the frequency table.

Ideally, noise levels should be below -120 dBm units and the difference between the average signal level and average noise level should be 26 dB or more. Noise levels significantly higher than this are an indication of a high level of interference that may degrade the performance of the link. High noise levels can often be mitigated with band pass filters, antenna placement or antenna polarization.

AVERAGE SIGNAL LEVEL

The average signal level indicates the level of received signal at this transceiver. For each of these, the signal source is the transceiver that transmits to it. The number is an average of the received signal levels measured at each frequency in the transceiver's frequency hop table. The individual measurement values at each frequency hop channel are shown in the frequency table. Pressing the **Enter** key when the Radio Statistics menu is displayed accesses the frequency table. For a reliable link, the margin should be at least 26 dB. Low Average Signal Levels can often be corrected with higher gain antennas and better antenna placement.

Note: Please consult the install manual for antenna and FCC requirements.

OVERALL RCV RATE (%)

The Overall Receive Rate measures the percentage of data packets that were successfully transmitted from the Master to the Slave on the first attempt. A number of 75 or higher indicates a robust link that will provide very good performance even at high data transmission rates. A number of 15 or lower indicates a weak or marginal link that will provide lower data throughput.

RADIO TEMPERATURE

The Radio Temperature value is the current operating temperature of the transceiver in degrees Celsius. For proper operation, a FreeWave transceiver must be in the temperature range of -30° to +60° C.

Factory Default Settings

FreeWave 415MHz transceivers are shipped from the factory with the following Default Settings:

Operation Mode	**Default**
Point to Point Slave	1
Set Baud Rate	**Default**
Baud Rate	19200
(A) Data Parity	0
(B) Modbus RTU	0
(C) RS232/485	0
(D) Setup Port	3
(E) TurnOffDelay/OnDelay	0/0
(F) Flow Control	0
Radio Parameters	**Default**
(1) MAX PACKET SIZE	9
(2) MIN PACKET SIZE	1
(3) XMT RATE	1
(4) RF DATA RATE	5
(5) RF XMT 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

MultiPoint Parameters	**Default**
(1) MASTER PACKET REPEAT	0
(2) MAX SLAVE RETRY	9
(3) RETRY ODDS	0
(4) DTR CONNECT	0
(6) NETWORK ID	255
(7) RESERVED	
(8) MULTI MASTER SYNC	0
(9) 1 PPS ENABLE DELAY	255
(B) DIAGNOSTICS	0
(D) RADIO ID	Not Set

Additional Transceiver information

This section contains additional important information about FreeWave transceivers. The following topics are included in this section:

- Operational RS422 and RS-485 Information
- RS232 Pin Assignments
- OEM Board Pin Assignments

Operational RS-422 and RS-485 Information

For both RS-422 and RS-485, the FreeWave transceiver can drive 32 standard unit loads and loads the bus with only 1/8 unit load. This means the user can tie up to 256 devices on the bus if all of the line receivers have 1/8 unit load.

RS-422 is used for 4-wire or full duplex communication with one Master and multiple Slaves. The FreeWave Master transceiver keeps the line driver asserted at all times. The maximum line length is 4,000 feet using 2, 120 ohm twisted pair cables with a 5th wire for data common.

RS-485 full duplex using 4 wire plus common is the same as RS-422, except the system can have multiple Masters on the bus.

The most common operation of RS-485 is a two-wire comprised of a 120 ohm impedance single twisted pair. In this system the loading of the FreeWave transceiver is as described above which allows up to 256 1/8 unit load units on the bus. Maximum line length is also 4,000 feet with a third wire required for data common. The FreeWave transceiver will check the line to be certain no other device is transmitting before enabling the line driver for data transmission.

When setting the transceiver to RS-485, enable Modbus and set Master Packet Repeat to 3 in the transceiver(s) that will use RS-485. Also set TurnOff Delay to 4.

The TurnOffDelay setting in the menu is used to control the length of time the transmitter driver stays asserted after data transmission has finished. This is needed to allow the last transmitted character to reach the end of a long line and is normally set to one character length of time. This setting also allows 3 complete reflections to the end of the line to ensure the ringing on the line has fully dampened before releasing the bus to another device. Shorter line lengths may use shorter delays, but four one-quarter-character delay times are recommended. In Modbus, a TurnOffDelay setting of 0 will cause internal timing errors.

There is no provision for hand shaking in any of the above modes of operation, so data rates of 57.6 KBaud and above are not recommended without a protocol that can handle error detection properly.

RS-422 and RS-485 Full Duplex Pin-Outs

Function	Bare Board Pin Number	DE-9 Pin Number
RX+	7	3
RX-	9	7
TX+	5	2
TX-	10	8
Signal Ground	4 or 6	5

RS-485 Half Duplex Pin-Outs

Function	Bare Board Pin Number	DE-9 Pin Number
Wire to both pins for Bus +	Short 5 and 7	Short 2 and 3
Wire to both pins for Bus -	Short 9 and 10	Short 7 and 8
Signal Ground	4 or 6	5

RS232 Pin Assignments

Pin		Assignment	Signal	Definition
1	CD	Carrier Detect	Output	Used to show an RF connection between transceivers.
2	TX	Transmit Data	Output	Used to transmit data bits serially from the transceivers to the system device.
3	RX	Receive Data	Input	Used to receive data bits serially from the system device connected to the transceivers.
4	DTR	Data Terminal Ready	Input	Used only in transceivers in Point-to-Point Slave/Master switchable mode or for DTR Connect.
5	GND	Ground		Signal return for all signal lines shared with Pin 9.
6	DSR	Data Set Ready	Output	Always high when the radio is powered from the 2.5mm power connector. Indicated power is on to the radio. Also, this pin can be used for +12Volts when powering the transceivers directly through the RS-232 port. **Note:** This is not used on the OEM module.
7	RTS	Request to Send	Input	The transceiver does not recognize RTS for flow control. RTS is used as a control line in RTS/CTS mode.
8	CTS	Clear to Send	Output	This signal is used to tell the system device connected to the transceiver that the transceiver is ready to receive data. When asserted, the transceiver will accept data, when deasserted the transceiver will not accept data. This should always be used for data rates above 38.4KB or there will be a risk of lost data if an RF link is not very robust.
9	GND	Ground		Signal return for all signal lines shared with Pin 5.

RF Board Pinout

The LRS400S series transceivers are available in both TTL and RS232 versions.

The TTL versions use reverse polarity from standard RS-232 at 0 to 5 Volt levels. All pin descriptions and pin numbering are the same as the RS232 version. The RS232 versions use standard RS232 polarity and voltage levels for all of the RS232 signal lines (DTR, Transmit Data, Receive Data, Carrier Detect, RTS, and Clear to Send) and TTL standard polarity and voltage level for the Interrupt pin.

Pin 1: B+ Power input.

Pin 2: Interrupt (INT) – Input – A 0 volt level on this pin will switch the radio into Setup mode.

Pin	Assignment	Color on ACS3610xx cable
1	B+ input	Red
2	Interrupt (temporarily ground to invoke menu)	Brown
3	Data Terminal Ready (DTR)	Orange
4	Ground	Black
5	Transmit Data (TXD)	Yellow
6	Ground	Black
7	Receive Data (RXD)	Green
8	Carrier Detect (DCD)	Blue
9	Request to Send (RTS)	Violet (purple)
10	Clear to Send (CTS)	Gray

Note: Pin 1 on the board level transceiver is the pin farthest from the three LEDs and pin 10 is closest to the LEDs.

FreeWave Technical Support

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

FreeWave provides Technical Support, Monday through Friday, 8:00 AM to 5:00 PM, Mountain Time (GMT -7) Call us toll-free at **1-800-548-5616 or factory direct after hours at 303-381-9200** or email us at moreinfo@FreeWave.com

Frequency List

The LRS400S transceivers tune from 406.1MHz to 430MHz with a tuning resolution of 6.25KHz. This gives a total of 3840 available channels. Using the license allowed frequency, the channel number can be determined using the following formula.

$$\text{Channel number} = (F^{MHz} - 390) / .00625$$

Note: This is an example list. If the required frequency is not listed use the F^{MHz} formula to obtain the appropriate channel number.

Channel #	Frequency		Channel #	Frequency		Channel #	Frequency		Channel #	Frequency
2576	406.1000		2910	408.1875		3260	410.3750		3610	412.5625
2578	406.1125		2920	408.2500		3270	410.4375		3620	412.6250
2580	406.1250		2930	408.3125		3280	410.5000		3630	412.6875
2590	406.1875		2940	408.3750		3290	410.5625		3640	412.7500
2600	406.2500		2950	408.4375		3300	410.6250		3650	412.8125
2610	406.3125		2960	408.5000		3310	410.6875		3660	412.8750
2620	406.3750		2970	408.5625		3320	410.7500		3670	412.9375
2630	406.4375		2980	408.6250		3330	410.8125		3680	413.0000
2640	406.5000		2990	408.6875		3340	410.8750		3690	413.0625
2650	406.5625		3000	408.7500		3350	410.9375		3700	413.1250
2660	406.6250		3010	408.8125		3360	411.0000		3710	413.1875
2670	406.6875		3020	408.8750		3370	411.0625		3720	413.2500
2680	406.7500		3030	408.9375		3380	411.1250		3730	413.3125
2690	406.8125		3040	409.0000		3390	411.1875		3740	413.3750
2700	406.8750		3050	409.0625		3400	411.2500		3750	413.4375
2710	406.9375		3060	409.1250		3410	411.3125		3760	413.5000
2720	407.0000		3070	409.1875		3420	411.3750		3770	413.5625
2730	407.0625		3080	409.2500		3430	411.4375		3780	413.6250
2740	407.1250		3090	409.3125		3440	411.5000		3790	413.6875
2750	407.1875		3100	409.3750		3450	411.5625		3800	413.7500
2760	407.2500		3110	409.4375		3460	411.6250		3810	413.8125
2770	407.3125		3120	409.5000		3470	411.6875		3820	413.8750
2780	407.3750		3130	409.5625		3480	411.7500		3830	413.9375
2790	407.4375		3140	409.6250		3490	411.8125		3840	414.0000
2800	407.5000		3150	409.6875		3500	411.8750		3850	414.0625
2810	407.5625		3160	409.7500		3510	411.9375		3860	414.1250
2820	407.6250		3170	409.8125		3520	412.0000		3870	414.1875
2830	407.6875		3180	409.8750		3530	412.0625		3880	414.2500
2840	407.7500		3190	409.9375		3540	412.1250		3890	414.3125
2850	407.8125		3200	410.0000		3550	412.1875		3900	414.3750
2860	407.8750		3210	410.0625		3560	412.2500		3910	414.4375
2870	407.9375		3220	410.1250		3570	412.3125		3920	414.5000
2880	408.0000		3230	410.1875		3580	412.3750		3930	414.5625
2890	408.0625		3240	410.2500		3590	412.4375		3940	414.6250
2900	408.1250		3250	410.3125		3600	412.5000		3950	414.6875

Channel #	Frequency		Channel #	Frequency		Channel #	Frequency		Channel #	Frequency
3960	414.7500		4420	417.6250		4880	420.5000		5340	423.3750
3970	414.8125		4430	417.6875		4890	420.5625		5350	423.4375
3980	414.8750		4440	417.7500		4900	420.6250		5360	423.5000
3990	414.9375		4450	417.8125		4910	420.6875		5370	423.5625
4000	415.0000		4460	417.8750		4920	420.7500		5380	423.6250
4010	415.0625		4470	417.9375		4930	420.8125		5390	423.6875
4020	415.1250		4480	418.0000		4940	420.8750		5400	423.7500
4030	415.1875		4490	418.0625		4950	420.9375		5410	423.8125
4040	415.2500		4500	418.1250		4960	421.0000		5420	423.8750
4050	415.3125		4510	418.1875		4970	421.0625		5430	423.9375
4060	415.3750		4520	418.2500		4980	421.1250		5440	424.0000
4070	415.4375		4530	418.3125		4990	421.1875		5450	424.0625
4080	415.5000		4540	418.3750		5000	421.2500		5460	424.1250
4090	415.5625		4550	418.4375		5010	421.3125		5470	424.1875
4100	415.6250		4560	418.5000		5020	421.3750		5480	424.2500
4110	415.6875		4570	418.5625		5030	421.4375		5490	424.3125
4120	415.7500		4580	418.6250		5040	421.5000		5500	424.3750
4130	415.8125		4590	418.6875		5050	421.5625		5510	424.4375
4140	415.8750		4600	418.7500		5060	421.6250		5520	424.5000
4150	415.9375		4610	418.8125		5070	421.6875		5530	424.5625
4160	416.0000		4620	418.8750		5080	421.7500		5540	424.6250
4170	416.0625		4630	418.9375		5090	421.8125		5550	424.6875
4180	416.1250		4640	419.0000		5100	421.8750		5560	424.7500
4190	416.1875		4650	419.0625		5110	421.9375		5570	424.8125
4200	416.2500		4660	419.1250		5120	422.0000		5580	424.8750
4210	416.3125		4670	419.1875		5130	422.0625		5590	424.9375
4220	416.3750		4680	419.2500		5140	422.1250		5600	425.0000
4230	416.4375		4690	419.3125		5150	422.1875		5610	425.0625
4240	416.5000		4700	419.3750		5160	422.2500		5620	425.1250
4250	416.5625		4710	419.4375		5170	422.3125		5630	425.1875
4260	416.6250		4720	419.5000		5180	422.3750		5640	425.2500
4270	416.6875		4730	419.5625		5190	422.4375		5650	425.3125
4280	416.7500		4740	419.6250		5200	422.5000		5660	425.3750
4290	416.8125		4750	419.6875		5210	422.5625		5670	425.4375
4300	416.8750		4760	419.7500		5220	422.6250		5680	425.5000
4310	416.9375		4770	419.8125		5230	422.6875		5690	425.5625
4320	417.0000		4780	419.8750		5240	422.7500		5700	425.6250
4330	417.0625		4790	419.9375		5250	422.8125		5710	425.6875
4340	417.1250		4800	420.0000		5260	422.8750		5720	425.7500
4350	417.1875		4810	420.0625		5270	422.9375		5730	425.8125
4360	417.2500		4820	420.1250		5280	423.0000		5740	425.8750
4370	417.3125		4830	420.1875		5290	423.0625		5750	425.9375
4380	417.3750		4840	420.2500		5300	423.1250		5760	426.0000
4390	417.4375		4850	420.3125		5310	423.1875		5770	426.0625
4400	417.5000		4860	420.3750		5320	423.2500		5780	426.1250
4410	417.5625		4870	420.4375		5330	423.3125		5790	426.1875

Channel #	Frequency		Channel #	Frequency		Channel #	Frequency		Channel #	Frequency
5800	426.2500		5960	427.2500		6120	428.2500		6280	429.2500
5810	426.3125		5970	427.3125		6130	428.3125		6290	429.3125
5820	426.3750		5980	427.3750		6140	428.3750		6300	429.3750
5830	426.4375		5990	427.4375		6150	428.4375		6310	429.4375
5840	426.5000		6000	427.5000		6160	428.5000		6320	429.5000
5850	426.5625		6010	427.5625		6170	428.5625		6330	429.5625
5860	426.6250		6020	427.6250		6180	428.6250		6340	429.6250
5870	426.6875		6030	427.6875		6190	428.6875		6350	429.6875
5880	426.7500		6040	427.7500		6200	428.7500		6360	429.7500
5890	426.8125		6050	427.8125		6210	428.8125		6370	429.8125
5900	426.8750		6060	427.8750		6220	428.8750		6380	429.8750
5910	426.9375		6070	427.9375		6230	428.9375		6390	429.9375
5920	427.0000		6080	428.0000		6240	429.0000		6400	430.0000
5930	427.0625		6090	428.0625		6250	429.0625			
5940	427.1250		6100	428.1250		6260	429.1250			
5950	427.1875		6110	428.1875		6270	429.1875			