FreeWave®
Spread Spectrum
Wireless Data Transceiver

User Manual

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Warranty

Your FreeWave Wireless Data Transceiver is warranted against defects in materials and manufacturing for a period of two years from the date of purchase. In the event of a product failure due to materials or workmanship, FreeWave Technologies will, at its discretion, repair or replace the product.

FreeWave Technologies, its suppliers, and its licensors shall in no event be liable for any damages arising from the use of or inability to use this product. This includes business interruption, loss of business information, or other loss which may arise from the use of this product.

The FreeWave Wireless Data Transceiver is made in the United States of America.

Printed in the United States of America.

FCC Notification

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

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

CAUTION: The model number FGR09 has a maximum transmitted output power of 955mW. It is required that the transmit antenna be kept at least 23 cm away from nearby persons to satisfy FCC RF exposure requirements.

The "I"-series radio transceivers have maximum transmitted output power of 500 mW. It is required that the transmit antenna be kept at least 36 cm away from nearby persons to satisfy FCC RF exposure requirements.

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

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

Note: Whenever any FreeWave Technologies module is placed inside an enclosure a label ***must*** be placed on the outside of that enclosure which includes the module's FCC ID.

This product is licensed by The United States. Diversion contrary to U.S. law is prohibited.

Shipment or re-export of this product outside of The United States may require authorization by the U.S. Bureau of Export Administration. Please contact FreeWave Technologies for assistance and further information.

Model# FGRO9CSU is suitable for use in Class 1, Division 2, Groups A, B, C, and D or non-hazardous locations only.

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Quick Start

When purchased as a pair the FreeWave® Wireless Data Transceivers are shipped from the factory pre-configured to operate together in point-to-point applications. The Transceivers are preset for high-speed data communications and to communicate only with each other.

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

To establish communications between a pair of FreeWave Wireless Data Transceivers just received from the factory:

1. Set the baud rate on each transceiver to match the baud rate of the instrument to which it is attached. Please note that when you are setting the transceiver's baud rate you are setting its RS232 data rate, which must match the rate for the instrument to which it is attached. This in turn means that the baud rate does not have to be on the same setting for the two transceivers.
2. Verify that the RS232 connector on the cable supplied will fit the RS232 interface on the instrument to which it is being connected. The cable supplied will fit a 9 pin male RS232 connector, any other format will need an adapter or different cable.
3. Connect Antennas to the modems. Any FreeWave transceiver may be operated without an antenna for benchtop testing without concern for damaging the product.
4. Connect the Transceiver to the instrument with the RS232 cable and attach the power adapter to the Transceiver. Shortly after both modems are plugged in they should establish a communications link with each other and your connection is complete!

Note: *The terms Modem and Transceiver are used interchangeably in this manual and in the text of the setup menu. While the words have different meanings, the two terms should be treated as one and the same for the purposes of use of the FreeWave product.*

Quick Start on a Multipoint System

0) Set Operation Mode

Program one of the units to be a multipoint Master (Operation Mode 2)

Program the Multipoint Slaves (Operation Mode 3)

1) Set Baud Rate

Set the Baud Rate to match the baud rate of the device to which the transceiver will be connected.

3) Edit Radio Transmission Characteristics

Set FreqKey, Max Packet Size, Min Packet Size, and RF Data Rate to identical settings on every radio to be used in the network. It is always a good idea to set the FreqKey, Max Packet Size, Min Packet Size to values other than the factory defaults.

4) Edit Multipoint Parameters

Will there be a repeater in the network or do you intend to be able to run diagnostics on the network? If so set that value to 1.

Set the NetworkID to a value between 1 and 4095, other than 255 (enables call book).

The rest is just fine tuning . . .

Tuning Transceiver Performance

FreeWave allows you to tune several parameters to optimize its performance for your particular application. All adjustments are done through the FreeWave setup program, a user interface which eliminates the need for setup diskettes, DIP switch settings, or custom software.

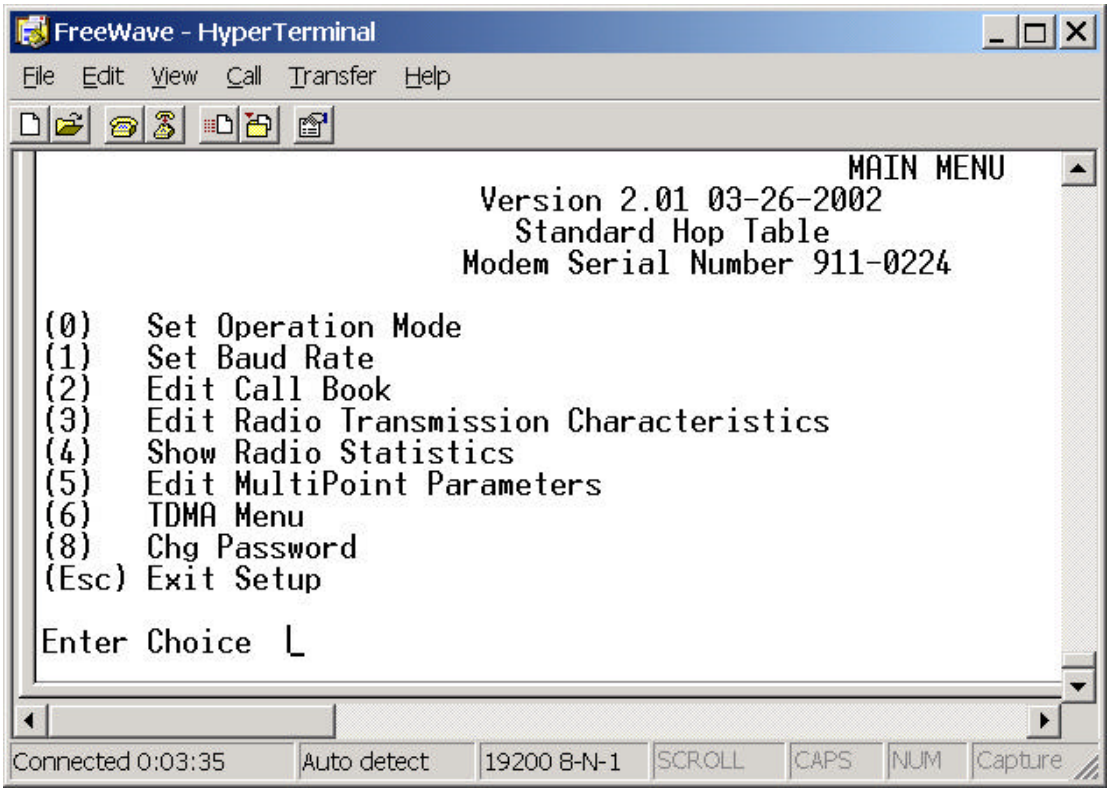
The setup program is invoked by connecting FreeWave to any computer running a terminal program, setting the baud rate for that terminal to 19200 baud, and putting the transceiver into setup mode (on most models this is done by pressing the Setup button). While any terminal which can be set to 19200 baud will work, examples for this manual were generated using Microsoft Windows' Terminal or Hyperterminal applications. You may connect to either the Data Port or the Diagnostics port (using a special cable that you may obtain from FreeWave).

Table 1: Setup Menu
Terminal Settings

Parameter	Setting
Baud Rate	19200
Data Bits	8
Parity	None
Stop Bits	1
Parity Check	None / Off
Carrier Detect	None / Off
Flow control	Xon/Xoff

When the setup program is invoked all three LEDs on the FreeWave front panel will turn green and will remain green for the entire time the Transceiver is in setup mode. The main menu screen for the setup program is shown in Figure 1:

Figure 1: Initial Menu

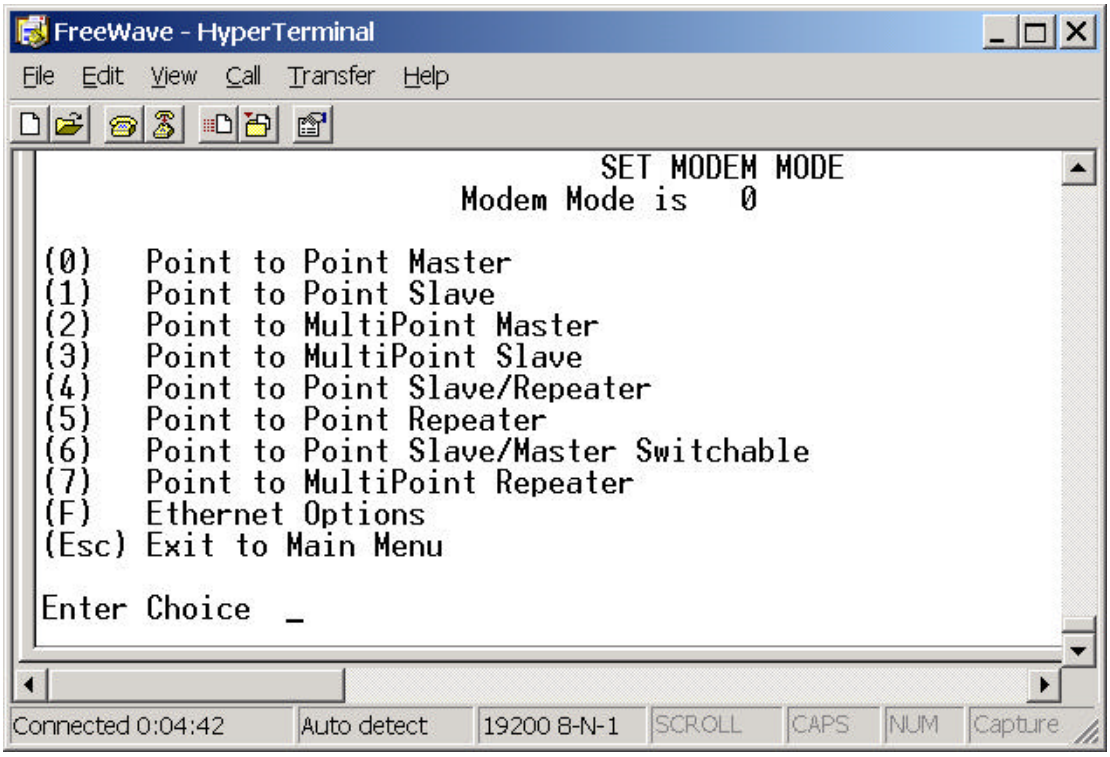


The initial menu provides the Transceiver's unique serial number, firmware version, and the set of choices for editing the operational parameters and viewing the performance data.

(0) Set Operation Mode

When item (0) is selected the Operation Mode Menu appears as shown in figure 2. The Operation Mode option is used to designate the method in which the particular FreeWave Transceiver will be used. FreeWave operates in a Master to Slave configuration; therefore, any Transceivers which are intended to operate together must be set up as such. In a point-to-point setup, either the master or slave may be used on either end of the communications link without any performance degradation. One consideration when setting up the Transceivers is that a number of parameters are controlled by the settings in the master; therefore, you may wish to deploy the master on the communications end where you will have easier access to the transceiver.

Figure 2: FreeWave Operation Mode Menu



Operation Mode Selections

(0) Point-to-Point Master
As mentioned previously, FreeWave operates in a Master/Slave configuration. When designated as a master in point-to-point mode the Transceiver will call any or all slaves it is instructed to call in the Call Book. In Point to Point mode the master determines the settings used for most of the Radio Transmission Characteristics, regardless of the settings in the slaves and/or repeaters. The settings for the slave and repeater(s) not determined by the master are RF Xmit Power, Slave Security, and Retry Time Out.

A quick method of identifying a master is to power up the Transceiver. Prior to establishing a communication link with a slave or repeater all three of the master's LEDs will be solid red.

(1) Point-to-Point Slave
When set up as a point to point slave a FreeWave Transceiver will communicate 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 (Figure 7) is not operational. The slave will communicate with any master listed in its Call Book that calls it.

(2) Point-to-Multipoint Master

The FreeWave Transceiver may be set to run in Multipoint mode, which allows one master to simultaneously be in communication with numerous slaves. A Point-to-Multipoint Master will communicate only with other transceivers designated as Point-to-Multipoint Slaves or Point-to-Multipoint Repeaters.

Please refer to the next chapter 'Multipoint Operation', for more information on running a Multipoint network.

(3) Point-to-Multipoint Slave

Setting (3) allows the transceiver to operate as a slave in a Multipoint network.

Please refer to the next chapter - 'Multipoint Operation' for more information on running a Multipoint network.

(4) Point-to-Point Slave/Repeater
Option 4 allows you to designate the transceiver to act as either a slave or a repeater, depending upon the instructions received from the master for the specific communications session. When a transceiver is placed in an ideal location, this setting offers the flexibility of using that transceiver as an end point in the communication link (slave) or to extend the link to a point further (repeater). These functions are not, however, available simultaneously (the transceiver cannot act as both a slave and a repeater at the same time). This option is available in point to multipoint operation.

A word of caution: A transceiver designated as a repeater has no security features, as explained below. When a transceiver is designated as a Point-to-Point Slave/Repeater, it will allow any master to use it as a repeater.

(5) Point-to-Point Repeater

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 rate, and radio transmission characteristics are disabled. A repeater will connect with any master which calls it (the repeater must still be set up in the master's call book).

The use of one repeater in a communications link will reduce the top data throughput available when compared to a direct master to slave link (generally on the order of 50%). This impact is generally noticed only when using the Transceivers at 115.2 KBaud. The throughput does not decrease further if two or more repeaters are used.

For more information of programming point to point links using one or more repeaters please refer to *Entering or Modifying numbers in the Call Book*.

(6) Point-to-Point Slave/Master Switchable

Mode 6 is a versatile option which allows the transceiver to be controlled entirely through software commands. When in mode 6, a number of key parameters in FreeWave's user interface may be changed either directly (as if using the Windows Terminal program) or through the use of script files. In addition, when the transceiver is in mode 6 and not calling a slave it will be a slave itself and accept any appropriate calls from other transceivers.

In mode 6:

- This mode only works through the data port with diagnostics turned off.
- The transceiver remains in slave mode until called by another Transceiver in its Call Book or instructed to call another transceiver through an AT command. The master will disconnect when DTR goes low.
- The user may change settings in the user interface without using the setup button (this may be of particular value if the transceiver is not in an easily accessible location).
- Predetermined script files may be used which allow any of the Transceiver's settings to be changed upon execution of that file. This, in turn, allows the user to establish push button command sets which will instruct the Transceiver to call a predetermined slave.

***Note**: All AT commands issued to the transceiver in Mode 6 must be in ALL CAPS.*

Table 2: AT Script File Commands

Script File Command	Function Controlled
ATXF_	Frequency Key
ATXT_	Max Packet Size
ATXD_	Min Packet Size
ATXX_	Transmit Rate
ATXR_	RF Data Rate
ATXP_	RF Transmit Power
ATDT_	Position in Call Book to Call
ATD_	Allows specific FreeWave Serial Number to be entered to call
ATXC_	Used in conjunction with the ATD command, instructs transceivers which repeater path to follow
ATXS	Instructs Transceiver to go into Setup Mode

Using Mode 6 to call a transceiver not listed in the Call Book

Mode 6 will accept the command ATD####### where ####### is any arbitrary modem serial number such as 5551234. Upon receipt of this command the modem will call that modem even though the number is not in the sending modem's Call Book.

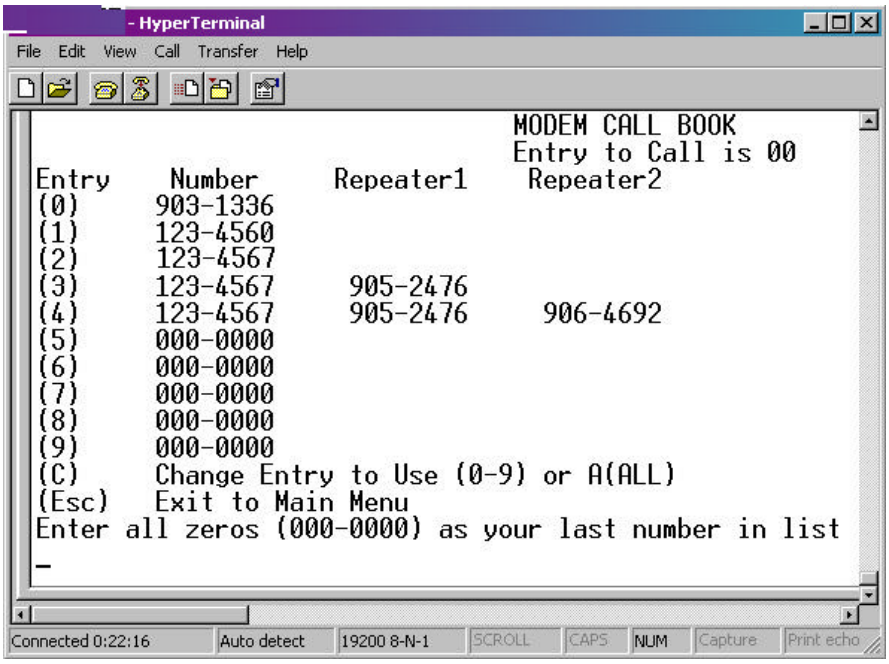
Using Mode 6 to call a transceiver through one or two repeaters

In conjunction with the ATD command the transceiver may be instructed to use the repeater(s) specified in the Call Book. This means it is possible to call an unlimited number of slaves through script files in mode 6 and have up to 10 different repeater combinations.

To call a transceiver through one or two repeaters:

1. The repeaters to be used must first be set up in the Call Book. This would be done by setting up a number to call (this may be a dummy number) through the repeater(s) which you wish to use. An example of this is shown below as entries 3 (one repeater) and 4 (two repeaters) in the Call Book.

Figure 3: Using Mode 6 to Call Through Repeaters



2. Issue the command ATXC# where # corresponds to the position in the Call Book where the repeater(s) is/are located

3. Issue the command ATD####### where ####### is the serial number of the transceiver with which you are attempting a link. The transceiver will link first to the repeater(s) specified and then to the slave transceiver.

4. If you wish to link to a different slave, this time without using a repeater, it is imperative that you reissue the ATXC# command. Either:

a) issue the command to a location in the Call Book with no repeaters. In the Call Book above, for example, this could be ATXC2; or
b) issue the command ATXCA, where A corresponds to All and no repeaters will be used.

The Slave security may be disabled so that a modem operating as a slave (Modes 1,4, and 6) will connect to any modem calling it regardless of whether the calling modem is in the slave's Call Book. This feature is necessary when there are more than 10 transceivers which may call into a slave and will allow any of the units in the system to call in. For more information please see Slave Security on page 37.

(7) Point-to-Multipoint Repeater

Setting (7) allows the transceiver to operate as a repeater in a Multipoint network.

Please refer to the next chapter, 'Multipoint Operation', for more information on running a Multipoint network.

(F) Ethernet options

This menu is only needed for Ethernet modems. Although this menu is included here, it has nothing to do with the Modem Mode (for example, if the modem mode is "0", entering "F" doesn't change the Modem Mode to "F"). Please see the Ethernet addendum for more information on this menu.

Multipoint Operation

Theory of Operation

In a Multipoint system a transceiver designated as a master is able to simultaneously be in communication with numerous slaves. In its simplest form, a Multipoint network functions with the master broadcasting its messages to all slaves and slaves responding to the master when given data by the device connected to the RS232 port.

It is important to note the differences between point to point and multipoint systems. In a point to point system all packets are acknowledged, whether sent from the master to the slave or from the slave to the master. In a multipoint system outbound packets (those sent from the master or repeater out to slaves or other repeaters) are sent a fixed number of times (see Master Packet Repeat). The receiving transceiver (slave or repeater) will accept the first packet received that passes the 32 bit CRC, however the packet is not acknowledged. On the return trip (data going back to the master) all packets sent are acknowledged or retransmitted until they are acknowledged. Therefore, the return link in a multipoint system 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. As such, the architecture of such a system is completely different from point-to-point applications. The theoretical maximum number of slaves that can be configured into a Multipoint network is a function of the data throughput needed from each of the 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. If, on the other hand, each slave will be transmitting data at greater levels then fewer slaves may be connected to the master (the overall system will be closer to capacity with fewer slaves). The theoretical limit of a Multipoint system is influenced by the following parameters:

1. Size of the blocks of data. The longer the data blocks the smaller the system capacity.
2. RS232 baud rate.
3. The amount of contention between slaves.
4. Use of repeaters. A single repeater in a Multipoint network will decrease overall system capacity by 50%; more than one repeater does not further decrease network capacity.

Installing Multipoint Systems

When installing multipoint systems it is important that some planning is done up front. Unlike point to point systems (where the master will set certain system parameters), a multipoint system requires that many parameters are set consistently on all transceivers in the system. This includes RF data rate, min and max packet size, number of repeaters, and frequency key.

Furthermore, if several independent multipoint systems are to be located in close proximity the planning becomes much more critical. In this scenario it becomes very important to include as much frequency and time diversity as possible through use of different frequency keys, min and max packet sizes, and frequency banks. Please contact FreeWave Technologies if you have any questions about the installation of multipoint systems.

Overlapping Multipoint Systems

Overlapping multipoint systems may be set up with FreeWave transceivers effectively if a couple of key parameters are set correctly.

Overlapping multipoint systems are defined as systems using different masters which share or overlap in a specific geographic area. It may include colocation of units (generally repeaters) which are part of different systems.

When colocating multipoint systems it is critical that the following parameters are unique for each system:

- Network ID (unless using Call Book)
- Frequency Key
- Max Packet Size
- Min Packet Size

Setting Multipoint Parameters

(0) Number Repeaters

In a Multipoint network it is critical for timing purposes to know whether or not there are repeaters in the network. Any transceiver that is used as a repeater essentially becomes a master to the slaves and other repeaters to which it is communicating. Therefore, the user must identify whether or not the network contains repeaters. This is done by assigning a value in parameter (0), Number Repeaters. The value should be 0 if there are no repeaters in the network and 1 if repeaters are present. This parameter must be set to the same value in all units in a Multipoint network (master, slaves, and repeater(s)).

(1) Master Packet Repeat

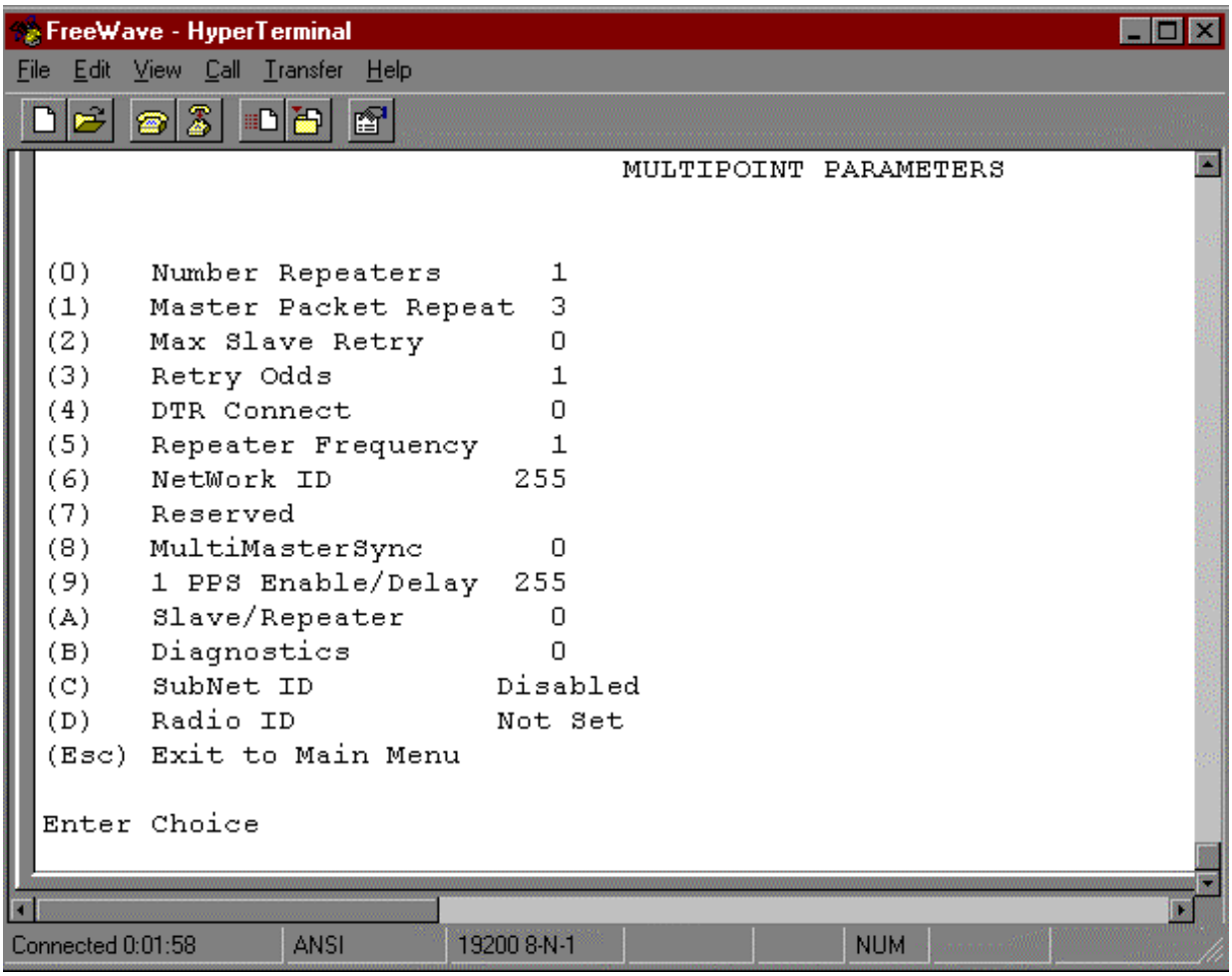
In point-to-point operation the FreeWave transceivers acknowledge every data packet transmitted. In a Multipoint network, transmissions from a master to the slaves are not acknowledged by the slaves. This is to prevent system overload. If the slaves acknowledged all data transmissions from the master in a large Multipoint system, then all system capacity would be spent having the master listen for acknowledgments from the slaves. Because the transmission is not acknowledged by the slaves 100% confidence does not exist that every slave has received every message from the master. To address this issue the user may modify option (1) Master Packet Repeat, 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 would be set at the lower end of the scale (0-1). If the network has some weak or marginal links it would be set toward the higher values. If a slave receives a good packet from a master more than once it will discard the repeated packets received. In addition, once a multipoint repeater receives a good packet from the master it will discard any of the repeated packets. In turn, the repeater will send the packet out (to the next repeater or to the slaves) the number of times corresponding to *its* Master Packet Repeat setting. For more information on this, see the next section, Master Packet Repeat in Multipoint Systems with Repeaters.

It is important to keep in mind that increasing the master packet repeat will not only increase the probability of a packet getting through, but will also increase latency in the system because each packet from the master or repeater is being sent more often. Therefore it is important to find the optimal mix between system robustness, throughput, and latency. In general a setting of 2 to 3 will work well for most systems.

Master Packet Repeat in Multipoint Systems with Repeaters

The Master Packet Repeat parameter must also be set in multipoint repeaters when they are used in a multipoint system. In a multipoint system a repeater looks like a master to a slave. Therefore, the repeater will send the packet out the number of times corresponding to its Master Packet Repeat parameter. If this parameter is set improperly the reliability of the overall system may be compromised. For example, assume the master's Master Packet Repeat parameter is set to 3, and the link between the master and repeater is robust. Now assume that the repeater's Master Packet Repeat is set to 0, resulting in marginal communications between the repeater and the slaves it is communicating with. The data communications between the master and those slaves communicating through the repeater will be marginal, because it is only as strong as the weakest link, which in this case is the link between the repeater and slaves.

Figure 4: Multipoint Parameters



(2) Max Slave Retry

(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. However, it is possible that more than one slave will attempt to transmit to the master at the same time, and it is therefore 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. 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. 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 and conversely a high setting will assign high odds. An example of how this parameter might be used would be when considering two different slaves in a Multipoint network, one close in with a strong RF link and the other far from the master with a weak link. It may be desirable to assign a higher Retry Odd to the slave with the weaker link to give it a better chance of competing with the closer slave for the master's attention.

When Retry Odds = 0 the slave will try to talk to the master the number of times specified in the Max Slave Retry parameter. If it is unsuccessful the slave will flash (purge) its RS232 input buffer.

(4) DTR Connect

Another parameter in a Multipoint network is (4) DTR Connect. When set at 1 the slave will connect to the master if it is free when the DTR line goes high on the 9 pin RS232 connector. In setting 2 the transceiver will accumulate data in its buffer and transmit in a burst when the buffer is full. This mode is valuable when a network has many low data rate devices and it is desirable to increase overall network capacity. In setting 0 the transceiver will transmit when RS232 data is received.

(5) Repeater Frequency

The repeater's hopping pattern must also be set in a Multipoint network; this is accomplished with parameter (5) Repeater Frequency. Setting this parameter is in contrast with point-to-point mode where the repeater automatically uses the master's hopping pattern. The repeater may be programmed to either use the master's hopping pattern (selection 0) or its own (selection 1).
Please refer to the Application Note on the wwww.freewave.com website.

(6) NetWork ID

Option (6) NetWork ID allows multipoint networks to be established without the use of the Call Book. If the NetWork ID is set to any value other than the default (255) and no higher than 4095 the slaves in the multipoint network will communicate with the first multipoint master or repeater heard with the same NetWork ID. When the NetWork ID is used multipoint masters and repeaters may be replaced without reprogramming all of the slaves in the network. In addition, this allows a slave to establish communications with different Masters (though not at the same time) without having the serial numbers in the Call Book. This is very useful in mobile multipoint applications.

(8) MultiMaster Synch

(8) MultiMaster Synch is reserved for applications (either point to point or multipoint) 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 GPS 1PPS signal from the master transceiver to all slaves in a multipoint network. When this parameter is properly enabled a 1 PPS pulse on the DTR pin 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:

1. The 1 PPS Enable/Delay parameter in the master must be set to 0.

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. The calibration on the slave is typically factory set. However, the slaves may also be calibrated with the following procedures:
    1. Trigger an oscilloscope on the 1 PPS pulse (from a GPS receiver) on the DTR pin 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 2 mS in synch 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 network will not function.*

(A) Slave/Repeater

The Slave/Repeater mode allows a transceiver in a multipoint system to simultaneously act as a slave and a repeater. When in this mode a transceiver will repeat any packets sent from a master as well as send them out the RS232 port. Thus where 2 transceivers would be necessary previously (one to repeat and one to be a slave) only one is now needed.

To operate a transceiver as a multipoint slave/repeater you must set the operation mode to (7) Multipoint Repeater and then enable the slave/repeater option (setting of 1).

(B) Diagnostics

This option, when enabled, provides diagnostics data over a multipoint network simultaneously with the application data. Proper use of diagnostics requires the following:

1. Diagnostics must be enabled on the Master (set to 1)
2. A second computer to run the diagnostics software
3. A diagnostics cable, available through FreeWave Technologies
4. Diagnostics software, also available through FreeWave Technologies

Please contact FreeWave if you are interested in using the diagnostics feature in your network.

(C) Subnet ID

In a Multipoint Network where the Network ID is used (instead of the Call Book) when a slave is initially powered it will connect with the first Repeater or Master that it hears with the same Network ID. Likewise, a repeater in the network, when initially powered up, will connect to the first master or repeater that it hears with the same Network ID.

In typical applications this approach works very well, however there are scenarios where you want to force communications to follow a specific path. For example, you may want to ensure that two repeaters in the system are communicating in series instead of in parallel, or it may be desirable to force slaves to communicate to specific repeaters for load balancing purposes.

There are two components to the Subnet ID:
1. Rcv Subnet ID. This setting identifies who a repeater or slave will listen to.
2. Xmit Subnet ID. This setting identifies the sub network this device transmits on, and in turn which devices will listen to it. *The Xmit Subnet ID parameter is relevant for Multipoint Repeaters only.*

To disable the Subnet ID both Rcv Subnet ID and Xmit Subnet ID should be set to F.

***Note**: The Subnet ID settings are irrelevant for the Master.*

***Note**: The Master always transmits on Subnet ID=0, regardless of the setting. To force communications directly through the Master the Slave or Repeater's Rcv SubnetID must be set to 0.*

***Note**: The Subnet ID works only in Multipoint Networks using NetworkID.*

***Note**: In typical Multipoint Networks the Freq Key must be at the same setting for all transceivers. If the SubnetID is used the sub network may be set to a different Freq Key.*

***Note**: If both Rcv SubnetID and Xmit SubnetID are set to 0 the SubnetID will show **Roaming** in the menu. This setting will allow a mobile slave to roam from subnet to subnet within a network.*

The drawing below depicts a Multipoint Network in which the Subnet ID is used to force communications along specific paths. In this example Repeater1 *must* talk directly to the Master, and Repeater2 *must* talk directly to Repeater1. Communications for Slaves 1, 2, and 3 are forced along the direction of the solid lines, and Slave4 may link to the first Master or Repeater it hears.

The respective Subnet ID settings are shown in the table below.

Figure 5: Multipoint Subnet Diagram

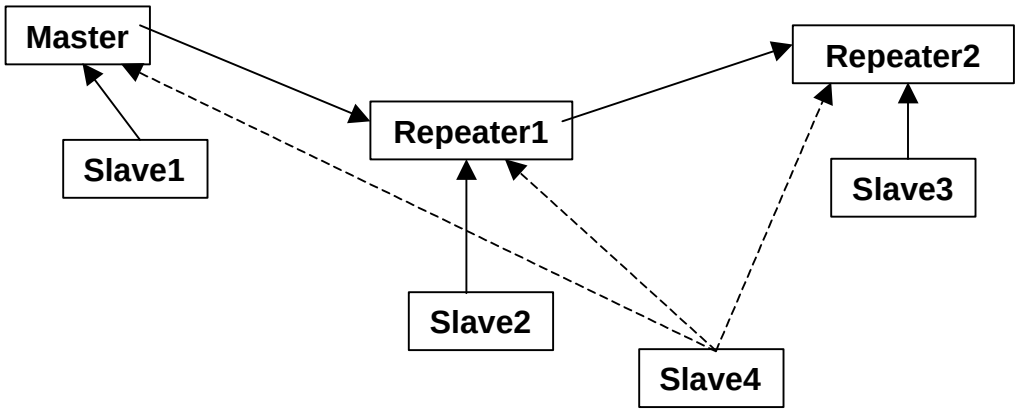


Table 3: Subnet ID Settings

Subnet ID Settings

Transceiver	Rcv SubnetID	Xmit SubnetID	Notes
Master	NA	NA	May be set to anything
Repeater1	0	1	0 forces it to link only to the Master
Repeater2	1	2	Rcv SubnetID=1 forces communication through Repeater1 (Repeater1 transmits on SubnetID 1)
Slave1	0	NA	Rcv SubnetID=0 forces communication through the Master
Slave2	1	NA	Rcv SubnetID=1 forces communication through Repeater1
Slave3	2	NA	Rcv SubnetID=2 forces communication through Repeater2
Slave4	F	F	Setting of FF allows the Slave to link with the first Master or Repeater it hears with the correct NetworkID

***Note**: If you set the Rcv Subnet ID to '0', the modem (other than a master) will communicate only with a master. If you set both Subnet IDs to 'FF', the modem will communicate with any other modem in the same sub-network. Other than that, you can set any value for these settings.*

(D) Radio ID

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

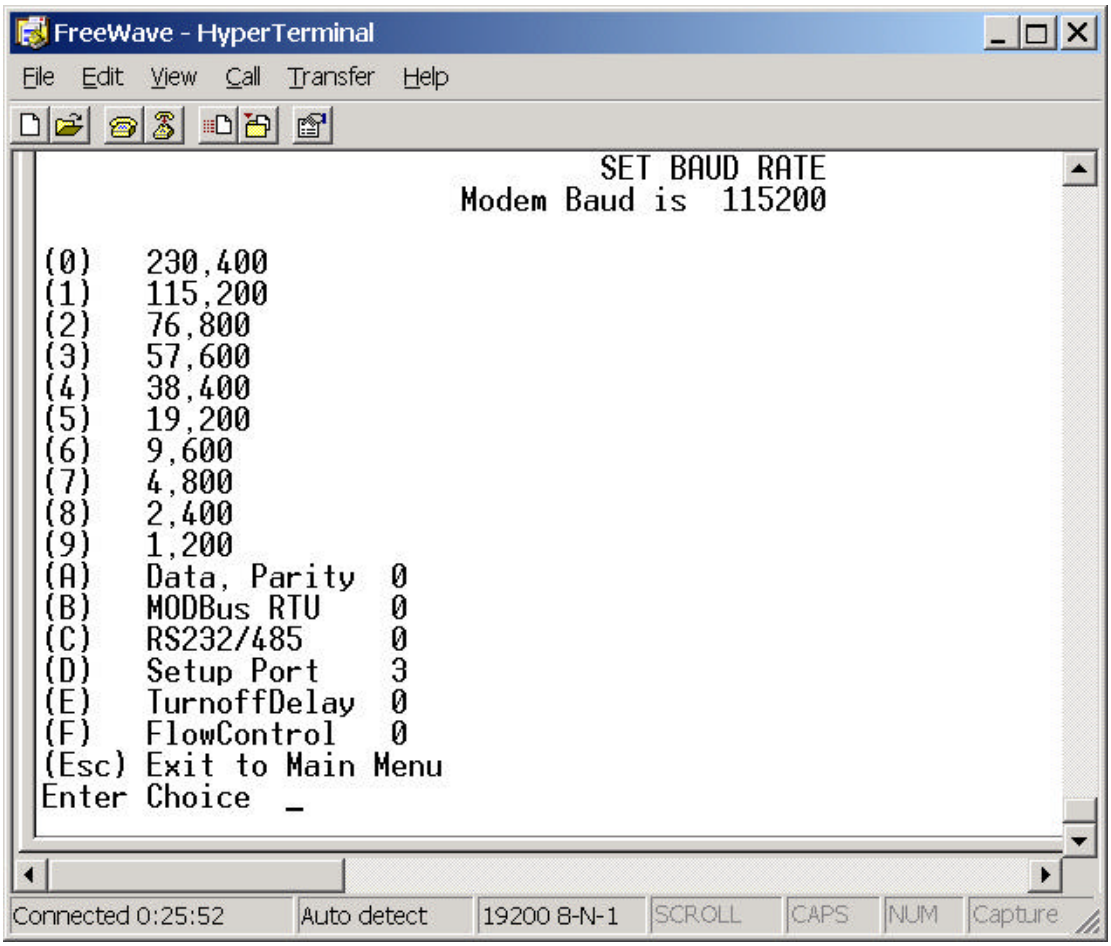
Baud Rate Selections

(1) Set Baud Rate

When item (1) is selected you will be able to change the Transceiver's RS232 baud rate - 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 communication loop. For example, FreeWave 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 computer might be set to 57,600 or 115,200.

In general, it is desirable to set the baud rate to the highest level supported by the device to which it is connected. However, please note that this may actually result in slower data communications in certain circumstances (see the Troubleshooting section).

Figure 6: Baud Rate, and other items related to the Data port



The Baud Rate section of the user interface provides two other important parameters, the ability to change the transceiver's word length and to put it into ModBus RTU mode.

(2) Data Word Length and Parity

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.

Data word length and parity selections available:

Table 4: Data Word Length and Parity Selections

Menu Setting	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

(3) ModBus RTU

Support for ModBus RTU protocol is available. The default setting for ModBus RTU is **0** (not enabled).

To enable the ModBus RTU mode:

1. In the **Set Baud Rate** menu enter **(B)** and then select **1**

2. In the **Set MultiPoint Parameters** menu, set **Master Packet Repeat** to **3**.

***Note**: When using the transceivers in ModBus RTU mode the Master Packet Repeat must be set to 3 regardless of whether the transceivers are being used in Point to Point or Multipoint mode.*

***Note**: The ModBus RTU mode must be selected in RS485 modems.*

RS232/485

In products for which the protocol of the Data port is software selectable (such as FGR09xx, FGR-115RC, FGR115W), use this menu to set the protocol of its data

port. In TTL RF board products (FGR09Tx) and Ethernet products (FRG-115RE), this setting must be "0".

Table 5: Data port protocol Selections

Default is 0 (RS232 or TTL).

Menu Setting	Protocol	Notes
0	RS232	Use this for TTL RF boards and Ethernet modems
1	RS422	
2	RS485	You must turn on ModBUS RTU mode.
3	DOT	Special for the Department Of Transportation

Setup Port

The modem may be set-up using a terminal connected to the Main data port, or to the Diagnostic port. Use this menu to specify which port may be used for that purpose.

The Main Data Port is the RS232 port (which is not available in Ethernet modems). The Diagnostics port is a 3-pin connector. In the FGR-115RC and the FGR-115RE (Ethernet modem) this is a small 3-pin connector on the rear panel. An adapter cable for this port ((ASC0409DC) is available from FreeWave.
In the FGR09xx (board level modem), this is part of a 2-row, 2 mm PCB female strip connector. An adapter cable for this port ((ASC2009DC) is available from FreeWave.
This port is not available in the waterproof model (FGR-115WC).

Table 6: Set-up port Selections

Menu Setting	Port	Notes
1	Main	The terminal is connected to the Main Data Port, in place of the device normally connected to it.
2	Diagnostics	The terminal is connected to the Diagnostic port.
3	Either one	The terminal may be connected to either port

This is set at the factory for the type of modem ('2' for Ethernet products, and for DOT and TTL options; '3' otherwise). Do not change it.
The Set-up Mode is invoked by sending a "U" (capital) to the Diagnostics port or by pressing the Set-up button, if available (this is NOT the Ethernet reset button), or by grounding the Set-up pin (in waterproof enclosures).

Turnoff Delay

Use this menu to specify the time after the end of transmission of a character to the RS485 bus, when the modem stops driving the bus and releases the bus to other devices on it. The units are ¼ of a character (so, an entry of 4 means a delay equivalent to the duration of a full character).
Default is zero delay.

Flow Control

Use this menu to specify the hardware flow control for the Data port.

Table 7: Flow control Selections

Menu Setting	Port	Notes
0	None	Use software control (XON XOFF)
1	RTS	
2	DTR	

Default is 0 (no hardware flow control).

Call Book Selections

(2) Edit Call Book

The Call Book is an innovative feature in FreeWave which offers both security and flexibility in use. The Call Book accomplishes this by allowing the user to determine with which other FreeWave Transceivers a given Transceiver will communicate, based on the serial numbers for both the master and slave. The transceiver's serial number is encoded in the microprocessor and identified on the bottom label of the unit. The instructions provided in this section are for point-to-point mode only. Use of the Call Book for Multipoint systems is explained later in this chapter.

For two FreeWave Transceivers to communicate in point-to-point mode, three events must occur:

1. The serial number for the master must be listed in the slave's Call Book.
2. The serial number for the slave must be listed in the master's Call Book (if slave security is disabled)
3. The master must be programmed to call the slave.

As shown in figure 7, the Call Book allows users to set up a list of up to 10 FreeWave Transceivers with whom they can communicate, designate up to 4 repeaters to be used in communicating with a given transceiver, and tell the master which slave to call. To direct the master to call a slave the user must be in the Call Book Menu. A specific slave may be called by entering C at the prompt, followed by the menu number corresponding to that slave. To call any available slave in the list the user should enter C and then A (for All).

Note: *To call a slave through one or more repeaters you must call that slave directly (as opposed to using the Call All option). When Call All is selected the master is not able to connect with any slaves through repeaters. This is because the master calls every slave in the list when instructed to call all and will connect with the first slave to respond. 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.*

Figure 7: Call Book Menu

```
                          Standard Hop Table
                       Modem Serial Number 571-1004

(0)   Set Operation Mode
(1)   Set Baud Rate
(2)   Edit Call Book
(3)   Edit Radio Transmission Characteristics
(4)   Show Radio Statistics
(5)   Edit MultiPoint Parameters
(6)   TDMA Menu
(Esc) Exit Setup

Enter Choice
                                    MODEM CALL BOOK
                                    Entry to Call is 00
Entry    Number     Repeater1    Repeater2
(0)     570-0432
(1)     565-1258     564-1102
(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
```

Entering or Modifying numbers in the Call Book

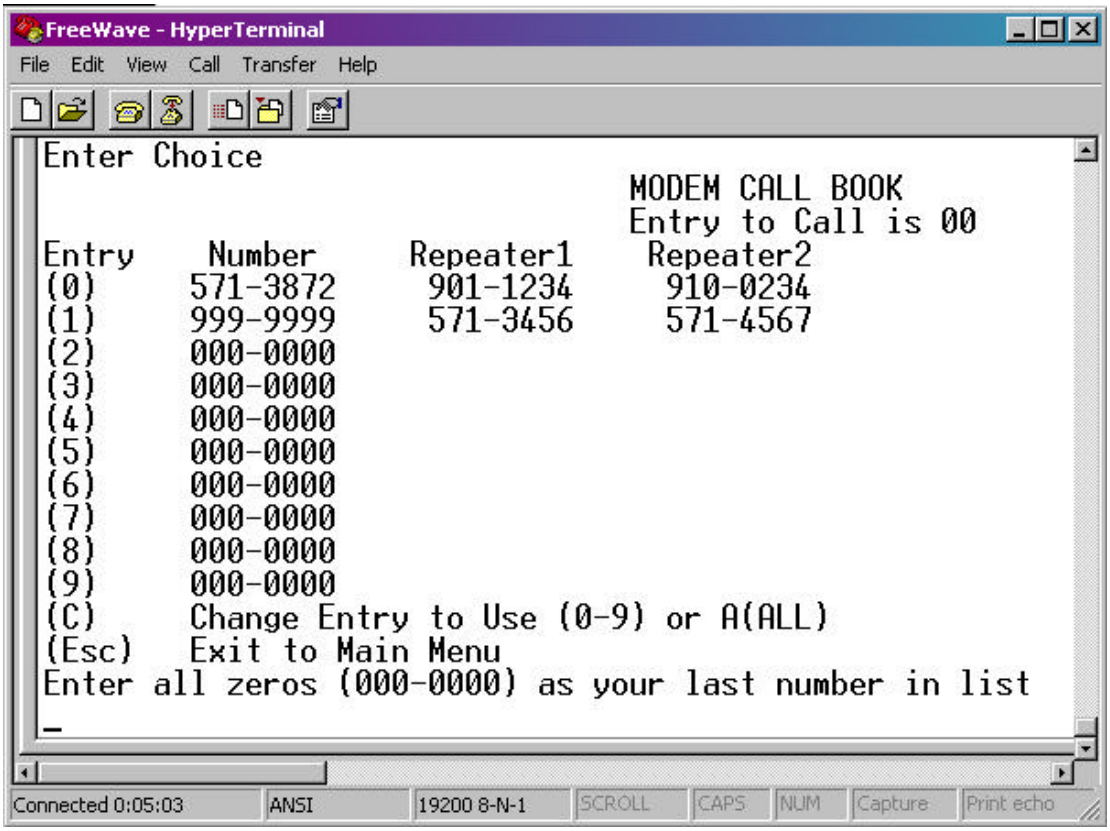
Entering or modifying serial numbers in the Call Book is a straightforward process. When in the Call Book menu enter the position number (0 - 9) you wish to edit. You will be prompted for the new number (formatting is automatic, you do not need to enter the dash). Once the number is entered (unless it is 000-0000) you will be asked for the number for the repeaters to be used. If no repeaters are to be used then enter the escape key; your entry will be complete and you will be back in the Call Book menu screen. If you enter a repeater number you will then be prompted for the number of the second repeater to use. If a second repeater is being used then enter the number at this time, if not then enter the escape key. Once again the modem will retain your entries, as shown in the updated Call Book menu screen.

Programming the Call Book to Use 3 or 4 Repeaters

In a point to point link FreeWave can utilize up to 4 repeaters. To use 3 or 4 repeaters program the Call Book with the slave being called, followed by the first 2 repeaters being used (from the master calling out to the slave). In the next position in the Call Book enter 999-9999 as the number to call. When prompted for the repeaters enter the third and fourth repeaters in the link.

Figure 8 depicts a point to point link where a slave is called through 4 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. Note that it is the entry of serial number 999-9999 in the position following the first two repeaters which instructs the master to continue calling through the repeaters programmed on that line.

Figure 8: Calling a Slave Through 4 Repeaters



Important: It is important that the Call Book slots (0 - 9) are filled sequentially beginning with 0, the first slot in the book. Serial numbers do not need to be entered in numerical order, however, there must not be any 000-0000 numbers in the middle of the list of good serial numbers. The reason for this is that when a master is instructed to Call All available slaves it will call all slaves listed until it reaches the first phone number of 000-0000. If a valid serial number is entered after the all zero number it will not be recognized as a valid number to call by the master.

Programming The Call Book in Multipoint Systems

In a Multipoint system the slaves and repeaters are not listed in the master's Call Book. When establishing such a system, it is necessary only to have the master's serial number in each slave's and repeater's Call Book, and to have each repeater's serial number in the Call Book of each slave which may potentially communicate through it.

The following example shows the Call Books of a multipoint system 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 555-0001)

Entry	Number	Repeater1	Repeater2
(0)	000-0000		
(1)	000-0000		

No serial number entries are necessary in the master's Call Book
The master's Call Book may be programmed to call any entry

Multipoint Repeater Call Book (Unit Serial Number 555-0002)

Entry	Number	Repeater1	Repeater2
(0)	555-0001		
(1)	000-0000		

Multipoint Slave Call Book (Unit Serial Number 555-0003)

Entry	Number	Repeater1	Repeater2
(0)	555-0001		
(1)	555-0002		
(2)	000-0000		

At times it may be desirable to force a slave to go through a specific multipoint repeater. If this is the case that slave's Call Book should contain only the serial number for the repeater in the upper left hand corner.

Note: *If the network ID option is used no entries are needed in the Call Book of any of the transceivers in a multipoint system.*

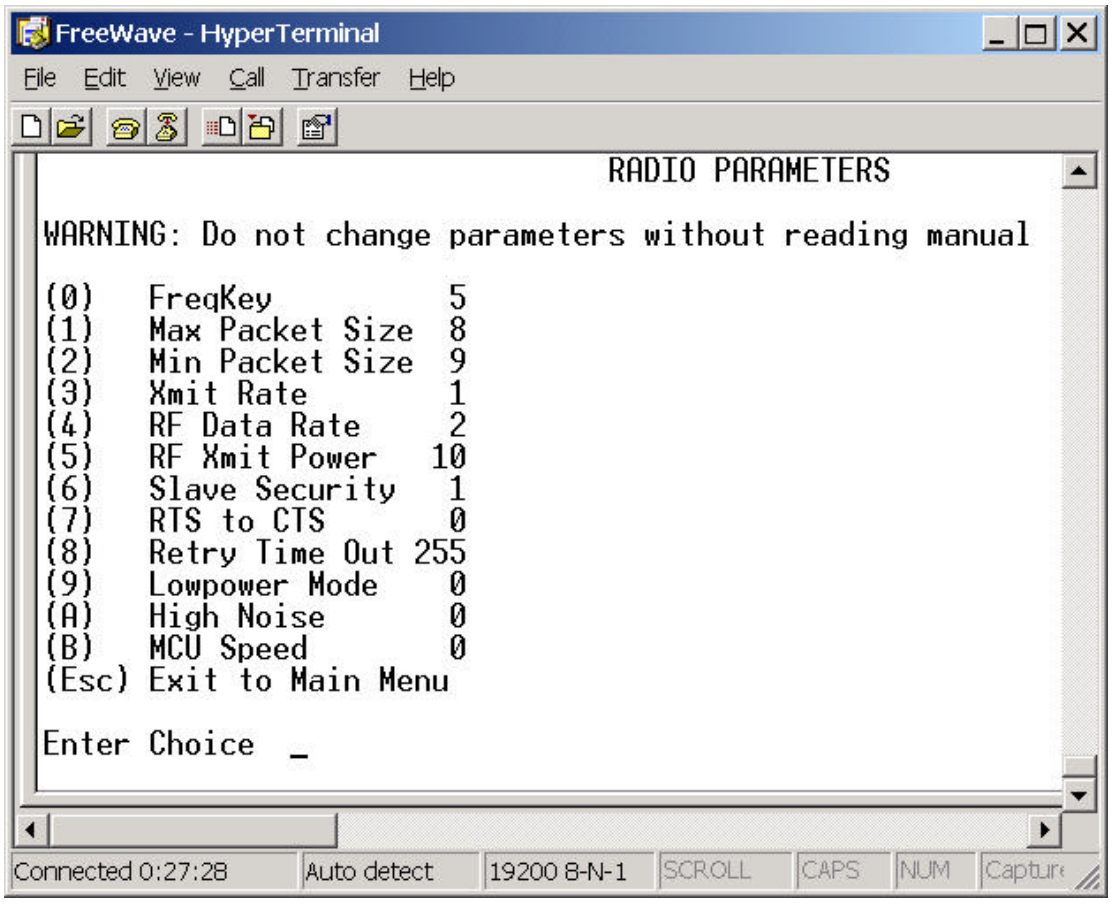
Radio Transmission Parameters

(3) Edit Radio Transmission Characteristics

When item (3) is selected in the main menu the screen in figure 9 appears, which allows the user to modify the radio transmission characteristics of the Transceivers. As stated in the warning, these parameters are for the sophisticated user who has a good understanding of the principles of radio data transmission. They should be changed only after consulting this manual.

In a point to point mode the radio parameters set in the Master will override the settings for the slave and repeater(s) in the link for all but RF Xmit Power, Slave Security, and Retry Time Out.

Figure 9: Radio Parameters Menu



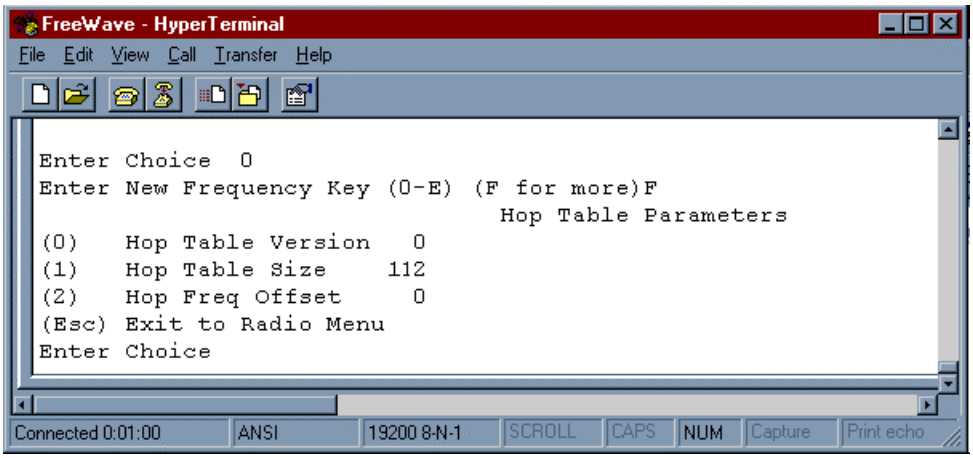
(0) FreqKey

Selection (0) in the Radio Parameters menu allows the user to modify the hopping patterns of the Transceivers to minimize the interference with other FreeWave Transceivers in operation in the area. For instance, if there were 10 pairs of FreeWave transceivers in operation within a factory or refinery, changing the Frequency Key would ensure that they would not jump onto the same frequencies at the same time for the same length of time.

There are 15 choices available for the Frequency Key (0-9 and A-E), representing 15 different pseudo-random patterns.

A selection of F provides additional options to use different portions of the 902-928 MHz band.

Figure 10: Hop Table Parameters



(0) Hop Table Version

Entry 0 allows the user to choose the portion of the band in which the transceiver will operate. These choices are show in the table below:

Table 8: Frequency Bands, 900 MHz

Selection	Name	Band
0	Standard	Full 902-928 MHz
1	Australia	915-928 MHz
2	International	902-928 MHz, 16 fewer frequencies than full US set
3	Taiwan	916-920 MHz
4	New Zealand	921-928 MHz
5	Notch	Uses 902-928 with center frequencies of 911-919 notched out
6	Brazil	902-915 MHz

Note: *Do NOT use Freq Key 14 (D) with the Australia (915-928MHz) hop table*

(1) Hop Table Size

Within a specified band you may select the number of frequencies to be used, ranging from 50 to 112.

(2) Hop Freq Offset

The Hop Freq Offset option is not functional in the 900 MHz spread spectrum transceiver.

Note: *Irrespective of the Freq Key used, all transceivers in either point to point or point to multipoint networks must be set to identical Hop Tables and Table Size (number of frequencies).*

2.4GHz

The Frequency Key for the FreeWave Technologies 2.4GHz transceivers offers the ability to select more than just a different pseudo random hop table, but also the portion of the band which the transceiver will use. Because this feature offers the ability to select which portion of the spectrum will be used it is critical that all radios in a link, whether point to point or point to multipoint, use the same selections.

Frequency Key

Selections 0-E provide 15 different pseudo random hop tables, similar to the 900 MHz transceiver.

Selection F allows the user to set the Hop Table parameters. The user is then presented with 3 additional choices

Selection 0 allows the user to determine which portion of the band to use:

Table 9: 2.4 GHz Frequency Band Selections Available

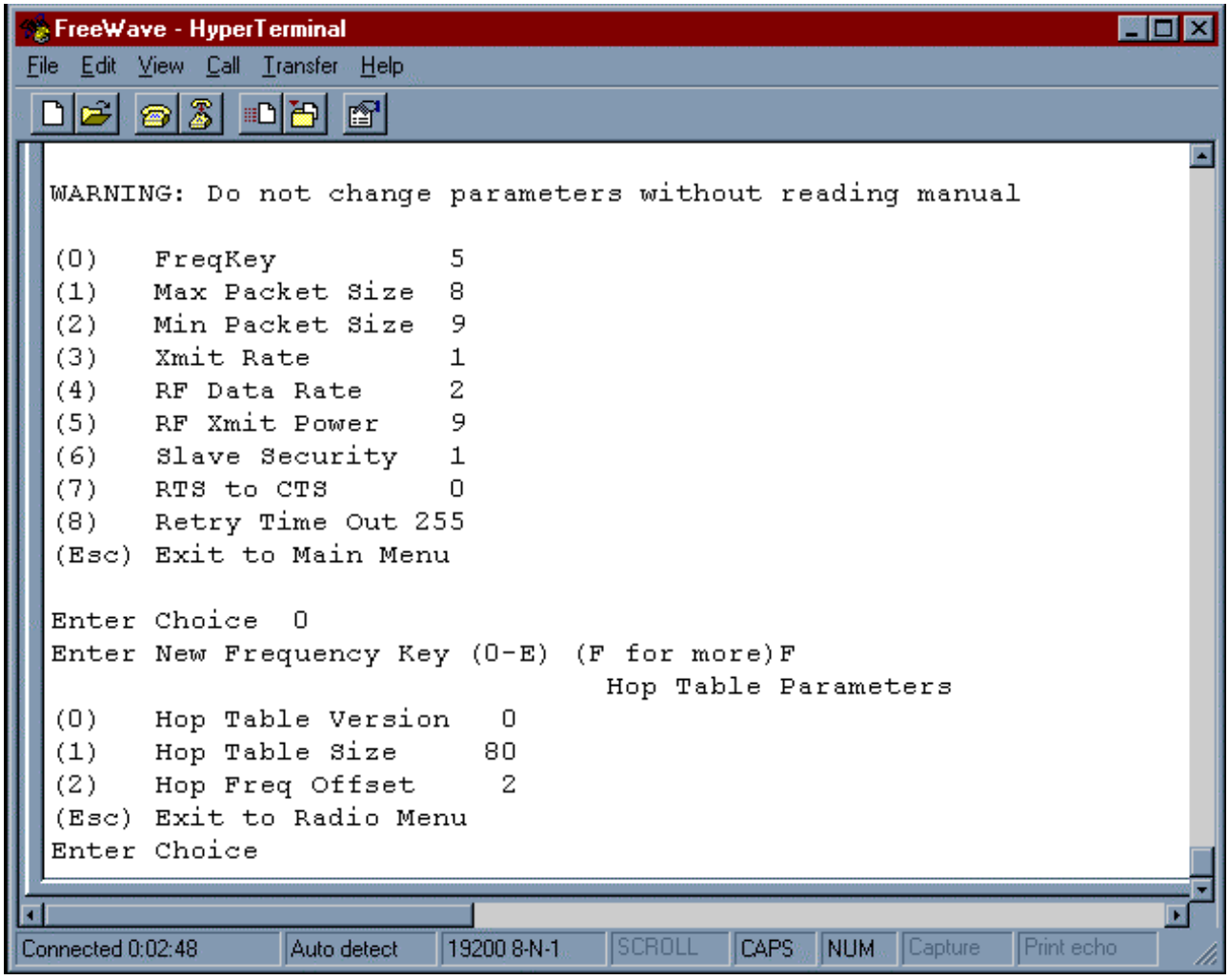
Selection	Band Used
0	Entire band, 2.400 - 2.4835 GHz
1	Entire band, but offset frequencies from selection 0
2	Lower 1/3rd of band
3	Middle of band
4	Upper 1/3rd of band
5	2 outer 1/3^{rds} of band, avoids the middle

Thus, 2 networks could be set up side by side using the entire band without collisions by setting one network up with selection 0 and the second network with selection 1.

Selection 1 allows the user to set the size (number of frequencies) of the hop table to use. The range available is from a minimum of 50 to a maximum of 80.

Selection 2 allows the user to select a frequency offset, whereby the frequencies used are offset by 115.2 KHz from other frequency selections in the same portion of the band. For example, if 2 networks are operating side by side in the lower 1/3rd of the band using 50 frequencies, with one set to Frequency Offset of 0 and the other to Frequency Offset of 1, the frequencies used in the different hopping patterns will be offset by 115.2 KHz

Figure 11: Frequency Key & Hop Table Options, 2.4 Ghz



(1) Max Packet Size and

(2) Min Packet Size

Selections (1) and (2) allow the user to designate the size of the packets (in bytes) used by the transceiver in its communication link. This may be of particular value when using FreeWave with different communications software packages; you may find that throughput is optimized when packet sizes are restricted by the transceiver. It should be noted, however, that in Point to Point modes the Max and Min Packet Settings will not have any material impact on throughput unless 115.2 KBaud is desired.

The combination of Max and Min Packet Size Settings determines the allocation of the communication link from the Master to the Slave and vice versa. With a given Max Packet Setting the master will transmit up to that number of bytes on every hop. If fewer than that number of bytes is transmitted the balance is allocated to the slave's transmission, in addition to the quantity in the Min Packet Size Setting.

Packet size is determined by a combination of the setting entered by the user and the RF Data Rate. Tables 7, 8, and 9 provide the packet sizes for each different combination of settings.

Table 10: Min Packet Size Settings (Bytes)

Setting	Min Packet Size RF Data Rate = 2	Setting	Min Packet Size RF Data Rate = 3
0	16	0	8
1	21	1	12
2	26	2	16
3	32	3	20
4	37	4	24
5	42	5	28
6	48	6	32
7	53	7	36
8	58	8	40
9	64	9	44

Table 11: Max Packet Size Settings (Bytes)
RF Data Rate=2

	Max Setting									
Min Setting	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	15	36	58	79	100	121	143	164	185	206
1	20	42	63	84	105	127	148	169	190	212
2	26	47	68	90	111	132	153	175	196	217
3	31	52	74	95	116	137	159	180	201	222
4	36	58	79	100	121	143	164	185	206	228
5	42	63	84	105	127	148	169	190	212	233
6	47	68	90	111	132	153	175	196	217	238
7	52	74	95	116	137	159	180	201	222	244
8	58	79	100	121	143	164	185	206	228	249
9	63	84	95	127	148	169	190	212	233	254

Table 12: Max Packet Size Settings (Bytes)
RF Data Rate=3

	Max Setting									
Min Setting	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	8	24	40	56	72	88	104	120	136	152
1	12	28	44	60	76	92	108	124	140	156
2	16	32	48	64	80	96	112	128	144	160
3	20	36	52	68	84	100	116	132	148	164
4	24	40	56	72	88	104	120	136	152	168
5	28	44	60	76	92	108	124	140	156	172
6	32	48	64	80	96	112	128	144	160	176
7	36	52	68	84	100	116	132	148	164	180
8	40	56	72	88	104	120	136	152	168	184
9	44	60	76	92	108	124	140	156	172	188

(3) Xmit Rate

There are two settings for the Transmit Rate parameter. For normal operation FreeWave should be set at Transmit Rate 1. Transmit Rate 0 is useful to qualitatively gauge signal strength. When set to Transmit Rate 0 the Transceivers will transmit data back and forth continuously, and the strength of the signal may be gauged by the Clear to Send LED. A solid red Clear to Send LED indicates a strong signal, the less the LED is on the weaker the signal.

Because the Transceivers transmit continuously when Transmit Rate is set to 0 (whether or not they have data to send) they use radio frequency spectrum unnecessarily. Therefore, in point-to-point operation, Transmit Rate 0 should be used only as a diagnostic tool and not for normal operation.

(4) RF Data Rate

FreeWave has two settings for the RF Data Rate (not to be confused with the RS232 Baud Rate). Setting 2 should be used when the transceivers are close together and data throughput is to be optimized. Setting 2 must also be used when full throughput of 115.2 KBaud is necessary. Setting 3 should be used when the transceivers are farther away and a solid data link is preferred over data throughput.

Note: *When using the transceivers in Multipoint mode, the RF Data Rate setting must be identical for all units in the system. Any transceiver with a different RF Data Rate than the master will not establish a communication link.*

(5) RF Xmit Power

(6) Slave Security

With option 6 the user may disable the transceiver's security so it will accept a call from any other FreeWave unit. The default setting is 0 where security is enforced (the caller's serial number must be in the slave's Call Book), with a setting of 1 security is disabled.

As mentioned in mode 6, Slave Security must be set to one when the unit is operating in a point-to-point system where it may need to accept calls from more than 10 different FreeWave Transceivers. However, it is important to note that when Slave Security is set to 1 the Transceiver will accept calls from any other FreeWave Transceiver, and additional system security measures should be taken to prevent unauthorized access.

(7) RTS to CTS

Menu selection 7 in the Radio Parameters provides the option of allowing the RTS line (pin 7) on the Master modem to control the CTS line (pin 8) of the Slave. This pass-through control can be enabled in point-to-point mode as well as point-to-multipoint. In the latter the Master RTS line will control all Slaves' CTS lines. When this mode is enabled the CTS line ceases to function as flow control. Therefore it is not recommended to enable this feature when operating at RS-232 speeds above 38.4 kB.

To enable this mode, enter 7 in the Radio Parameters menu. An entry of 1 will enable the RTS-CTS control, 0 will disable it.

Just before the time the Master is scheduled to transmit a packet, it will sense the state of the RTS line. 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 to be sent or not. In the former case 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 point-to-multipoint mode the Master will repeat the message the number of times equal to the Master Packet Repeat number in the Multipoint Setup menu.

Because the Master transmit time is completely asynchronous to the occurrence of any change of the RTS line, the latency time from RTS to CTS is variable. The maximum time, however, is determined by the frequency of Master transmission times. This frequency is determined by the Maximum Packet Size and Minimum Packet Size parameters in the Radio Parameter menu. Setting both parameters to their maximum of 9 and 9 will produce a maximum latency time of approximately 21 ms. At their minimum numbers the time will be approximately 5.9 ms. Please note that this latency can go up 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: *The RTS to CTS mode does not function in point to point links which contain a repeater. If this feature is needed in a link with a repeater you should use it in conjuction with point to multipoint mode.*

(8) Retry Time Out

The Retry Time Out parameter allows the user to determine when a slave will drop a connection to a master or repeater in multipoint mode. The default setting is 255, meaning that if one packet in 255 from the master is sent successfully to the slave it will maintain a link. The lowest setting is 8, at which a slave will drop a connection much more quickly.

The Retry Time Out parameter is useful when a multipoint system is used with a moving master or slaves. As the link gets weaker, a lower setting will allow a transceiver to drop a link and search for a stronger connection.

While intended primarily for multipoint systems, the Retry Time Out parameter may also be modified in point to point systems. In point to point mode the Retry Time Out should not be set to a value of less than 151.

(9) Lowpower Mode

The Lowpower Mode is an option that, when enabled, allows the transceiver to function as a multipoint slave while consuming less power.

With a setting of 1 Lowpower Mode saves current consumption primarily by dimming the transceiver's LEDs. When set to higher values (2 through 63) 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.

Note: *1) The Lowpower Mode is for use only in point to multipoint systems, and only on the multipoint slaves. The power savings occur when the option is enabled and the slave is connected to the master or a repeater. There are no power consumption savings when the slave is transmitting data back to the master. Designed primarily for SCADA systems, the Lowpower Mode is of little value when significant amounts of data need to be sent from the slave to the master.*

2) Additional power savings may be realized when the number of repeaters is set to 1 throughout the network, even if no repeaters are being used. This is shown in the following table in the Draw1 column, the Draw0 column shows power draw with a setting of 0 repeaters.

3) Because the Lowpower mode puts the transceiver to sleep a latency will be introduced before it become fully linked to the master. This latency can range from 6 ms to 2.5 seconds.

4) To communicate to the 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 or when CTS goes high.

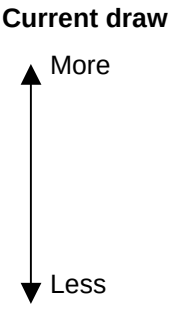
5) If the RTS line on the slave is held high the transceiver will remain in normal operation regardless of the Lowpower Mode setting. Once RTS is dropped it will go back into the lowpower mode that corresponds to its setting.

The following table shows how the power consumption is reduced at different Lowpower Mode settings. The actual current draw depends an many factors, so

the table gives only qualitative indication of savings of supply current. Set this setting to empirically, considering that a low number reduces latency, and a high number reduces current consumption.

Table 13: Low Power Settings

Setting	Description
0	Low-power disabled
1	LEDs dimmed, transceiver remains awake
2	LEDs dimmed, transceiver sleeps every other slot
3	LEDs dimmed, transceiver sleeps 2 of 3 slots
4-63	LEDs dimmed, transceiver sleeps number of slots corresponding to setting. For example, with a setting of 63 the transceiver is sleeping during 62 of the slots.



(A) High Noise

Use this menu to indicate if the modem will be operated in an environment with a high degree of radio noise and interference.
With a setting of 1, the rejection of interference is improved, at the cost of reduced range and/or throughput.

(B) MCU speed

Use this menu to set the speed of the processor (Micro Controller Unit) in the Modem.

Table 14: MCU speed Settings

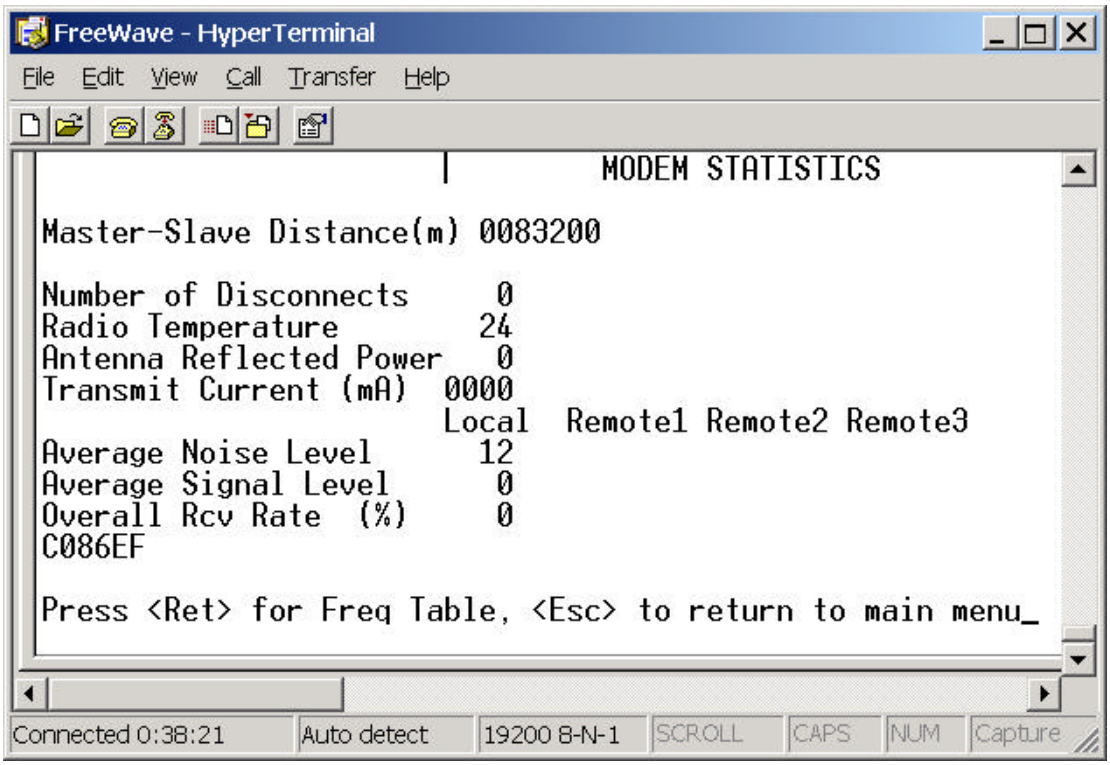
Setting	Description	Notes
0	Low Speed	Reduces current consumption
1	High Speed	Required for 230 Kbaud Data Port rate

The default is 0 (low speed).

Radio Statistics

Option (4) in the main menu allows the user to view data transmission statistics which have been gathered by the Transceiver during the most recent session. This is of value when the user wishes to look at signal strength, noise levels, and the distance of the link between transceivers. Statistics are gathered during each data link and are reset when the next link begins.

Figure 12: Modem statistics



Ideally, noise levels should be below 30, and the difference between the average signal level and average noise level should be 15 or more. High noise levels tend to indicate other sources of RF interference, while low signal levels indicate a weak link. The following sections provide information useful to the process of troubleshooting and improving radio links.

Average Noise Level

The average noise level indicates the level of background noise and interference at this modem and at each of the modems used as repeaters in the link. The number is an average of the noise levels measured at each frequency in the modems' frequency hop table. The individual measurement values at each frequency hop channel are shown in the frequency table. The frequency table is accessed by pressing the ENTER key on the computer when the radio statistics menu is displayed.

Average noise levels will typically fall in the range of 15 to 30. Average 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 improved with bandpass filters, antenna placement or antenna polarization. Please contact FreeWave Technologies for more information.

Average Signal Level

The average signal level indicates the level of received signal at this modem and at each of the modems used as repeaters in the link. For each of these, the signal source is the modem that transmits to it. The number is an average of the received signal levels measured at each frequency in the modem's frequency hop table. The individual measurement values at each frequency hop channel are shown in the frequency table. The frequency table is accessed by pressing the ENTER key on the computer when the radio statistics menu is displayed.

For a reliable link, the average signal level should be at least 15 higher than the average noise level reading.

Low Average Signal Levels can often be corrected with higher gain antennas, antenna placement, and use of repeaters or use of antenna amplifiers. Contact FreeWave Technologies for more information.

Note, later revisions of the firmware show the signal level in RSSI units.

Overall Rcv Rate (%)

The Overall Rcv Rate measures the percentage of data packets that were successfully transmitted from the master to the slave on the first attempt without requiring retransmission. 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 25 or lower indicates a weak or marginal link that will provide lower data throughput. An Overall Rcv Rate of 100% will provide approximately 100 Kbaud of bandwidth with an RF data rate of 3 (Radio Transmission Parameters Menu) and approximately 150 Kbaud of bandwidth with an RF Data Rate of 2. These numbers are reduced approximately 50% if there are one or more repeaters in the network.

Number of Disconnects

If, during the course of performing a link test, the link between the master and the slave is broken, and the radios lose carrier detect, the occurrence is recorded in the Number of Disconnects value. The value indicates the total number of disconnects that have occurred from the time the link test started until the radio was put into reset mode. Under normal operating conditions, the number of disconnects should be 0. One or more disconnects may indicate a very weak link, the presence of severe interference problems or loss of dc power to any of the radios in the link.

Radio Temperature

The radio temperature value is the current operating temperature of the radio in degrees C (Celsius.) For proper operation, FreeWave radio modems must be in the range of –40° to 75°C.

Password

Caution!!! If the password feature is enabled and you cannot remember the password the radio will need to be sent back to FreeWave to have the password disabled.

Option (8) in the Main Menu allows the user to set a password which will prevent access to or changing of any of the radio's parameters. This option is useful if it is desirable to prevent unauthorized personnel from gaining access to the radio settings.

Setting a Password

To enable the Password feature choose (8) from the Main Menu. You will be prompted with

New PW? (<esc> to exit)

To back out of the process and not enable the password hit escape. To set a password type in **exactly 4 characters**. At any point in the process you can cancel by hitting the escape key. Once the 4 characters have been entered you will be prompted with:

<Enter> to accept,<esc> to quit

At this point if you wish to accept the password entered and enable the feature press the enter key. The password that you have chosen is displayed on the line above (please note that the password is case sensitive). To quit the process and not enable the password press escape.

Changing a Password

Once the password feature has been enabled it is possible to change to a new password. To enter a new password select (8) from the Main Menu. You will be prompted with "Enter Security Code" to enter the current password. Once the password has been entered correctly (it **is** case sensitive) you will be prompted to enter the new password. At any point this process may be cancelled by pressing escape.

Disabling a Password

The process to disable the password is similar to the process to change the password. However, when prompted to enter the new password the following procedure needs to be followed:

1. Hold down the Alt key and type 0255
2. Release the Alt key
3. Repeat this step 3 more times (hold Alt and type 0255 a total of 4 times).

Transceiver Location

Placement of your FreeWave unit is likely to have a significant impact on its performance. In general the rule of thumb with FreeWave is that the higher the placement of the antenna the better the communication link - height is everything! In practice you should also place the transceiver away from computers, telephones, answering machines, and other similar equipment. The included 6 foot RS232 cable will usually provide ample room for placement away from other equipment. To improve the data link, FreeWave Technologies offers directional and omnidirectional 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. It is also possible that slight adjustments in antenna placement (as little as 2 feet) will solve noise problems. In extreme cases, such as when the transceiver is located close to Pager or Cellular Telephone transmission towers, FreeWave offers band pass filters (a standard filter and a cavity filter) to reduce the out of band noise.

The FGR115W is waterproof and may also be mounted outdoors without additional weather protection. The waterproof enclosure also requires an external antenna, and includes a 6 foot data and power pigtail cable.

Front Panel LEDs

The LEDs on FreeWave's front panel provide important information on the operation of the transceiver. Compare the status of a Transceiver's LEDs with the table below to aid you in the troubleshooting process.

Table 15: LED Status in Point to Point Mode

Point to Point Communications

	Master			Slave			Repeater		
Condition	**CD**	**TR**	**CTS**	**CD**	**TR**	**CTS**	**CD**	**TR**	**CTS**
Powered, disconnected	SR	SR	SR	SR	O	BR	SR	O	BR
Connected, no repeater, sending sparse data	SG	IF	IF	SG	IF	IF			
Master calling slave through repeater	SR	SD	SR	SR	O	BR	SR	O	BR
Master connected to repeater, not to slave	FO	SD	SR	SR	O	BR	SR	SD	SR
Repeater connected to slave	SG	IF	IF	SG	IF	IF	SG	IF	IF
Mode 6, disconnected	SR	O	BR	SR	O	BR			
Setup Mode	SG	SG	SG	SG	SG	SG	SG	SG	SG

Legend:

BR	Blinking Red
FO	Flashing Orange
IF	Intermittent Flash Red
O	Off
SD	Solid Red, Dim
SG	Solid Green
SR	Solid Red, Bright

LED:

CD	Carrier Detect LED
CTS	Clear to Send LED
TR	Transmit LED

Table 16: LED Status in Multipoint Mode

MultiPoint Communications

	Master			Slave			Repeater		
Condition	**CD**	**TR**	**CTS**	**CD**	**TR**	**CTS**	**CD**	**TR**	**CTS**
Powered, disconnected	SR	SD	O	SR	O	BR	SR	O	BR
Repeater and slave connected to master, no data	SR	SD	O	SG	O	SR*	SG	SD	SR*
Repeater & slave connected to master, master sending data to slave	SR	SD	O	SG	O	SR*	SG	SD	SR*
Repeater & slave connected to master, slave sending data to master	SG-SR	SD	IF	SG	IF	SR*	SG	SR	SR*

Legend:

BR	Blinking Red
FO	Flashing Orange
IF	Intermittent Flash Red
O	Off
SD	Solid Red, Dim
SG	Solid Green
SR	Solid Red, Bright

LED:

CD	Carrier Detect LED
CTS	Clear to Send LED
TR	Transmit LED

*CTS will be Solid Red with a solid link, as the link weakens the CTS light on the repeater and slave wll begin to flash.

RS232 Pin Assignments

Table 17: RS232 Pin Assignments

Pin	Assignment	Signal
1	Carrier Detect	Output
2	Transmit Data	Output
3	Receive Data	Input
4	DTR	Input
5	Ground	
6	Data Set Ready	Output
7	RTS	Input
8	Clear to Send	Output
9	Ground	

Definitions:

Pin 1: Carrier Detect (CD) — Used to show that there is an RF connection between modems.

Pin 2: Transmit Data (TX) — This is used to transmit data bits serially from the modem to the system device connected to the modem.

Pin 3: Receive Data (RX) — This is used to receive data bits serially from the system device to the modem device connected to the modem.

Pin 4: Data Terminal Ready (DTR) — The modem only uses this line in Point-to-Point Slave/Master switchable mode (refer to Operation Mode Selections) or for DTR Connect (refer to Multipoint Operation).

Pin 5: Ground (GND) — Signal return for all signal lines shared with Pin 9.

Pin 6: Data Set Ready (DSR) — 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 modem directly through the RS-232 port. Note: This is not used on the OEM module.

Pin 7: Request to Send (RTS) — The modem does not recognize RTS for flow control. RTS is used as a control line in RTS/CTS mode (refer to Radio Transmission Parameters).

Pin 8: Clear to Send (CTS)	This signal is used to tell the system device connected to the modem that the modem is ready to receive data. When asserted, the modem will accept data, when deasserted the modem 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.
Pin 9: Ground (GND)	Signal return for all signal lines shared with Pin 5.

FGRO RF Board only Pinout

The FGRO Small Footprint 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.

Table 18: FGRO Series Pinout

Pin	Assignment
1	B+ input
2	Interrupt (Ground to invoke menu)
3	DTR
4	Ground
5	Transmit Data
6	Ground
7	Receive Data
8	Carrier Detect
9	RTS
10	Clear to Send

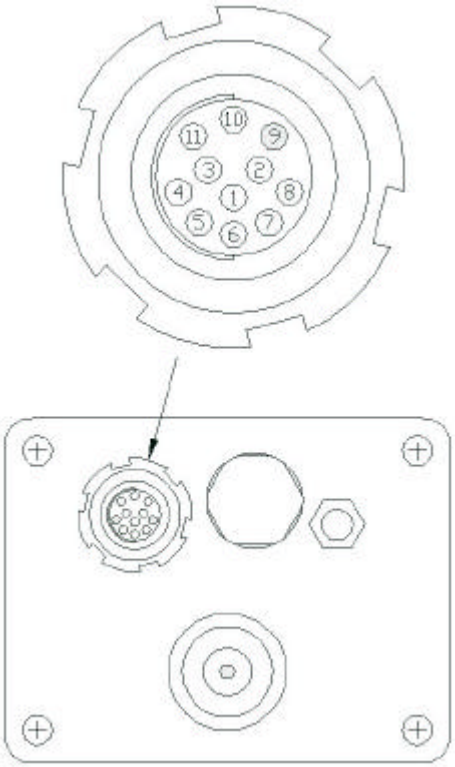
Note: *Pin 1 on the FGRO9 board level transceiver is the pin farthest from the three LEDs and pin 10 is closest to the LEDs.*

FGR-115WC Waterproof Enclosure Pinout for Cable ASC0612WW

Table 19: FGR-115WC Pinout

Pin	Color	Function	Signal
1	Brown	Carrier Detect	Output
2	Red	Transmit Data	Output
3	Orange	Receive Data	Input
4	Yellow	DTR	Input
5	Green	Ground	Signal Ground
6	Blue	Diagnostics TXD	Output
7	Violet	RTS	Input
8	Gray	Clear to Send	Output
9	White, shield	Power Ground, shield	Power Ground
10	Black	B+	Power Input
11	Pink	Diagnostics RXD	Input

Figure 13: Waterproof Connector



Establishing Data Communication Links

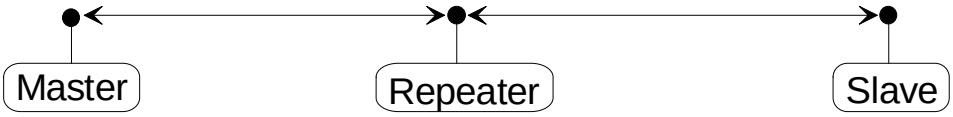
FreeWave's versatility allows data communication links to be established using a variety of different configurations. This, in turn, makes it possible to extend the range of FreeWave and get around obstacles.

Diagram (A) shows the most common and straightforward link, a master communicating to a slave in a dedicated link.

(A)

Diagram (B) depicts how a link might be set up using a repeater. The repeater may be sitting on a hilltop or other elevated structure to link the master to the slave. In this setup it may be desirable to use an external omnidirectional antenna on the repeater; to extend the range Yagi antennas could be used on either or both of the master and slave.

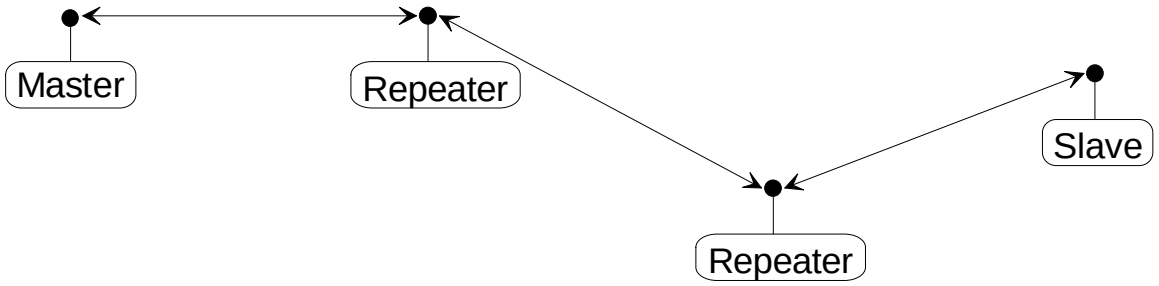
When a repeater is used the RF speed is cut in half, making 115 KBaud uncompressed throughput unachievable. The baud rate, however, may still be set at 115200.



(B)

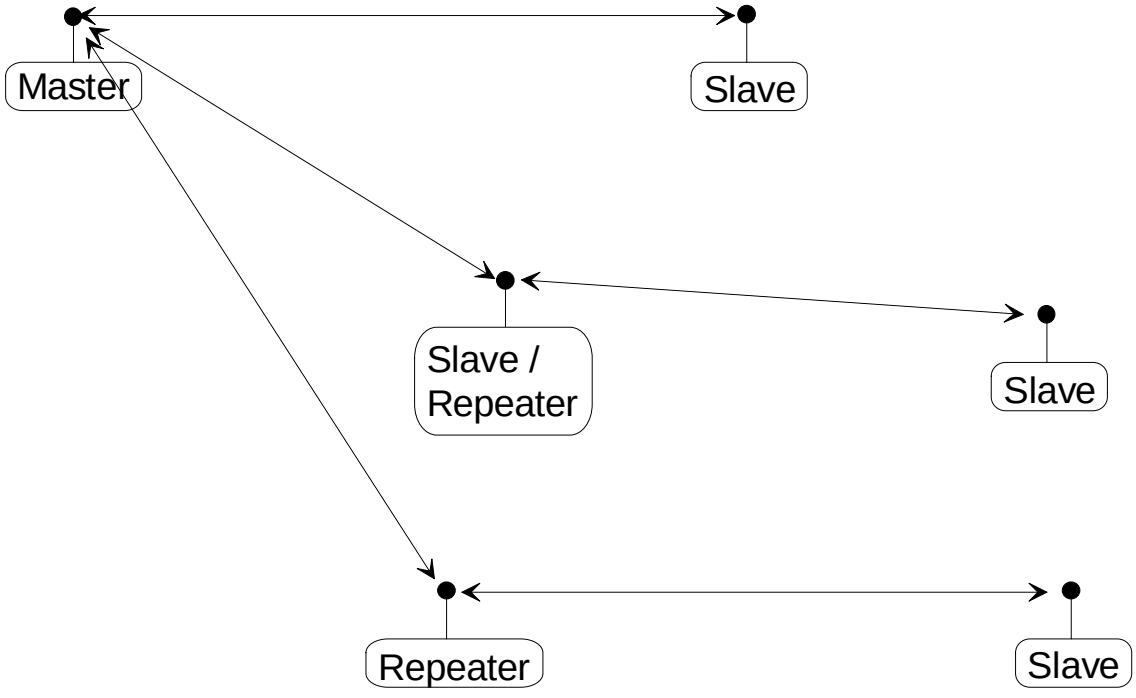
Diagram (C) shows a link with two repeaters between the master and slave. With two repeaters there is clearly more flexibility in getting around obstacles and greater total range is possible. Once again, it would be desirable to use external omnidirectional antennas with the repeaters, and attaching a Yagi to the master and slave would increase the range of the link.

When two repeaters are used there is no further degradation in the RF speed of the link.



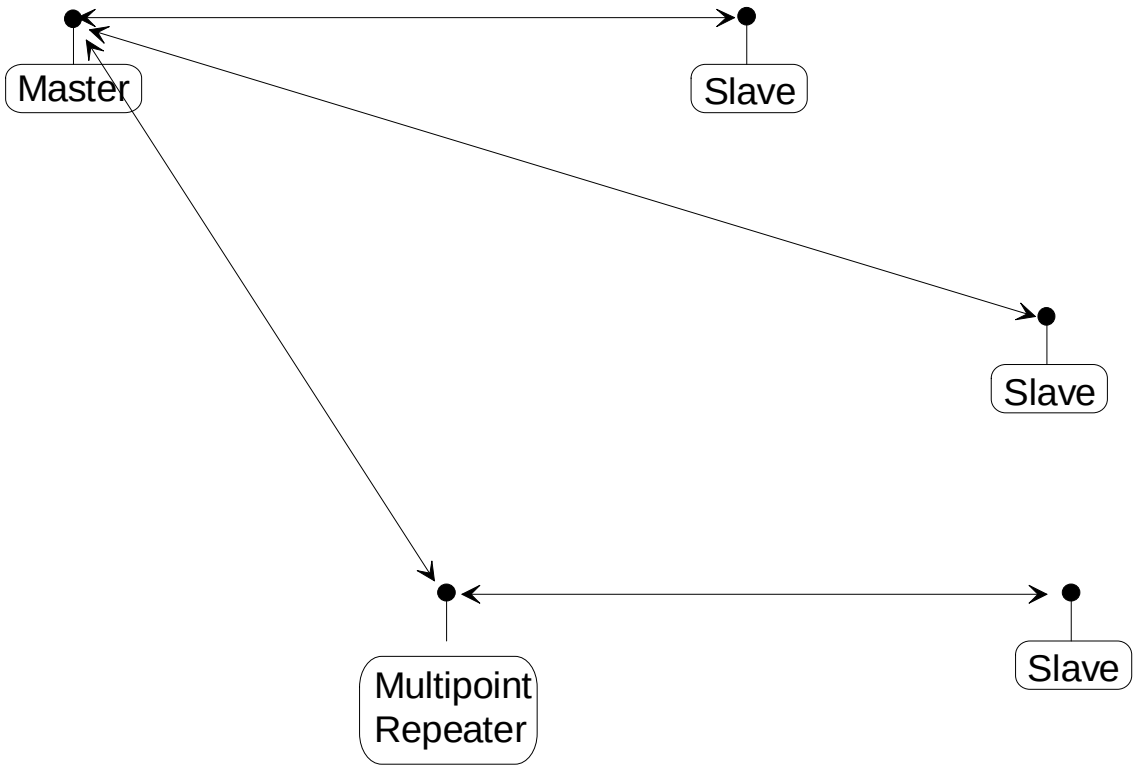
(C)

In example (D) a setup is shown where a master routinely calls a number of slaves at different times. The master is communicating with a transceiver designated as a slave/repeater which is connected to a remote instrument in the field. Since this instrument 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 desirable the master may call any of the slaves, establish a connection, and retrieve and send data.



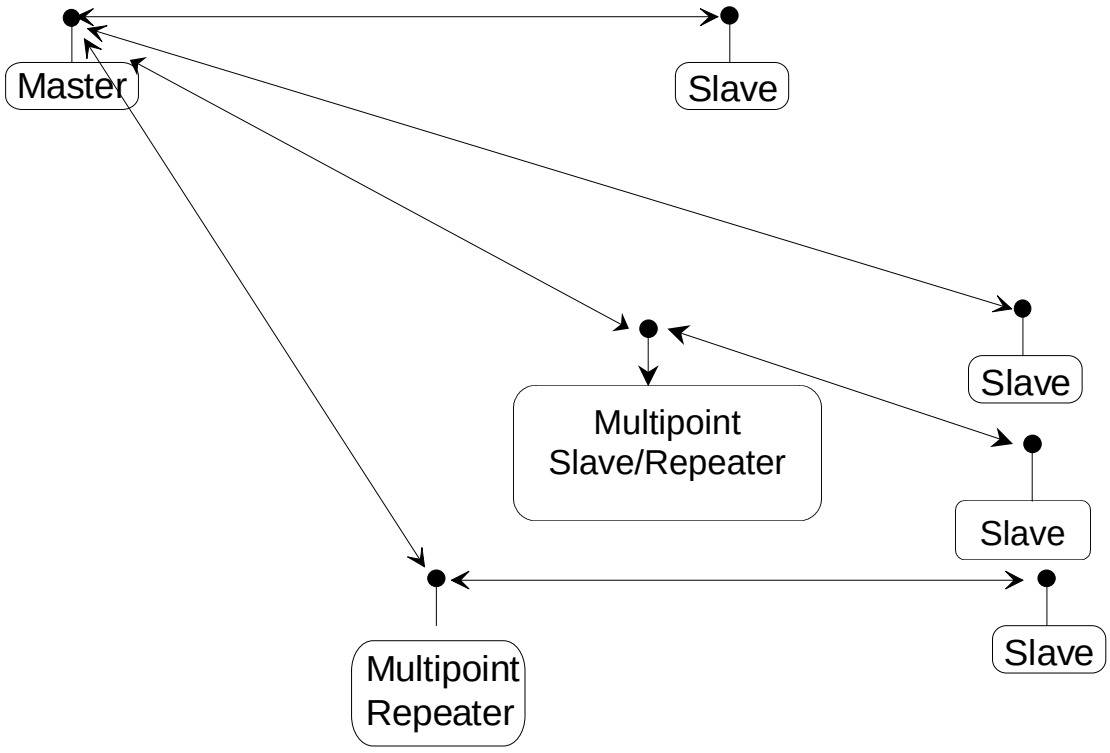
(D)

Example (E) depicts a standard point-to-multipoint system. In this example any data sent from the master is broadcast to all three slaves, one of which receives it through a multipoint repeater. The data is in turn sent out of the RS232 port of each of the three slaves.



(E)

In (F) a point-to-multipoint system is depicted which uses one of the slave sites as a repeater simultaneously, all through the same radio. This system works in a manner very similar to a standard multipoint system with repeaters, however the number of radios needed is reduced with the use of the multipoint slave/repeater feature.



(F)

RS422 & RS-485 Operation

For both RS-422 and RS-485 the Freewave modem can drive 32 standard unit loads and loads the buss with only 1/8 unit load. This means the user can tie up to 256 devices on the buss if all of the line receivers have 1/8 unit load (different devices have different loads).

RS-422 is used for full duplex (4 wire) communication with one master and many slaves. The Freewave modem is the master unit and keeps the line driver asserted (in the on state) at all times. The maximum line length is 4,000 feet using a pair of 120 ohm twisted cables with a 5th wire for data common (neutral).

RS-485 full duplex (4 wire plus common) is the same as RS-422 except the system can have multiple masters on the buss.

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

When setting the modem to RS-485 for point-to-point mode you must turn Modbuss on and set master packet repeat to 3 in both the master and slave radios. In point-to-multipoint you must turn Modbuss on and set master packet repeat to 1 or more on all radios.

The “Turn off delay” time in the menu is used to control the length of time the transmitter driver stays asserted (on) after data transmission has finished. This is needed to allow the last transmitted character to reach the end of a long line (4,000 feet) and is normally set to one character length of time (four one quarter character times in the menu) at the selected baud rate. This time also allows 3 complete reflections to the end of the line to ensure the ringing on the line has fully dampened out before turning the buss over to another device. Shorter line lengths may use smaller delays if desired but four one-quarter-character delay times (one complete character) are recommended. A setting of zero delay time is not allowed as it causes internal timing errors.

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

RS-422 & 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

Table 20: RS-422 & RS 485 full duplex

RS-485 Half Duplex pin-outs

Function	Bare Board Pin Number	DE-9 Pin Number
Wire to both pins for Buss +	Short 5 & 7	Short 2 & 3
Wire to both pins for Buss -	Short 9 & 10	Short 7 & 8

Table 21: RS 485 half duplex

Other Settings

A number of parameters other those shown in the setup menu may be set on FreeWave transceivers. The parameters below may be set with DOS based software available by contacting FreeWave Technologies.

Baud Rate

The transceiver's RS232 baud rate may be set to 300, 600, or 900 baud.

Setup Timeout

When enabled this mode invokes a timeout feature for the Setup Menu. If the transceiver goes into setup and does not receive a legitimate menu selection within 3 to 5 seconds it will go back out of setup and into its previous mode.

Technical Specifications

Specification	
Frequency:	902 to 928 MHz
Transmitter:	
Output Power	1 mW to 1 W (+30 dDm)
Range*	60 miles
Modulation	Spread Spectrum GFSK, 120 kBs – 170 kBs
Spreading method	Frequency hopping
Occupied Bandwidth	230 kHz
Receiver:	
Sensitivity	-108 dBm for 10^{-6} BER standard speed -111 dBm for 10^{-6} BER low speed -110 dBm for 10^{-4} BER standard speed -113 dBm for 10^{-4} BER low speed
Selectivity	20 dB at fc ± 115 kHz 60 dB at fc ±145 kHz
System gain	140 dB
Data Transmission:	
Error Detection	32 Bit CRC, resend on error
Forward error correction (low speed)	(24,12) Golay, retransmit on uncorrectable error
Data Encryption	Substitution, dynamic key
Max Link Throughput	115 Kbaud standard speed, 38.4 Kbaud low speed
Data Interface	RS-232/RS485 1200 Baud to 230.4 KBaud, asynch, full duplex TTL (RF board level only) Ethernet 10BaseT
Power Requirements:	
Supply voltage	6 to 30 Vdc, 10 to 60 Vdc with HV option
Max Transmit current, for 1 W transmit power, low MCU speed	6 Vdc: 1 A 12 Vdc: 500 mA 30 Vdc 200 mA
Max Receive current, low MCU speed	6 Vdc: 110 mA 12 Vdc: 60 mA 30 Vdc 40 mA
Max Idle current, low MCU speed	6 Vdc: 30 mA 12 Vdc: 16 mA 30 Vdc 9 mA
Max Sleep current, low MCU speed	6 Vdc: 8 mA 12 Vdc: 5 mA 30 Vdc 2 mA
Operating Modes:	Point-to Point Point-to-Multipoint Peer-to-Peer Store and Forward Repeater
Operating Environment	-40°C - +75°C, 0 to 95% humidity non-condensing

* Line of sight distance with unity gain antenna

** Throughput measured assuming 75% frequency availability.

	FGR09xx	FGR-115RE	FGR-115RC	FGR-115WC
Data port	10-pin PCB connector	Ethernet	RS232, DE9-F	RS232, circular connector
Enclosure	Bare board	Extruded Aluminum	Extruded Aluminum	Extruded Aluminum Waterproof
Dimensions	16 mm H x 62 mm W x 128 mm L	57 mm H x 74 mm W x 165 mm L	57 mm H x 74mm W x 165 mm L	60 mm H x 78 mm W x 165 mm L
Weight		441 grams	441 grams	496 grams
Power Requirements	• 6 – 30 Vdc	• 6 – 30 Vdc • AC Wall Adapter Provided • May also be powered through Pin 6 of DB9 connector.	• 6 – 30 Vdc • AC Wall Adapter Provided • May also be powered through Pin 6 of DB9 connector.	• 6 – 30 Vdc • 6 foot data and power pigtail provided. • Data and power cable also available terminated with DB9 and power jack.
Antenna	SMA female connector. External antenna required	N type female connector. External antenna required.	N type female connector. External antenna required.	N type female connector. External antenna required.
FCC Identifier	KNY21161341911919	KNY21161341911919	KNY21161341911919	KNY21161341911919
DOC Identifier	2329 102 336A	2329 102 336A	2329 102 336A	2329 102 336A

Specification	
Frequency:	2.400 to 2.4835 GHz
Transmitter:	
Output Power	100 mW to 500 mW
Range*	20 miles
Modulation	GFSK, 115.2 Kbps or 153.6 Kbps
Occupied Bandwidth	230 kHz
Receiver:	
Sensitivity	-108 dBm at 10-6 raw BER
Selectivity	20 dB at fc ± 115 kHz 60 dB at fc ± 145 kHz
System Gain	137 dB
Data Transmission:	
Error Detection	32 Bit CRC, Retransmit on Error
Data Encryption	Substitution, dynamic key
Link Throughput	115 Kpbs
Interface	RS-232
Power Requirements:	
Supply Voltage	9.5 – 30 VDC
Transmit Current	400 mA at 9.5 VDC 320 mA at 12 VDC 150 mA at 30 VDC
Receive Current	130 mA at 9.5 VDC 100 mA at 12 VDC 13 mA at 30 VDC
Idle Current	37 mA at 9.5 VDC 30 mA at 12 VDC 13 mA at 30 VDC
Sleep Current	8 mA at 9.5 VDC 5 mA at 12 VDC 2 mA at 30 VDC
Operating Modes:	Point-to Point Point-to-Multipoint Peer-to-Peer Store and Forward Repeater
Operating Environment	-40°C - +75°C, 0 to 95% humidity non-condensing

* 5 dB omni at 2.4 GHz.
** Throughput measured assuming 75% frequency availability.

	Board Level	I-800X009	I-900X009
Data port	10-pin PCB connector	RS232, DE9-F	RS232, circular connector
Enclosure	Bare board	Extruded Aluminum	Extruded Aluminum Waterproof
Dimensions	16 mm H x 62 mm W x 128 mm L	57 mm H x 74mm W x 165 mm L	60 mm H x 78 mm W x 165 mm L
Weight		441 grams	496 grams
Power Requirements	• 9 – 30 Vdc	• 9 – 30 Vdc • AC Wall Adapter Provided • May also be powered through Pin 6 of DB9 connector.	• 9 – 30 Vdc • 6 foot data and power pigtail provided. • Data and power cable also available terminated with DB9 and power jack.
Antenna	SMA female connector. External antenna required	N type female connector. External antenna required.	N type female connector. External antenna required.

Troubleshooting

For up to date troubleshooting information check the FAQ page at www.freewave.com.

Notes:

OEM Board Level Mechanical Drawing