

# **FreeWave<sup>®</sup> Spread Spectrum Wireless Data Transceiver**

## **User Manual**

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Printed in the United States of America.

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## 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 numbers DGR09 and DGR-115 have maximum transmitted output power of 955mW and 1 Watt, respectively. It is recommended that the transmit antenna be kept at least 23 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.





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**Model# DGRO9RFS 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

This manual covers the operation of both the 900 MHz and 2.4 GHz spread spectrum transceivers manufactured by FreeWave Technologies. For the most part operation of the products is identical, where operating differences exist every effort has been made to clearly identify which product family is being referred to.

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. Screw the included whip antennas in the modem (DGR-115 model only), ensuring they are snug and properly seated. 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.*

## 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.

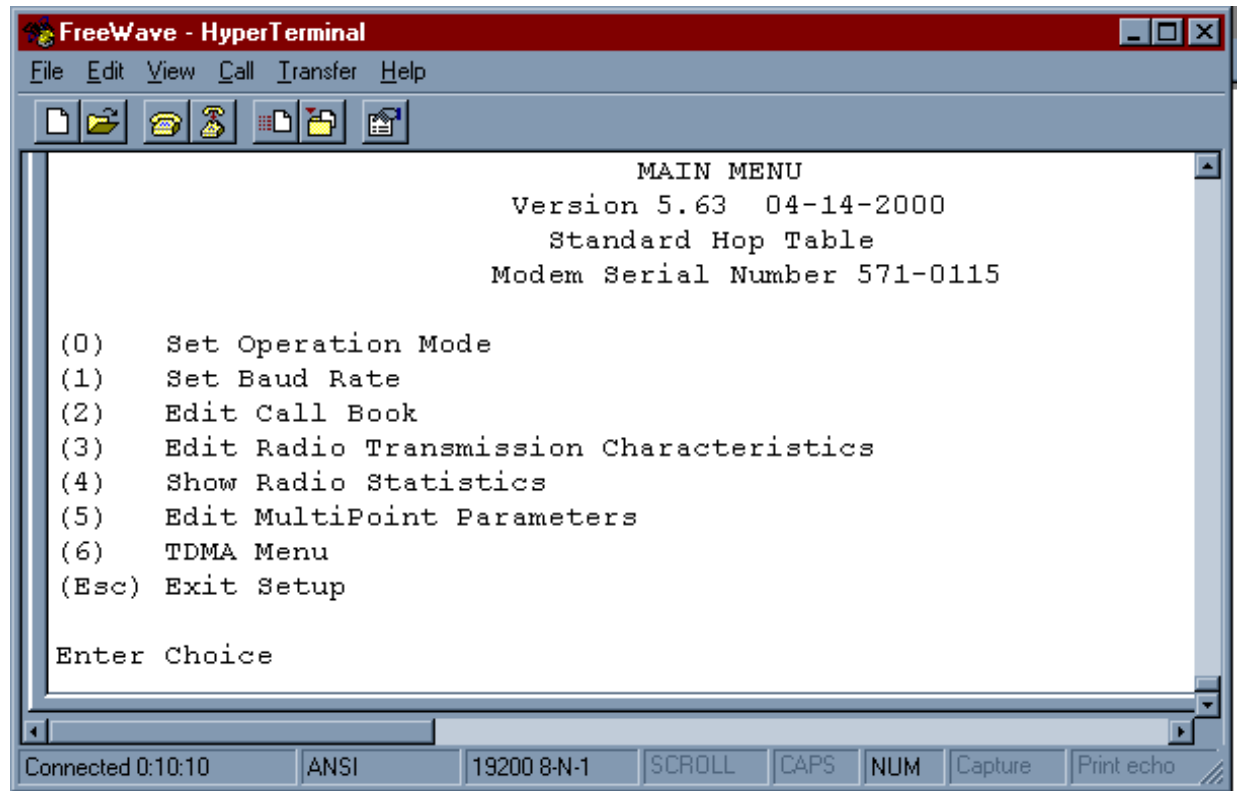
The setup program is invoked by connecting FreeWave to any terminal program, setting the baud rate for that terminal to 19200 baud, and putting the transceiver into setup mode (on most models this is done by pressing the Setup button). While any terminal which can be set to 19200 baud will work, examples for this manual were generated using the Terminal application from Microsoft Windows 3.1 or Hyperterminal.

<b>Table 1:</b> 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

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

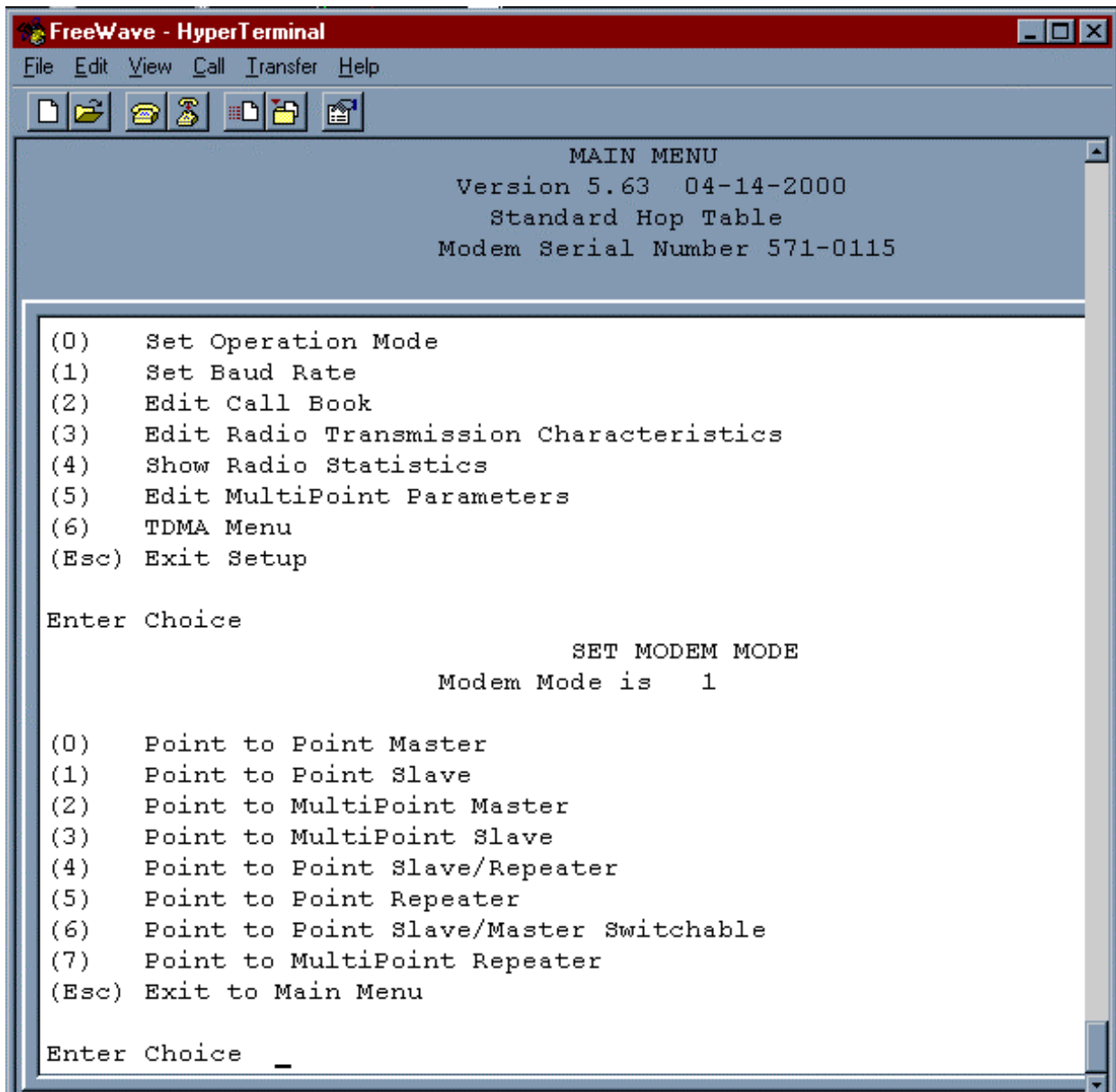


The initial menu provides the Transceiver's unique serial number, firmware version, and the set of choices for editing the operational parameters and viewing the performance data.

### (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 slave a FreeWave Transceiver will communicate with any master in its call book, either directly or through one or two repeaters. When functioning as a slave, the Entry to Call feature in the Transceiver's call book (Figure 5) is not operational. The slave will communicate with any master on the list that calls.

### **(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 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 two repeaters in a 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 repeaters are used.

**(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:

- ◆ The transceiver remains in slave mode until called by another Transceiver in its Call Book or instructed to call another transceiver through an ATDT 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.*

<b>Table 2: AT Script File Commands</b>
---

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. The modem will use the repeater(s) specified in the Call Book. This means it is now possible to call an unlimited number of slaves through script files in mode 6 and have up to 10 different repeater combinations.

To use the new features the following steps should be followed:

1. If one or two repeaters are to be used they 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.
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, with `#` being either a position in the Call Book that contains no repeaters or the letter A. When the command `ATXCA` is issued the modem is instructed to Call All and no repeaters are 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. An entry exists in the Edit Radio Characteristics Menu so that this feature can be enabled or disabled.

### (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.



## 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.

## **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**

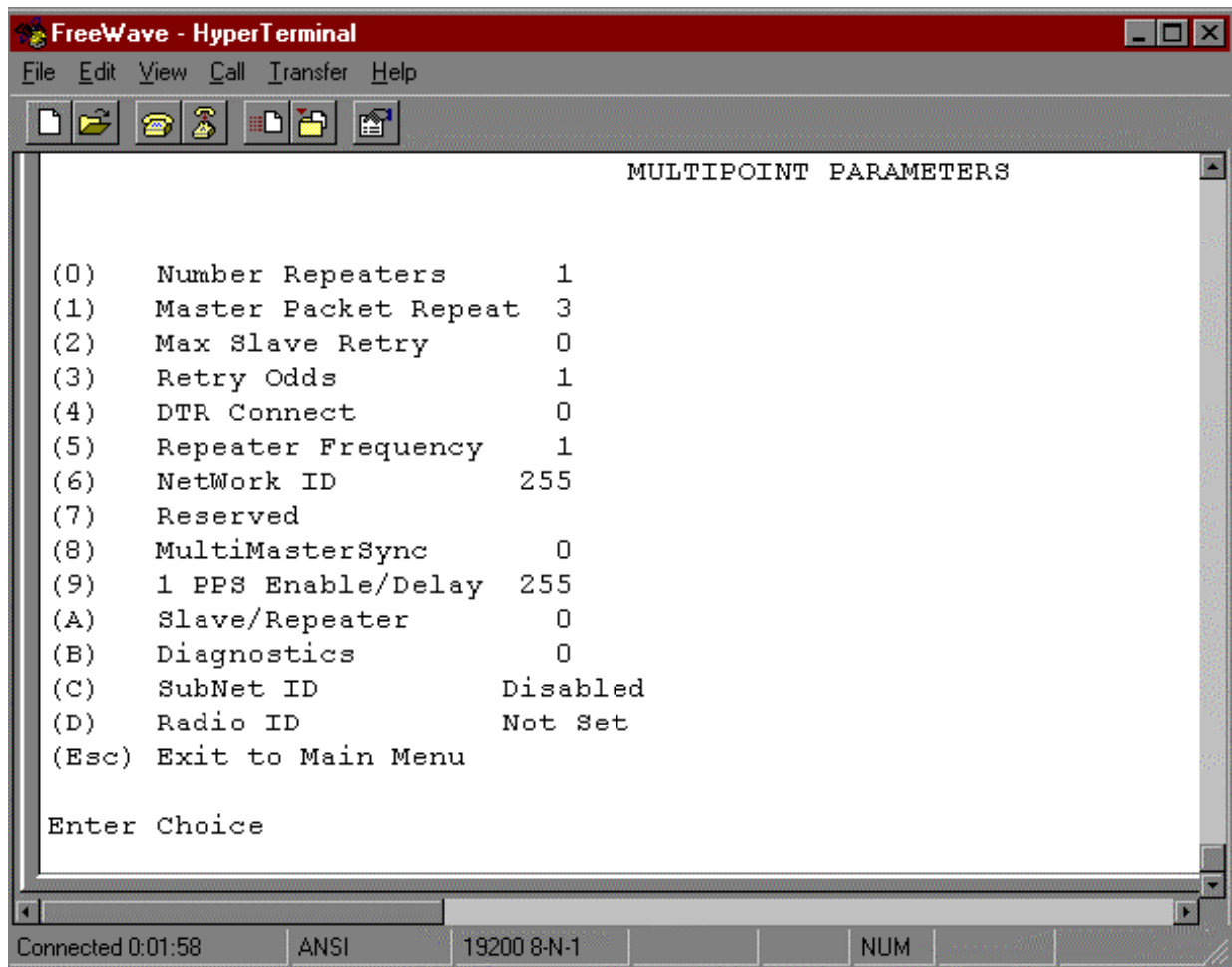
In point-to-point operation the FreeWave transceivers acknowledge every data packet transmitted. In a Multipoint network, transmissions from a master to the slaves are not acknowledged by the slaves. This is to prevent system overload. If the slaves acknowledged all data transmissions from the master 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 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 3: 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.

**(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).

**(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 lower than the default (255) 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. Version 5.62 / 1.62 or later firmware in every transceiver in the network
2. Diagnostics must be enabled on the Master (set to 1)
3. Number of Repeaters must be set to 1 on every transceiver in the network, even if there are no repeaters in the network.
4. A second computer to run the diagnostics software
5. A diagnostics cable, available through FreeWave Technologies
6. 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 feature has not been enabled at the time of the printing of this manual.*

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 4: Multipoint Subnet Diagram

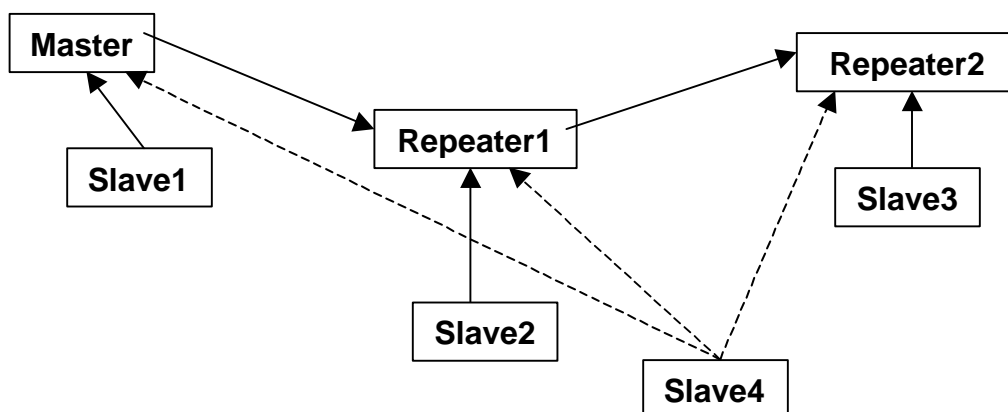


Table 3: Subnet ID Settings

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:** The specific SubnetID settings in the previous example are arbitrary. Other than using Rcv SubnetID = 0 to listen only to the Master, and Rcv SubnetID and Xmit SubnetID set to FF to listen to the first Master or Repeater, any settings may be used to set the sub networks up.



**(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.

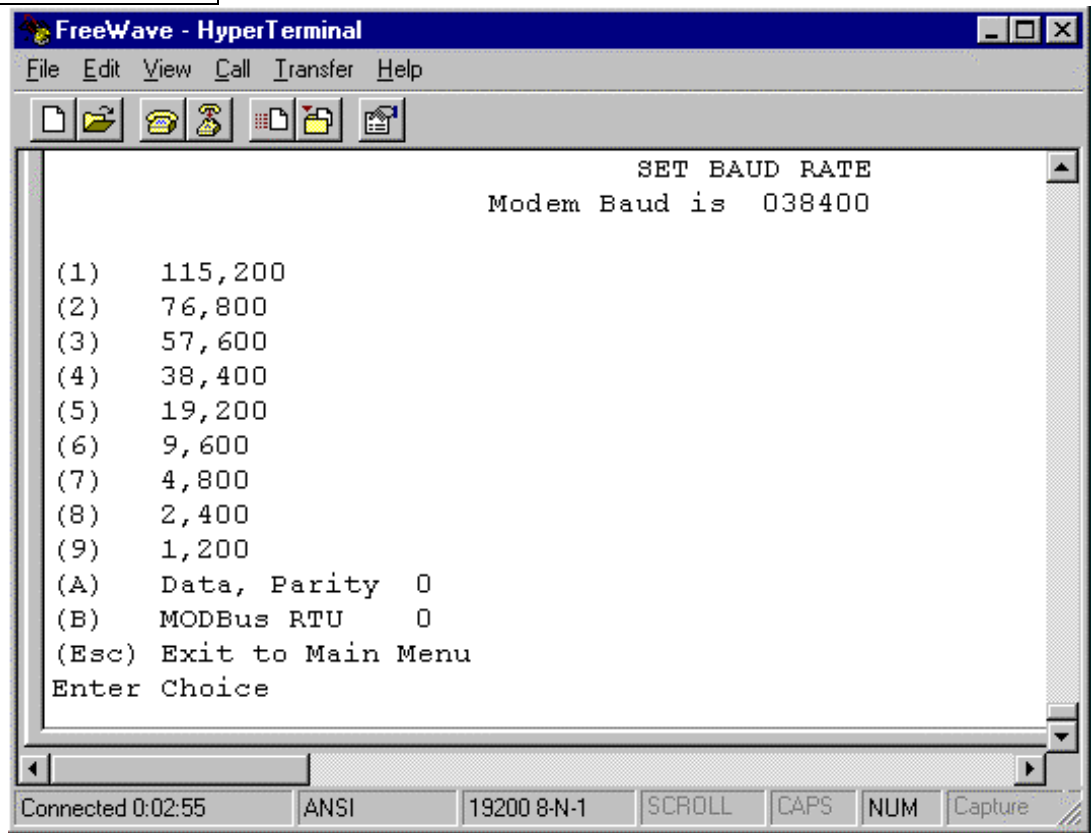
## Baud Rate Selections

### (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 5: Baud Rate, Word Length, & Modbus



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.

## 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.
3. The master must be programmed to call the slave.

As shown in figure 5, the Call Book allows users to set up a list of up to 10 FreeWave Transceivers with whom they can communicate, designate up to 2 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 two 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 6: 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.

**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.*

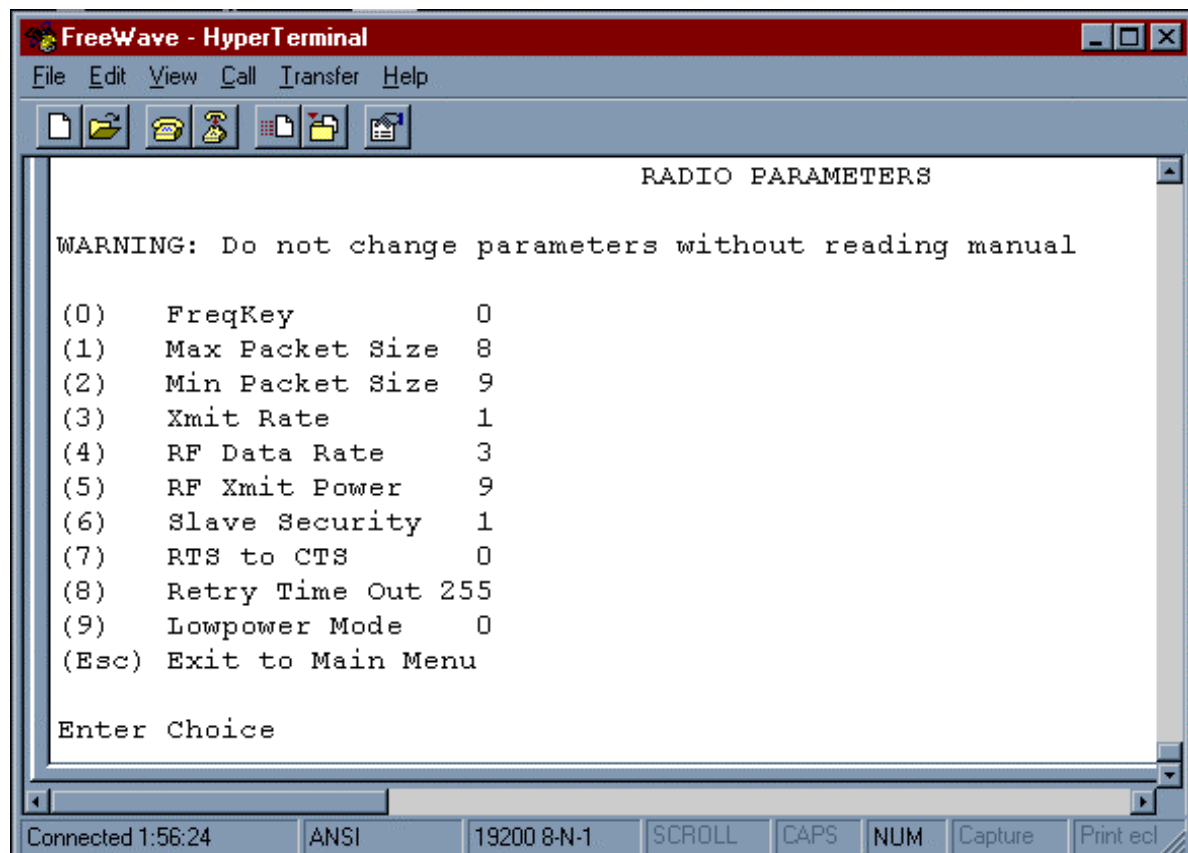
## Radio Transmission Parameters

### (3) Edit Radio Transmission Characteristics

When item (3) is selected in the main menu the screen in figure 6 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 7: Radio Parameters Menu



## (0) FreqKey

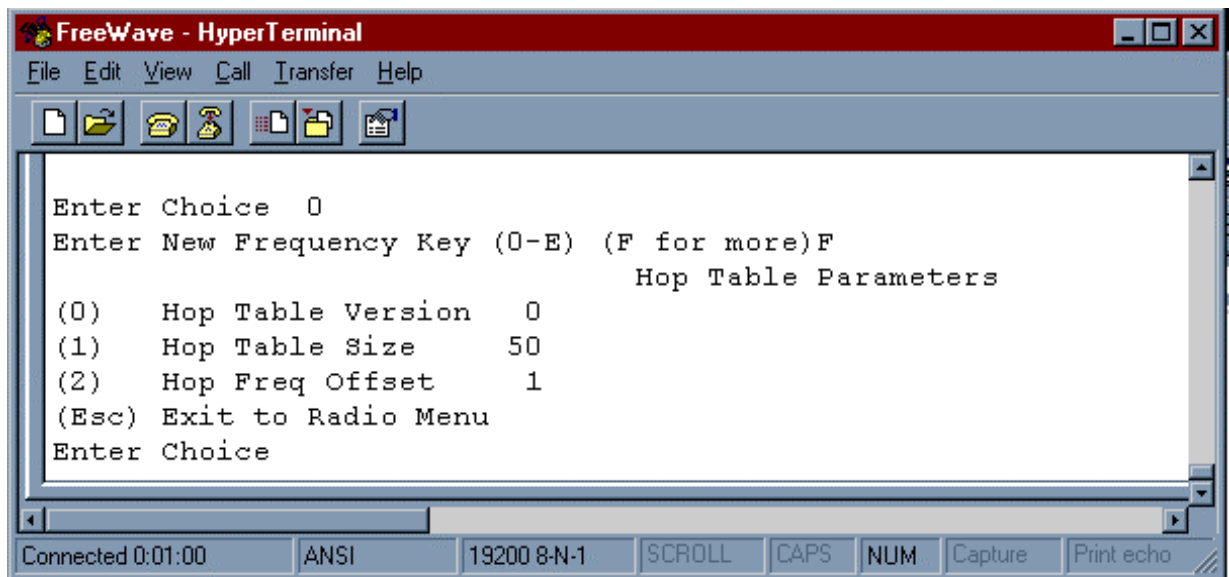
### 900MHz

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 8: 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 shown in the table below:

Table 5: 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 6:** 2.4 GHz Frequency Band  
Selections Available

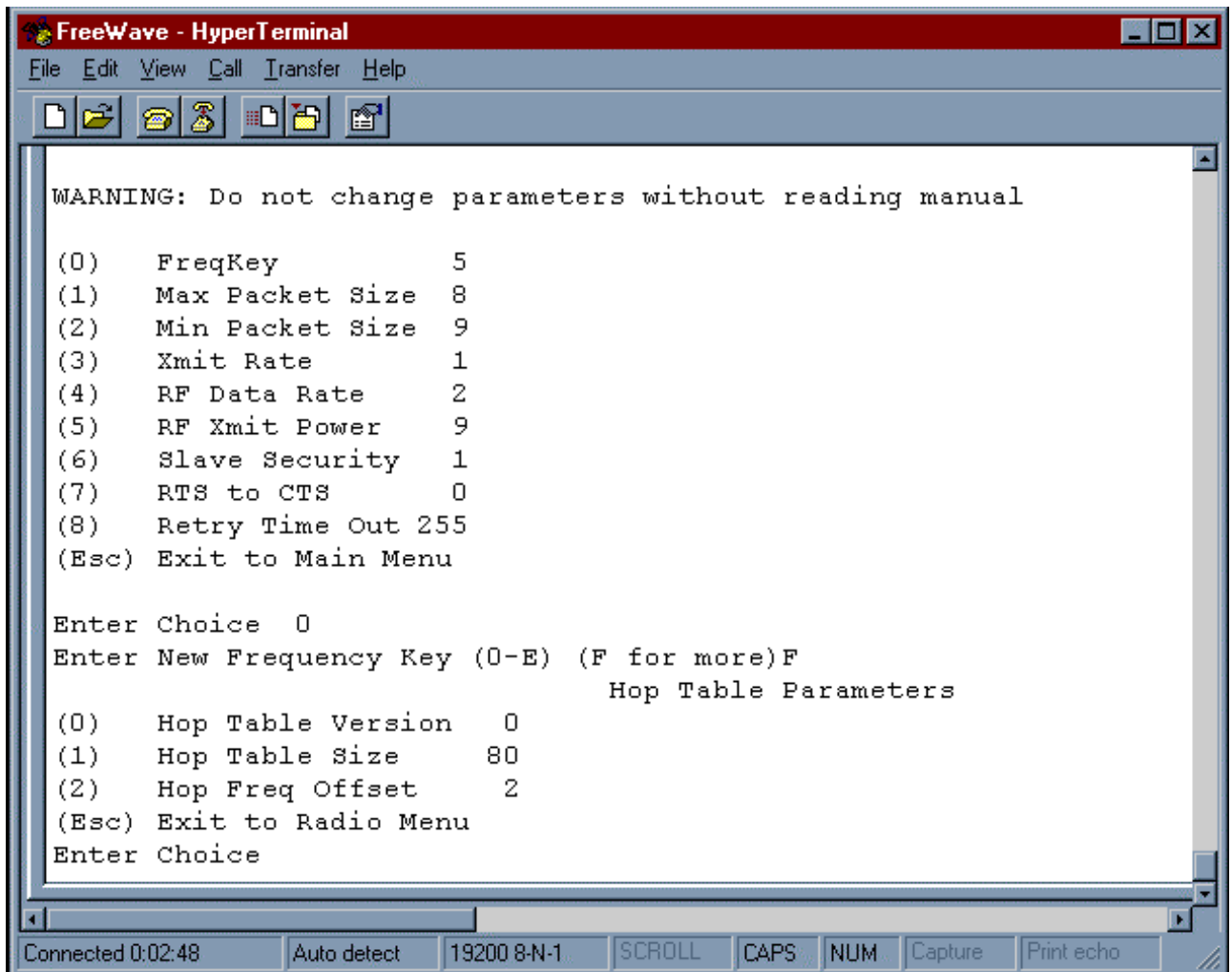
Selection	Band Used
0	Entire band, 2.400 - 2.4835 GHz
1	Entire band, but offset frequencies from selection 0
2	Lower 1/3 <sup>rd</sup> of band
3	Middle of band
4	Upper 1/3 <sup>rd</sup> of band
5	2 outer 1/3 <sup>rd</sup> s of band, avoids the middle

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 1/3<sup>rd</sup> 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 9: 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 7: 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 8:** Max Packet Size Settings (Bytes)  
RF Data Rate= 2

Min Setting	Max 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 9:** Max Packet Size Settings (Bytes)  
RF Data Rate= 3

Min Setting	Max 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, 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

FreeWave offers users the ability to modify the Transmission Power of the Transceiver. By reducing the Transmission Power when appropriate, users can ensure the Transceivers do not overwhelm each other when used in close proximity. There are 9 power settings available (1-9) which are roughly linear, therefore a setting of 9 is full power or 1 Watt and 1 is ~10% power or 100 mW. The following guidelines should be followed when setting the RF Transmission Power:

Table 10: Power Transmit Settings

Setting	Power Level	Used When
1 - 3	Low	Pair or pairs of transceivers operating within same or adjoining rooms.
4 - 6	Medium	More than one pair of modems operating within same facility.
7 - 9	Full	Normal operation extending beyond a facility.

### (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 25 mS. At their minimum numbers the time will be approximately 10 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 conjunction 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*

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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 20 to 200 milliseconds.

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 provides the power consumption figures for a 12 volt RS232 transceiver at different Lowpower Mode settings.

Table 11: Low Power Settings

Setting	Description	Draw0	Draw1
0	Lowpower disabled	70mA	63mA
1	LEDs dimmed	40mA	33mA
2	LEDs dimmed, transceiver sleeps every other slot	35mA	30mA
3	LEDs dimmed, transceiver sleeps 2 of 3 slots	32mA	29mA
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.	30-26	28-26

## 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, bytes transmitted, bytes received, and the distance of the link between transceivers. Statistics are gathered during each data link and are reset when the next link begins.

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 the measurement site. 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 the measurement site. The signal source is the slave modem, or if the link includes repeaters, the closest repeater to the measurement site. 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. Table 12 provides an approximate conversion of average signal level values into the more common dBm (decibel milliwatts).

Table 12: Conversion of Average Noise Level to dBm
--

Average Signal Level	41	49	60	66	85
Level in dBm	-110	-100	-90	-80	-70

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.

### 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  $-40^{\circ}$  to  $75^{\circ}\text{C}$ .

## 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 a band pass filter to reduce the out of band noise.

The standard enclosure for the DGR-115 does not provide protection against water or environmental hazards, and will fade when placed in direct sunlight. For outdoor applications the DGR-115H should be used. The DGR-115H provides a weather resistant enclosure, allowing placement of the Transceiver in more demanding environmental conditions. The DGR-115H must be mounted in a vertical position to be weather resistant. An optional mounting bracket (part number MBRK/115H) is available to mount the transceiver to a tower or mast. The DGR-115H requires the use of an external antenna.

The DGR115W 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 13: LED Status in Point to Point Mode**

### Point to Point Communications

Condition	Master			Slave			Repeater		
	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 14: LED Status in  
Multipoint Mode

## MultiPoint Communications

Condition	Master			Slave			Repeater		
	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*

\*CTS will be Solid Red with a solid link, as the link weakens the CTS light on the repeater

## Legend:

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

and slave will begin to flash.

## LED:

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

## Using an External Antenna

All FreeWave Technologies spread spectrum transceivers require the use of an external antenna other than the model DGR-115. The Transceivers are equipped with an external jack allowing the use of a directional Yagi or omnidirectional antenna. When using an external antenna the whip antenna on the DGR-115 must be removed.

The use of an external antenna may radically improve the results obtained with FreeWave Transceivers. It is highly desirable to obtain line of sight with the antennas, and changes in placement height of as few as a couple of feet may make the difference between no link and one that is solid and reliable.

Per FCC regulations, any antenna used with FreeWave transceivers must be provided by FreeWave Technologies. FreeWave Technologies offers a variety of omnidirectional and directional external antennas, with both bracket and magnetic mounts. These antennas allow versatility in FreeWave's deployment, extending its range and allowing it to get around obstructions. Any FreeWave transceiver which includes a standard RF connector is for professional installation only, and the professional installer must ensure frequency emission limits are not exceeded.

If external directional antennas are used FCC regulations concerning effective radiated power limitations must be followed. Table 15 provides the maximum output power settings for a 955 mW 900MHz transceiver given antenna gain and cable loss combinations.

**Table 15:** Output Power Settings at given Antenna Gain & Cable Loss Combinations, 900 MHz.

		Cable Loss			
		1dB	2dB	3dB	4dB
Antenna Gain	10dB	5	6	7	9
	8dB	8	9	9	9
	6dB	9	9	9	9

**Table 16:** EIRP for 10dB Yagi Antenna, 900MHz, Cable loss vs RF Xmit Power Setting.

		Cable Loss			
		1dB	2dB	3dB	4dB
RF Xmit Power	9	38.80	37.80	36.80	35.80
	8	38.50	37.50	36.50	35.50
	7	37.75	36.75	35.75	34.75
	6	36.40	35.40	34.40	33.40
	5	34.44	33.44	32.44	31.44

**Note:** Shaded area indicates combinations where EIRP limitations exceed FCC regulations and RF Xmit Power must be reduced.

**WARNING:** Any antennas placed outdoors must be properly grounded. Use extreme caution when installing antennas and follow all instructions included with the antennas.

The use of external antennas subjects the transceiver to greater exposure to direct lightning strikes.

Long RS232 cable runs should also be avoided in areas with increased lightning activity or static electricity unless they are properly isolated from the transceiver. Nearby lightning strikes or elevated levels of static electricity may lead to voltage spikes on the line, causing failure in the transceiver's RS232 interface.

Table 17: Approved Antennas,  
900MHz and 2.4GHz

The following antennas are approved for use with FreeWave transceivers:

#### 900MHz Directional Antennas

Gain	Manufacturer	Manufacturer Model Number	FreeWave Model Number
10dB	Mobile Mark	YAG10-915N	EAN0900YB
10dB	Larsen	YA0006	EAN0900YA
6dB	Mobile Mark	YAG6-915N	EAN0906YB
6dB	Larsen	YA6-900	EAN0906YA

#### 900MHz Omnidirectional Antennas

Gain	Manufacturer	Manufacturer Model Number	FreeWave Model Number
5dB	Antennex	EB8965C	EAN0905WC
	Maxrad	BMEFC8985HD	
3dB	Maxrad	MAX-9053	EAN0900WC
0dB	JEMA	JA900SS	EAN0900WR
0dB	Mobile Mark	PSTG0-915FW	EAN0900RQ
0dB	Mobile Mark	PSTN3-915S	EAN0900SH
0dB	Mobile Mark	PSTG0-915SE	EAN0900SQ
0dB	Mobile Mark	PSTN3-915N	EAN0900NH

#### 2.4GHz Directional Antennas

Gain	Manufacturer	Manufacturer Model Number	FreeWave Model Number
14dB	Mobile Mark	SCR14-2400	EAN2414CR

#### 2.4GHz Omnidirectional Antennas

Gain	Manufacturer	Manufacturer Model Number	FreeWave Model Number
5dB	Maxrad	MAXC24505	EAN2405WC
0dB	Mobile Mark	PSTN3-2400N	EAN2400NH



### **Antenna Alignment**

FreeWave modems have a convenient, built-in tool that simplifies the task of aligning directional antennas. This tool is particularly useful when the antenna on either end is not visible from the other end due to distance or obstructions. To use this feature, the modems must be configured for point to point operation.

#### **Setup procedure**

1. Program the modem operation mode (menu 0) for point to point operation, i.e., program one modem as a point to point master and one modem as a point to point slave. This procedure may also be used with intermediate repeaters. If intermediate repeaters are used, program the modem(s) to be used as repeaters for point to point repeater operation.
2. Program each modem's call book (menu 2) as necessary for point to point communications.
3. On the modem programmed as the point to point master, set the Xmit Rate parameter on the Radio Transmission Parameters menu (menu 3, item 3) to 0.
4. When the modems are returned to operation, the master modem will transmit a continuous stream of high-speed data. The slave modem sends acknowledgements for each of the data packets received from the master. The CTS LED on either the slave or the master provides an indication of the quality of the link. A solid indication on the CTS LED indicates a strong link with minimum packet retransmissions. A flickering indication on the CTS LED indicates a weaker link with a higher percentage of packet retransmissions. While observing the CTS LED display, adjust the alignment of the directional antenna for the most solid indication.
5. After the antennas have been aligned for optimum performance, restore the Xmit Rate parameter on the master radio to 1 for normal operation.

#### **Point to multipoint procedure**

Following the above procedure, each individual slave/master link in a multipoint network can be aligned. After all links have been aligned, all modems in the network are programmed for multipoint operation.

## RS232 Pin Assignments

Table 18: 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)	<u>The modem does not recognize RTS for flow control.</u> 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.

## DGRO Small Footprint Series Pinout

The DGRO 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 19:** DGRO 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

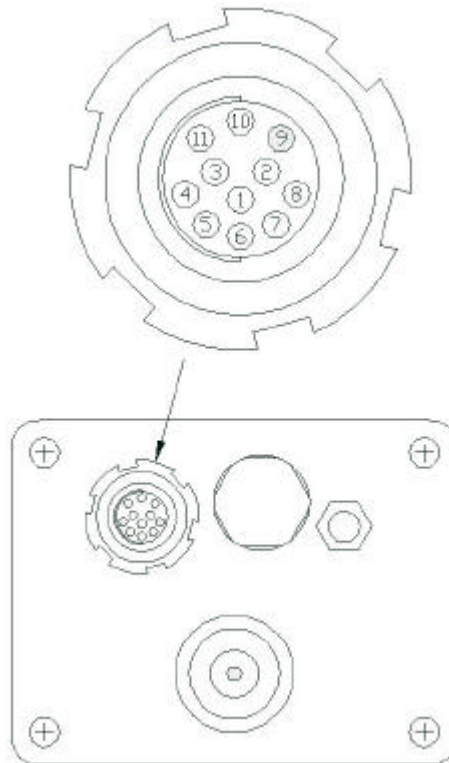
**Note:** Pin 1 on the DGRO9 and DGR24 board level transceiver is the pin farthest from the three LEDs and pin 10 is closest to the LEDs.

## DGR-115W Waterproof Enclosure Pinout

Table 20: DGR-115W 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	Data Set Ready	Output
7	Violet	RTS	Input
8	Gray	Clear to Send	Output
9	White	Power Ground	Power Ground
10	Black	B+	Power Input
11	Shield	Shield Ground	Shield Ground

Figure 10: Waterproof Connector



## Data Communications Settings

The device to which FreeWave is connected should be configured to match the settings shown in Table 21.

Table 21: Data Communication Settings

Parameter	Setting
Baud Rate	Match to FreeWave
Data Bits	8
Parity	None
Stop Bits	1
Parity Check	None / Off
Carrier Detect	None / Off
Flow Control	RTS/CTS / Hardware
Connection Started by	Carrier Detect
Connection Ended by	Carrier Detect
DTR Signal	Always On
RTS Signal	Always On

## 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.

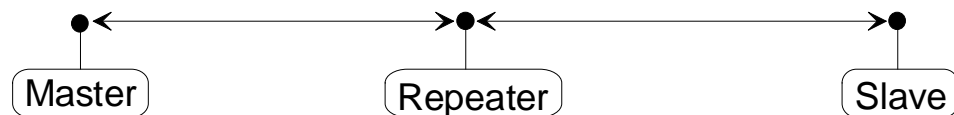
Diagram (A) shows the most common and straightforward link, a master communicating to a slave in a dedicated link.



**(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.

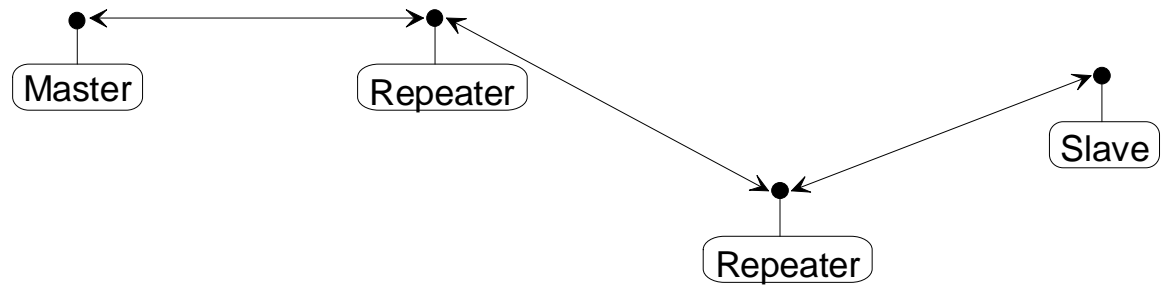
When a repeater is used the RF speed is cut in half, making 115 KBaud uncompressed throughput unachievable. The baud rate, however, may still be set at 115200.



**(B)**

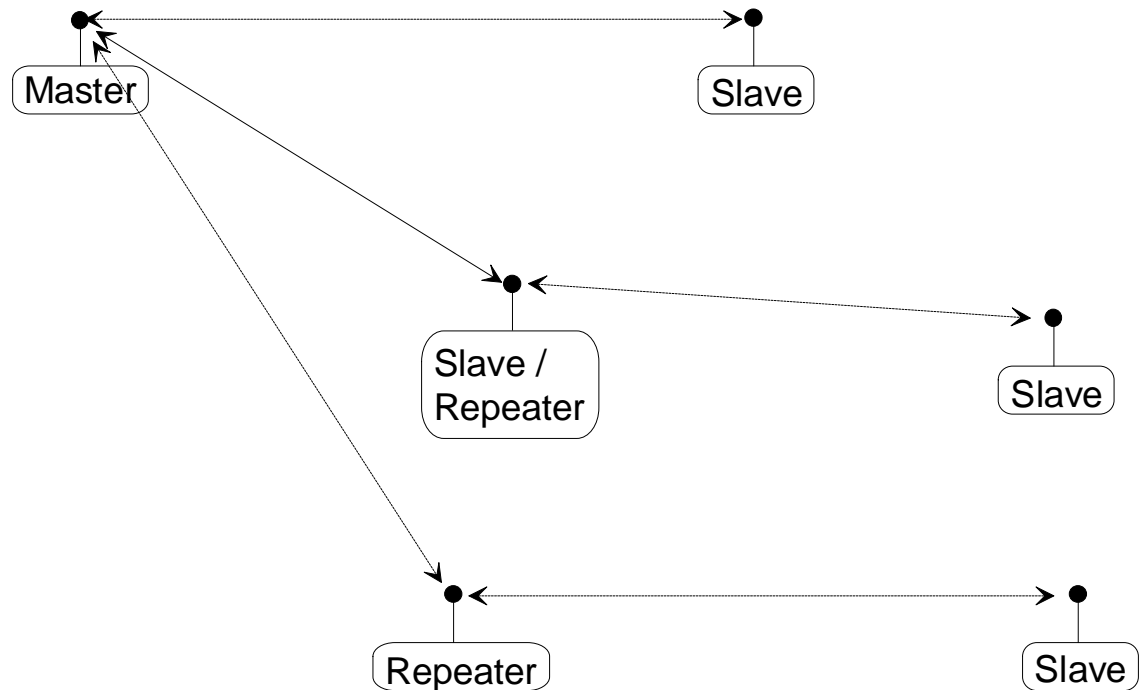
Diagram (C) shows a link with two repeaters between the master and slave. With two repeaters there is clearly more flexibility in getting around obstacles and greater total range is possible. Once again, it would be desirable to use external omnidirectional antennas with the repeaters, and attaching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

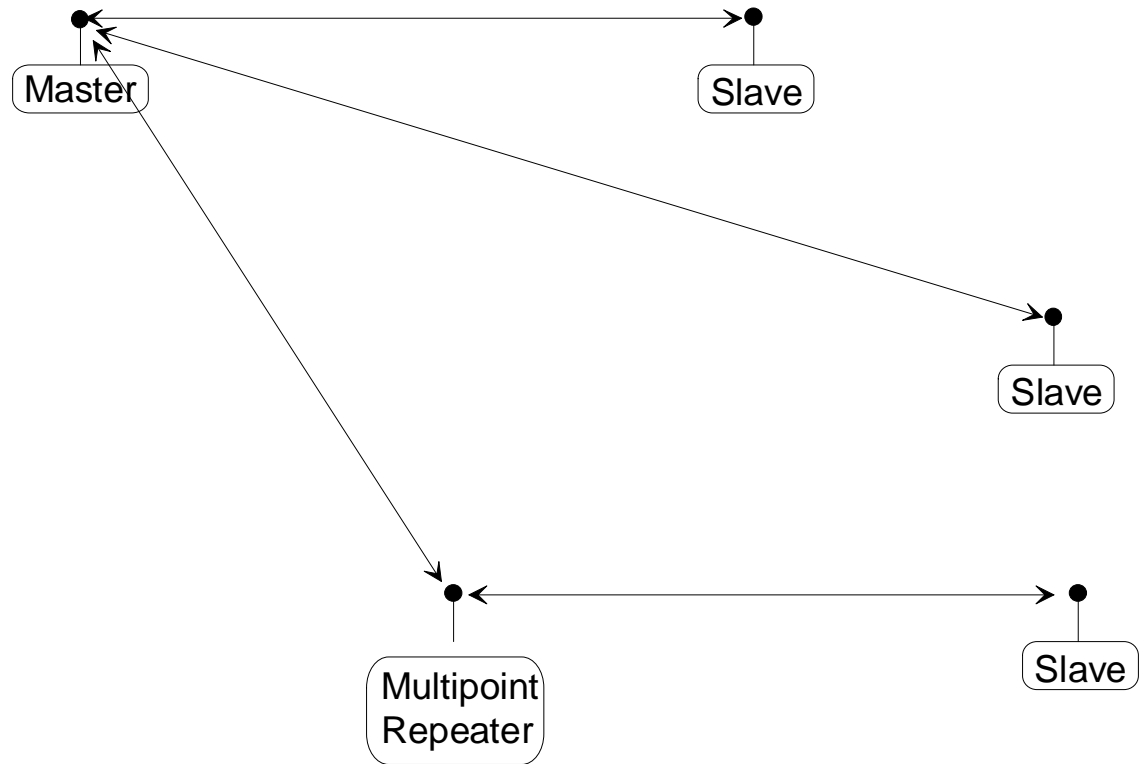
In example (D) a setup is shown where a master routinely calls a number of slaves at different times. The master is communicating with a transceiver designated as a slave/repeater which is connected to a remote instrument in the field. Since this instrument is placed in an elevated location, the transceiver 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)

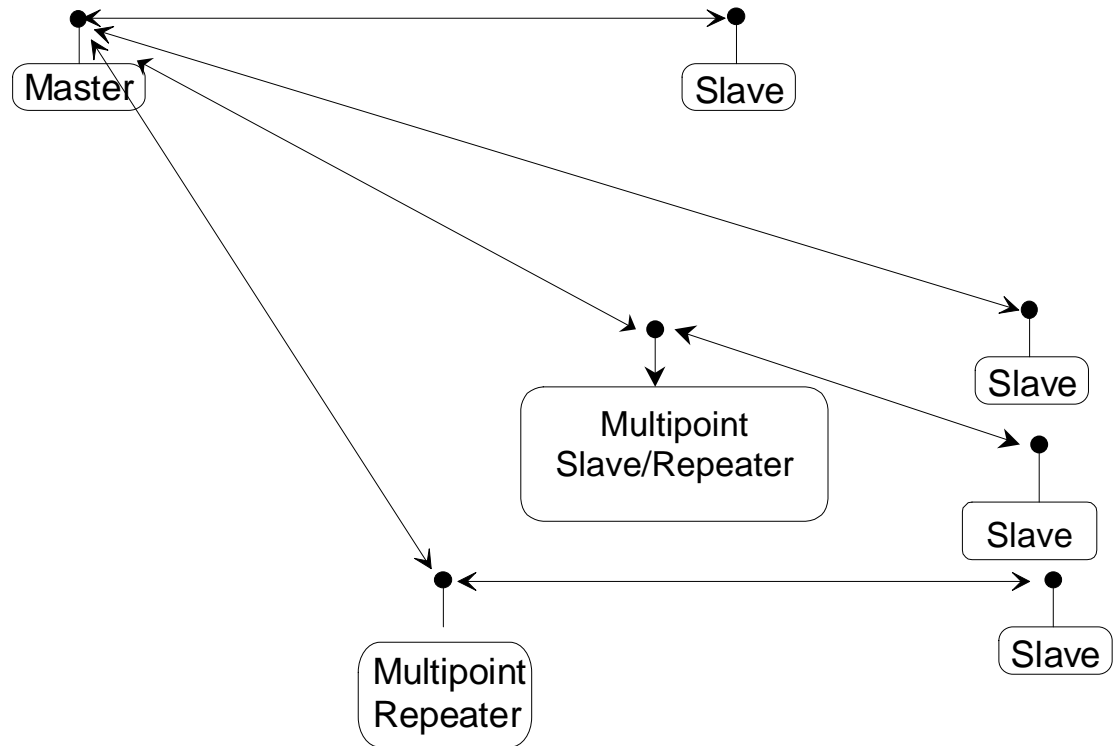


Example (E) depicts a standard point-to-multipoint system. In this example any data sent from the master is broadcast to all three slaves, one of which receives it through a multipoint repeater. The data is in turn sent out of the RS232 port of each of the three slaves.



(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)

## Other Settings

A number of parameters other than 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	2.400 to 2.4835 GHz
Transmitter:		
Output Power	955 mW (+29.8 dBm) at 9.5 to 14.0 V 400 mW (+26 dBm) at 7.5 to 9.5 V	500 mW (+27 dBm) at 9.5 to 14.0 V 400 mW (+26 dBm) at 7.5 to 9.5 V
Range*	20 miles	20 miles
Modulation	GFSK, 120 kBs – 170 kBs	GFSK, 120 kBs – 170 kBs
Occupied Bandwidth	230 kHz	230 kHz
Receiver:		
Sensitivity	-108 dBm at 10-6 raw BER	-108 dBm at 10-6 raw BER
Selectivity	40 dB at $f_c \pm 230$ kHz 60 dB at $f_c \pm 460$ kHz	40 dB at $f_c \pm 230$ kHz 60 dB at $f_c \pm 460$ kHz
Data Transmission:		
Error Detection	32 Bit CRC, resend on error	32 Bit CRC, resend on error
Data Encryption	Substitution, dynamic key	Substitution, dynamic key
Link Throughput	115 KBaud	115 KBaud
Interface	RS-232 1200 Baud to 115.2 KBaud, asynch, full duplex	RS-232 1200 Baud to 115.2 KBaud, asynch, full duplex
Power Requirements:		
Transmit current	650 ma at 12V for 1W 600 ma at 8.5V for 400mW	650 ma at 12V for 500mW 600 ma at 8.5V for 400mW
Receive current	100 ma at 12V	100 ma at 12V
Idle current	65ma at 12 V	65ma at 12 V
Operating Modes:	Point-to Point Point-to-Multipoint Peer-to-Peer Store and Forward Repeater	Point-to Point Point-to-Multipoint Peer-to-Peer Store and Forward Repeater
Operating Environment	-40°C - +75°C	-40°C - +75°C

\* Line of sight distance with unity gain antenna at 900 MHz, 5 dB omni at 2.4 GHz.

\*\* Throughput measured assuming 75% frequency availability.

	<b>DGR-115</b>	<b>DGR-115H</b>	<b>DGR-115R / DGMR-115R</b>	<b>DGR-115W / DGMR-115W</b>
Enclosure	Plastic	Milled Aluminum	Extruded Aluminum	Extruded Aluminum Waterproof
Dimensions	41mmH x 99mmW x 188mmL	28mmH x 102mmW x 205mmL	57mmH x 74mmW x 165mmL	60mmH x 78mmW x 165mmL
Weight	340 grams	560 grams	441 grams	496 grams
Power Requirements	<ul style="list-style-type: none"> <li>• 9.5 - 18.0 VDC</li> <li>• Center Pin Positive</li> <li>• AC Wall Adapter Provided</li> <li>• May also be powered through Pin 6 of DB9 connector.</li> </ul>	<ul style="list-style-type: none"> <li>• 9.5 - 18.0 VDC</li> <li>• Center Pin Positive</li> <li>• AC Wall Adapter Provided</li> <li>• May also be powered through Pin 6 of DB9 connector.</li> </ul>	<ul style="list-style-type: none"> <li>• 9.5 - 14.0 VDC</li> <li>• Center Pin Positive</li> <li>• AC Wall Adapter Provided</li> <li>• May also be powered through Pin 6 of DB9 connector.</li> <li>• 6.0-14.0 VDC*</li> <li>• 15.0-32.0 VDC*</li> </ul>	<ul style="list-style-type: none"> <li>• 9.5 - 14.0 VDC</li> <li>• 6.0-14.0 VDC*</li> <li>• 15.0-32.0 VDC*</li> </ul>
Antenna	3 inch whip provided. Reverse thread SMA connector for external antenna.	Reverse thread female SMA connector. External antenna required.	N type female connector. External antenna required.	N type female connector. External antenna required.
FCC Identifier	KNY-DGR-115	KNY-DGR-115	KNY-205-108213 (900) KNY-209228624168 (2.4)	KNY-205-108213 (900) KNY-209228624168 (2.4)
DOC Identifier	2329 101 340A	2329 101 340A	2329 102 336A (900) 2329391130A (2.4)	2329 102 336A (900) 2329391130A (2.4)

\* Voltages available in different models.

## Troubleshooting

*"I am using FreeWave to communicate between two PCs. I am using pcANYWHERE, which is set to direct connection. Both pcANYWHERE and the modem are set to 115.2 KBaud, yet throughput is considerably lower."*

The communication link between two computers may be slowed considerably by the UART used in the serial port of one or both computers. If you suspect that the serial port on the computer will not support high speed communications, then try reducing the baud rate for that end of the connection (both on the computer and the Transceiver) to see if throughput improves.

*"I have two transceivers, one configured as a master and the other as a slave. When they are plugged in, the LEDs indicate they are receiving power, and yet they will not connect. Why not?"*

There are several reasons why this may occur:

- The Transceivers are running at full power and are too close to each other. If the Transceivers are within 5-10 feet of each other and will not link try either reducing the RF power to 1 on each or moving one unit to another room. (This problem occurred on the initial generation of product with the 555 serial number prefix. It has been addressed in transceivers with serial numbers 556 and higher.)
- The Transceivers are not in each other's Call Books.
- The number of the slave is in the master's Call Book, but the master's menu is not set to call that number.
- There are several phone numbers in the Call Book, the master is set to Call All, and is connecting with another transceiver in the list first.
- The master is set to Call All and the phone number of the Transceiver with which you are trying to communicate is preceded by a setting of 000-0000.

*"I am able to link to a remote unit within line of sight when the Transceiver I have is outside. However, as soon as I walk inside with it I lose the link, even if I place the Transceiver by the window which faces the remote unit."*

Many modern buildings use energy efficient glass which wreaks havoc on RF signals. This glass contains a metal film which is very effective in blocking all radio waves. If your situation is as described above the preferable solution is to install an antenna outdoors.

*"I have several transceivers set up to communicate with each other in a point-to-multipoint mode, yet they are not establishing contact."*

In a Multipoint system there are two critical parameters which must be set correctly to establish a communications link:

1. The slave's Call Book must contain the serial number or Network ID of the master and/or repeaters to which it will be communicating.
-

2. All radios must be set to run at the same RF data rate. Unlike point-to-point systems, slaves in a Multipoint system do not change their RF data rate to match the master's rate.

*"In bench testing several units in a Multipoint system, it appears that they are not communicating through the Multipoint repeater. When all units are powered the slaves' Carrier Detect lights are green, indicating a connection, yet when I unplug the repeater those slaves set up to communicate through that repeater remain connected."*

In a Multipoint system a slave will attempt to communicate with any master or repeater (which looks like a master in a Multipoint system) that is in its Call Book. Therefore, it may be that the slaves are communicating with the repeater when it is powered, and when it is unplugged they are establishing a link with the master. To test whether or not this is what is occurring go into the Call Book of the slaves which are set up to communicate through the repeater and remove the master's serial number. When all units are powered the slaves' Carrier Detect lights should be green, when the repeater is unplugged the slaves should lose contact and Carrier Detect should turn red.

*"My transceivers have established a solid connection as indicated by the LEDs, yet the application I am running is not transmitting and/or receiving data correctly."*

The quickest acid test in a situation like this is to try to get the application up and running using an RS232 null modem cable before deploying FreeWave in the field. FreeWave essentially functions as a null modem cable. If the application will not work with a hard wire connection then it will not work with FreeWave, and the problem lies within the application or other hardware (such as the computer serial ports).

*"I have 2 DGR-115 transceivers set up between two computers and have been unsuccessful in my attempts to establish a link using LapLink."*

At various times difficulty using FreeWave with LapLink has been documented by FreeWave Technologies. The cause, while not confirmed, is believed to be due to LapLink changing baud rates, which FreeWave does not support. If you encounter this problem it is recommended that you test the link with a terminal program such as Windows 3.1 Terminal, Hyperterminal, or Procomm. If either of these applications is used and characters typed on one computer appear on the screen of the other computer in the link, then the transceivers are functioning properly.

For up to date troubleshooting information check the FAQ page at [www.freewave.com](http://www.freewave.com).



**Notes:**

**Notes:**

## Antenna Installation Drawing

