NBT

SR900 Reference Manual

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1 Introduction

Congratulations on choosing the SR900 wireless modem module! Your new SR900 modem is a state-of-the-art, 900 MHz frequency-hopping spread-spectrum communications transceiver module. When the SR900 module is incorporated into the design of new or existing equipment, terminal devices (DTEs) up to 25 km (or more)[1] apart will be capable of establishing high-speed[2] communications wirelessly.

SR900 modules provide a practical and reliable alternative to using traditional analog phone-line modems or “permanent wire” serial cable (RS-232) connections for data communications between terminal equipment. Moreover, wireless data communications using the SR900 module means you will benefit from:

- greater flexibility and freedom to relocate terminal equipment,
- eliminated requirement for access to wire-based transfer media such as telephone lines,
- the ability to communicate through walls, floors, and many other obstacles.

While the SR900 module is compact in its design, it delivers power and convenience and offers quality and dependability. The SR900 module’s versatility makes it the ideal solution for applications ranging from office-productivity to industrial data control and acquisition.

While a pair of SR900 modules can link two terminal devices (“point-to-point” operation), multiple SR900 modules can be used together to create a network of various topologies, including “point-to-multipoint” and “repeater” operation. Multiple independent networks can operate concurrently, so it is possible for unrelated communications operations to take place in the same or a nearby area without sacrificing privacy, functionality, or reliability.

1.1 Features

Key features of the SR900 module include:

- transmission within a public, license-exempt band of the radio spectrum[3] – this means that it can be used without access fees (such as those incurred by cellular airtime);
- a serial I/O data port (RS232) with handshaking and hardware flow control, allowing the SR900 module to interface directly to any microprocessor with an asynchronous serial interface.
- 62 sets of user-selectable pseudo-random hopping patterns, intelligently designed to offer the possibility of separately operating multiple networks while providing security, reliability and high tolerance to interference;
- encryption key with 65536 user-selectable values to maximize security and privacy of communications;
- built-in CRC-16 error detection and auto re-transmit to provide 100% accuracy and reliability of data;
- ease of installation and use – Windows based configuration software, and the SR900 module supports a subset of standard AT style commands, very similar to those used by traditional telephone line modems.

[1] Ideal conditions with clear line-of-sight communications, using high-gain antennas.

[2] Up to 115,200 bits per second (bps).

[3] 902-928 MHz, which is license-free within North America; may need to be factory-configured differently for some countries.

While the typical application for the SR900 is to provide a mid- to long-range wireless communications link between DTEs, it can be adapted to almost any situation where an asynchronous serial interface is used and data intercommunication is required.

1.2 Additional Requirements

Since the SR900 module is a unique product in a class of its own, it will communicate only with another SR900 module which has been compatibly configured. Thus, at least two SR900 modules will be required to establish a wireless communications link.

- An external antenna is required. (customer supplied).

1.3 Hardware

Dimensions: 3 x 4.8 x 2.2 in.

Ant. Connector: MCX

1.3.1 Power

2 point pluggable terminal strip
12 to 24 VDC 400 ma max

1.3.2 Serial Connection

DB9-Female DCE

Pin	1	Data Carrier Detect	(to DTE)
Pin	2	Receive Data	(to DTE)
	3	Transmit Data	(from DTE)
	4	DTR	(from DTE)
	5	Signal Common	
	6	DSR	(to DTE)
	7	Request to Send	(from DTE)
	8	Clear to Send	(to DTE)
	9	NU	

.(also see section 1.4.1.1 for cabling instructions)

1.3.3 Indicators

LEDs (left to right)

(Red)	R	Receive Data	
(Red)	T	Transmit Data	
(Grn)	2	RSSI-2	
(Grn)	1	RSSI-1	RSSI LEDs indicate relative signal strength
(Grn)	0	RSSI-0	(all three on = max strength)
(Grn)	R	(NU)	

RX Indicator - Active output indicates the modem is receiving data packets with correct CRC. When the unit is configured as a Slave, this LED will typically be on solid under good operating conditions.

TX Indicator - Active output indicates the modem is transmitting.

Receive Signal Strength Indicator (RSSI) - As the signal strength increases, the number of active RSSI lines increases, starting with RSSI0. The LED's perform a "scanning" function, blinking on and off in sequence when a Slave or Repeater modem is searching for synchronization.

Table 3 - RSSI mode operation

Signal			

Strength (dBm)	RSSI1	RSSI2	RSSI3
-108	50% duty cycle	off	off
-101	on solid	off	off
-93	on solid	50% duty cycle	off
-86	on solid	on solid	off
-79	on solid	on solid	50% duty cycle
-71	on solid	on solid	on solid

1.4 Software

1.4.1 SR900 Configurator

The SR900 configurator runs in a Windows environment. It provides the ability to set all of the parameters and operating modes for a radio. It allows the creation and editing of Master, Slave or Repeater station configuration files.

There are several system wide parameters which must be the same for each radio that in a given system. These parameters should be set up for the master station file. Subsequent stations within a system can then be uniformly created by loading the master file parameters and modifying the other site specific parameters.

1.4.1.1 RS232 Connection to Radio

The SR900 is DB-9 connector is compatable with direct (straight through) cabling to a PC serial port. Connection of the radio to controllers with DCE ports requires the use of a null modem cable.

1.4.2 Quick System Designer

The Quick System Designer software runs in a Windows environment. It allows a whole network of sites to be laid out in a tree like structure for ease and to insure that the necessary parameters are set in all sites.

The intended use of the SR900 Configurator and the Quick System Designer is to create a Master station file with the SR900 configurator, and then use the Quick System Designer to add all other sites in the system. In the case of a simple two site system, both sites can just as easily be configured right in the SR900 Configurator.

The Quick System designer will clone the master parameters and set up the unit address and slave/repeater and hop group settings to each additional station created. A configuration file for each site is stored in the “system” sub-directory for subsequent downloading to each radio.

1.5 File and directory use/organization

Both the Configurator and the Quick System Designer use the following storage scheme.

A ‘base’ directory is assigned after these applications are installed. (It normally is the sub-directory that the application is installed into.

Under this 'base' sub-directory, a sub-directory is established for each new system that is created. (The system name is the new sub-directory name.) The display field of the system name is updated when a file is loaded or saved.

Within the system sub-directory, a file is created for each unit (SR900) which is saved. The name of the file being saved is the name of the unit.

This provides an easy to use and organized method of retaining all unit information.

2 Installation

2.1 Estimating the Gain Margin

Successful communication between SR900 modules is dependent on three main factors:

- System Gain
- Path Loss
- Interference

System gain is a calculation in dB describing the performance to be expected between a transmitter-receiver pair. The number can be calculated based on knowledge of the equipment being deployed. The following four factors make up a system gain calculation:

1. Transmitter power (user selectable 0, 10, 20 or 30 dBm)
2. Transmitter gain (transmitting antenna gain minus cabling loss between the transmitting antenna and the SR900 module)
3. Receiver gain (Receiving antenna gain minus cabling loss between the receiving antenna and the module)
4. Receiver sensitivity (Specified as -105 dBm on the SR900 module)

In the following illustration, the transmitting antenna has a gain of 6 dB, and the receiving antenna has a gain of 3 dB. The cable loss between the module and the antenna is 2 dB on both the transmitting and receiving side.

The power level has been set to 30 dBm (1W) on the transmitter, and the receiver sensitivity for the SR900 is -105 dBm.

System gain would be calculated to be:

30 - 2 + 6 + 3 - 2 + 105 = 140 dB.

When deploying your system, care must be taken to ensure the path loss (reduction of signal strength from transmitter to receiver in dB) between equipment does not exceed the system gain (140 dB in the above example). It is recommended to design for a gain margin of at least 10 dB to ensure reliable communication. Gain margin is the difference between system gain and path loss. Referring to the same example, suppose the path loss is 100 dB, the gain margin would be 40 dB, which is more than adequate for reliable communication.

Path loss is a very complicated calculation which mainly depends on the terrain profile, and the height of the antennas off the ground.

The following table provides path loss numbers for varying antenna heights and antenna separation: These numbers are real averages taken from rural environments. They do not apply to urban, non-line-of-sight environments.

Distance (km)	Base Height (m)	Mobile Height (m)	Path Loss (dB)
5	15	2.5	116.5
5	30	2.5	110.9
8	15	2.5	124.1
8	15	5	117.7
8	15	10	105
16	15	2.5	135.3
16	15	5	128.9
16	15	10	116.2
16	30	10	109.6
16	30	5	122.4
16	30	2.5	128.8

Once the equipment is deployed, you can verify the signal strength by entering into Command Mode and reading Register S123. This register provides the average signal strength in dBm. The minimum strength for communication is roughly -105 dBm. For consistent reliable communication, you should try to deploy the equipment such that signal strength exceeds -95 dBm.

2.2 Antennas and Cabling

This section describes the recommended procedure for installing cabling and antennas for use with the SR900 module.

2.2.1 Internal Cabling

The most common method for installing the module is to run a cable from the module's MCX connector to a Male N Type bulkhead connector on the chassis of the equipment. Reverse TNC is shown in Figure 11 for use with stubby antenna. This cable can be purchased from NBT, Inc.

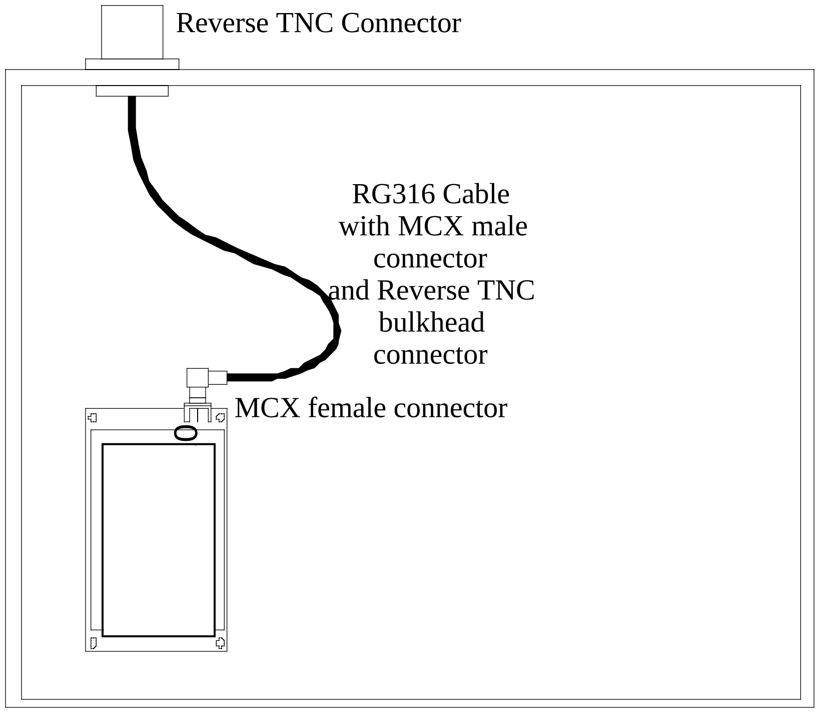


Figure 11. Example Suggested Internal Cabling

Cable losses are negligible for the short piece used within the chassis. Additional losses up to 0.5 dB may be present in the MCX and Reverse TNC connections.

2.2.2 Installing External Cables, Antennas and Lightning Arrestors

The installation, removal or maintenance of all antenna components must be carried out by qualified and experienced professionals.

Never work on an antenna system when there is lightning in the area.

Direct human contact with the antenna is potentially unhealthy when the SR900 is generating RF energy. Always ensure that the SR900 equipment is powered down during installation.

Surge Arrestors

The most effective protection against lightning is to install two lightning (surge) arrestors. One at the antenna, and the other at the interface with the equipment. The surge arrestor grounding system should be fully interconnected with the transmission tower and power grounding systems to form a single, fully integrated ground circuit. Typically, both ports on surge arrestors are N-female.

Cabling

The following coax cables are recommended:

Cable	**Loss (dB/100ft)**

LMR 195	10.7
LMR 400	3.9
LMR 600	2.5

Factors to take into consideration when choosing a cable are:

- price;
- bend radius limitations (the lower performance cables generally can bend more sharply)
- performance requirements; and,
- distance between the equipment and the antenna.

When installing the cable, always begin fastening at the top near the antenna connector/surge arrestor. The cable must be supported at the top with a hose clamp or wrap lock, and at 5 ft intervals down the length of the tower. Over-tightening the fasteners will dent the cable and reduce performance. If properly grounded surge arrestors are not installed at both the top and the bottom of the cable, then the cable should be grounded to the tower at these locations using a cable grounding kit. If the tower is non-conductive, then a separate conductor, physically separate from the cable, should be run down the tower.

<u>Antenna</u>

Before choosing an antenna, you should have some knowledge of the path loss and the topology of the equipment. If the equipment is in a fixed location and is to communicate with only one other unit also in a fixed location, then a Yagi antenna is suitable. Choose a Yagi with enough gain to ensure adequate gain margin. When deploying the Yagi, point the antenna towards the intended target, ensuring the antenna elements are perpendicular to the ground.

If the equipment must communicate with multiple or mobile transceivers, then select an Omni-directional antenna with appropriate gain.

The Effective Radiated Power (ERP) emitted from the antenna cannot exceed +36 dBm ERP.

With the SR900 set to full power, ERP is calculated as follows:

ERP = 30 - (Cabling and Connector Losses) + (Antenna Gain) < 36

Use the guidelines in the previous section for calculating cable and connector losses. If cabling and connector losses are 2 dB, then the maximum allowable gain of the antenna will be 8 dB.

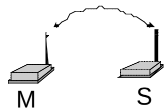
<u>External Filter</u>

Although the SR900 is capable of filtering out RF noise in most environments, there are circumstances that require external filtering. Paging towers, and cellular base stations in close proximity to the SR900 antenna can desensitize the receiver. NBT's external cavity filter eliminates this problem. The filter has two N-female ports and should be connected in line at the interface to the RF equipment.

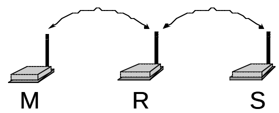
<u>Weatherproofing</u>

Type N and RTNC connectors are not weatherproof. All connectors should be taped with rubber splicing tape (weatherproofing tape), and then coated with a sealant.

3 System Configurations



Network 1



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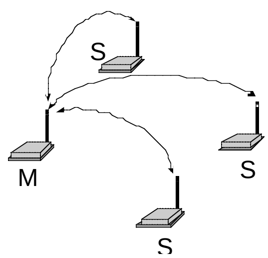
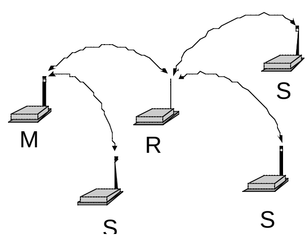
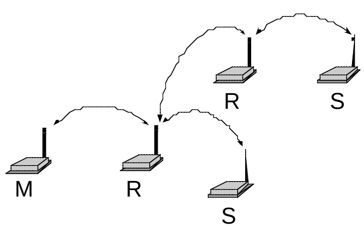


Network 3



Network 4



Network 5

Figure 2 - Sample Network Topologies.

Prior to establishing a wireless link, each SR900 module participating in the link must be correctly configured for compatibility and for the desired mode of operation.

Network topologies consisting of a single *Master* and virtually any combination of *Slaves* and *Repeaters* may be deployed. The functionality of any particular SR900 can be configured as follows:

- **Master Point-to-Point**: The module is configured to communicate with a single *Slave*, either directly, or through one or more *Repeaters*.
- **Master Point-to-Multipoint**: The module is configured to communicate with one or more *Slaves* and/or *Repeaters*.
- **Slave**: The module is configured to communicate with one particular *Repeater* or *Master.*
- **Repeater**: The module is configured to pass information from either a *Master* or another *Repeater* onto subsequent *Repeaters* and/or *Slaves* and vice versa. The *Repeater* also acts as a *Slave* in the sense that, like a *Slave*, it passes information to/from its serial port.

All units within a *network* must be assigned a common Network Address; thus enabling multiple networks to co-exist in the same vicinity without unwanted crosstalk between modules. Examples of different network topologies are shown in Figure 2. Network 1 shows Point-to-Point communication between a Master and Slave. Network 2 makes use of a Repeater to communicate with the Slave. Network 3 illustrates a simple Point-to-Multipoint network with no Repeaters. Networks 4 and 5 gives examples of Point-to-Multipoint networks consisting of both Repeaters and Slaves. There is effectively no restriction to the number of Repeaters and Slaves that can be added to a network. As seen in Network 4, a Master can communicate directly with both Slaves and Repeaters. The SR900 has been designed to allow for additional Repeaters and Slaves to be added to an existing network without having to reconfigure any units already in the network. This saves a tremendous amount of time when deploying additional units in the field.

Virtually any Combination of Slaves and Repeaters May be Used.

3.1 Checking the Link

To check if the units are communicating, observe the LED indicators on the development board. If the link is good, up to three RSSI outputs on the Slave modem should be active; and if the link is absent (due to a fault at one end or another, such as misconfiguration), the outputs will be inactive.

Characters typed at the Master terminal should appear at the Slave's terminal, and vice versa. Also, verify that the RX LED blinks as packets of data are received at the Master modem. As data is sent from Slave to Master, the RX indicator should blink on as correct packets of data are received.

It is recommended that if SR900 modules will be deployed in a field where large distances separate the units, the modems should be configured and tested in close proximity (*e.g.*, in the same room) first to ensure a good link can be established and settings are correct. This will facilitate troubleshooting, should problems arise.

3.2 Discussion of Operating Modes

The SR900 modem can be easily configured to meet a wide range of needs and applications. The module is designed such that all communication is through one serial port (Pins 21 to 28 on the module). This port has two functions:

1. It provides the asynchronous interface with the host equipment for data that is sent/received on the RF channel. When operating in this fashion, the module is said to be in **data mode**.
2. It is also used for configuring and programming the module. When operating in this fashion, the module is said to be in **command mode**.

In addition to **data mode** and **command mode**, there is a third mode of operation called **diagnostics mode**. The module will always be in one of these three modes.

The Operating Mode partly defines the "personality" of the SR900 module. Allowable selections are as follows:.

- Master: (Master Point to Multipoint)
- Slave
- Repeater

(Note: Master Point to Point is discussed in section 3.2.2)

1)Master - Point to Multipoint. In any given network, there is always only one Master. All other units should be configured as either Slaves or Repeaters. When defined as a Point-to-Multipoint Master, the modem broadcasts data to all Slaves and Repeaters in the network, and is also the ultimate destination for data transmitted by all Slaves and Repeaters. In addition, the Master defines the following network parameters to be utilized by all other modems in the network (See the appropriate sections for a complete description of these parameters):

- Link Handshaking (122)
- Wireless Link Rate (103)
- Hop Interval (109)
- Maximum Packet Size (See Advanced Setup) (112)
- Minimum Packet Size (See Advanced Setup) (111)

2)Master - Point to Point. This mode of operation is identical to Master Point-to-Multipoint, with the exception that the Master only broadcasts to one particular Slave or Repeater. The modem with which communication occurs is defined by the Unit Address (S105). For example, if a Slave has been assigned Unit Address 100, and the Master wishes to communicate with that Slave, the Master must also be assigned a Unit Address of 100. If there are Repeaters in the network, they will pass the packet through to the Slave, and vice versa. Because Repeaters also have Slave functionality (i.e., a Repeater can be connected to a terminal), the Master can choose to communicate solely with a Repeater. This would be accomplished by assigning the same Unit Address to both the Master and the Repeater.

3)Slave. Up to 65534 Slaves may exist in a network, all of which communicate with the common Master (either directly or via Repeater(s)). Slaves cannot directly communicate with other Slaves, nor can they acknowledge packets of data sent by the Master. Clearly this would cause conflicts when there are multiple Slaves. The Master does, however, send acknowledgements to all messages it receives from Slaves. The Master initiates communications by sending a broadcast message to all Slaves. All Slaves are free to respond in a "Slotted ALOHA" fashion, meaning that each Slave can choose one of several windows in which to transmit. If there happens to be two Slaves attempting to talk at the same time, the Master may not receive the data, and the Slaves therefore would not get an acknowledgement. At this point, the Slaves would attempt to get the information through at random time intervals, thus attempting to avoid any more conflicts. Special parameters which control the Slave's response characteristics can be modified with S Registers S115 and S213.

4) Repeater. A more precise title would be Repeater/Slave, because a Repeater also has much of the same functionality as a Slave. A terminal can be connected at the Repeater location and communicate with the Master terminal. There is no restriction to the number of Repeaters in a network, allowing for communication over virtually limitless distances. The presence of one Repeater in a network automatically degrades system throughput by half. Additional Repeaters, regardless of the quantity, do not diminish system throughput any further. To understand Repeater operation, consider the module as belonging to two hopping patterns at the same time: The Primary Hopping Pattern and the Secondary Hopping Pattern. In Figure 3, the Master belongs to Hopping Pattern 1, and communicates with the Repeater on this hopping pattern. The Slave belongs to Hopping Pattern 2, and communicates with the Repeater on this hopping pattern. The whole system belongs to Network 50 (i.e., all units must be assigned the same Network Address (S104), which in this case was selected to be 50. Note that Slaves and Master only communicate on their respective Primary Hopping Pattern. Repeaters communicate on the Primary Hopping Pattern when communicating with the Master (or with another Repeater between itself and the Master). Repeaters communicate on their Secondary Hopping Pattern when communicating with Slaves (or with another Repeater between itself and the Slaves). Figure 4 shows another example.

If the Repeater is not also being used as a Slave (there is no DTE connected to the serial port), it is recommended that the Repeater's baud rate be set to 115K, and that handshaking be disabled (&K0). This will help ensure a smooth flow of data through the network.

If there is no DTE connected to the Repeater, turn off handshaking (&K0) and set the baud rate to 115K.

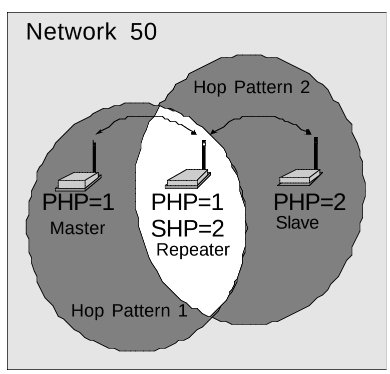


Figure 3 - Repeater Operation

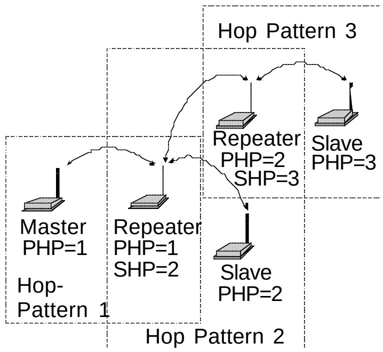


Figure 4 - A Network Utilizing Three Hopping Patterns

4 System Parameters/Setup

4.1 Configurator operation-parameters

The following is based on the SR900 Configurator main display page.

The initial display shows the common parameters to be setup for a SR900 radio. The main function is to establish the desired configuration for your system application, and then to 1) create a file of those settings, and 2) download those settings to the radio itself.

The Advanced setup parameters are accessed via a menu selection and allow setting of parameters which, in most cases, can be left in their default condition.

In addition to the primary functions described above, there are terminal screen options to allow a more detailed interaction with a given radio or to act as a terminal to interact with an online system.

Uploading, downloading configurations or loading/saving information to files are all easily accomplished through menu selections.

4.1.1 System Name selection

This is established when a configuration is saved. It is the name of the sub-directory where the configuration file(s) is (are) stored. (filled automatically when the save is done)

4.1.2 Name and field

This is established when a configuration is saved. It is the name of the file where the configuration file is stored. (filled automatically when the save is done) This field will be read or written to/from the unit with other configuration infomation. (max of 16 characters) (do not use characters which are not legal file name characters, i.e., :, . or \)

4.1.3 Serial number field

The serial number is a read only field from the unit. Otherwise, the serial number field is simply a manual entry field to record an ID number which is then saved in the configuration file when stored.

4.1.4 Port Selection

Any Com port (1-8) on your PC can be selected for connection to your radio units. The baud rate and data format are also selectable. Default selections are Com1, 9600, 8N1.

4.2 Operating Mode Setup

The Operating Mode partly defines the "personality" of the SR900 module. Allowable Option button selections are as follows:

- Master: (Master Point to Multipoint)
- Slave
- Repeater
- Master Point to Point

Note: The Master unit establishes several of the parameters for all units in a system. It should be fully configured first. It then can be used as a template to create other sites in the system with less effort and possibility of error.

4.2.1 Transparent vs. Handshaking

It is easier and more common to use the SR900 radios in a transparent (or non-handshaking) mode. However, handshaking is available for those devices which require it. RTS, CTS and CD lines can be used for 'framing' data. (See section 3.5.1 for more information / Advanced setup display)

4.2.2 Master Point to Point

Point-to-point operation is a mode where the master can establish exclusive connection with one remote unit, directly or via a repeater. This mode can be useful to run RTU programming software or other applications that normally would not run in a multi-point environment. The Master can be set to Point to point mode by setting the Unit Address on the Master to the same unit address as the desired Slave (or Repeater) unit. (usually a temporary setting) This mode may be used as a temporary situation for system programming/setup of RTU's or may be used on a permanent basis when there is a single master and a single remote.

NOTE: In the Configurator, use the menu selection: 'Radio', and 'Set Pt-Pt to remote'. (or 'Clear Pt-Pt') to initiate this mode as a temporary online setting.

4.3 System Wide Parameters- (set in Master only)

104 - Network Address
106 - Primary Hopping Pattern
206 - Secondary Hopping Pattern (Set only for Repeaters)
107 - Encryption Key
Major Hop Group
122Flow Control
109 - Hop Interval
103 - Forward Error Correction

104 - Network Address

The Network Address defines the membership to which individual units can be a part of. By establishing a network under a common Network Address, the network can be isolated from any other concurrently operating network. As well, the Network Address provides a measure of privacy and security. Only those units which are members of the network will participate in the communications interchange. Valid values for the Network Address range from 0 to 65535, inclusive.

To enhance privacy and reliability of communications where multiple networks may operate concurrently in close proximity, it is suggested that an atypical value be chosen – perhaps something meaningful yet not easily selected by chance or coincidence.

Default is 1.

Note: In point-to-point operation, the Unit Address on the Master is set to the same unit address as the Slave (or Repeater) unit. (must be the same). (usually a temporary setting)

Major Hop Group

Selectable (Group A or Group B- This is a selector to choose between even and odd hopping patterns in the range of 0-63. If this selection and the Primary Hop pattern selection disagree in terms of odd and even, a prompt message is displayed.

106 - Primary Hopping Pattern

206 - Secondary Hopping Pattern (Set only for Repeaters)

Since the SR900 is a frequency-hopping modem, the carrier frequency changes periodically according to one of 62 pseudo-random patterns, defined by the Primary and Secondary Hopping Patterns. Valid entries for each are 0 through 61.

The concept of Primary and Secondary Hopping Patterns was introduced in the discussion of Operating Mode. Note: The Quick System Designer will assist in defining complex systems and assigning hop patterns.

Using the designations M[a,] Rx[a,b] and Sx[a] where:

- *M* indicates Master;
- *R* indicates Repeater;
- *S* indicates Slave;
- *x* is the Unit Address;
- *a* is the primary hopping pattern; and,
- *b* is the secondary hopping pattern;

107 - Encryption Key

The Encryption Key provides a measure of security and privacy of communications by rendering the transmitted data useless without the correct key on the receiver. Valid Encryption Keys range from 0 to 65535.

Keep in mind that all units within the network must use the same key for communications to succeed.

109 - Hopping Interval

This option determines the frequency at which the modems change channel. Note that the Master controls this parameter for the entire network. This setting is ignored in units configured as Slaves or Repeaters.

The allowable settings are:

1	8 msec
2	12 msec
3	16 msec
4	20 msec
5	30 msec
6	45 msec
7	80 msec
*8	120 msec

See Appendix E for optimal Hopping Interval settings in relation to packet size and link rate.

103 - Wireless Link FEC

The Wireless Link Rate is the speed and optimization method for which modems will communicate over the RF link. It is only necessary to set this parameter on the Master unit. Units configured as Repeaters and Slaves will ignore this setting, and adjust automatically to the rate of the Master.

Depending on the application requirements, each mode will provide different throughput and performance. Appendix E. Performance Tables give some indication of the performance to be expected in each mode.

4.4 Per site parameters

105 - Unit Address
108 - Output Power Level
110 - Data Format

105 - Unit Address

For normal Master Point to multipoint operation, the Unit address field for the master is set to 0. (Does NOT match any slave or repeater!) Each other unit in a multipoint system must have a unique Unit Address ranging from 1 to 65535. (Do not use a Unit Address more than once within the same Network) This is required because the Master must be able to acknowledge each unit individually, based on the Unit Address.

Remember to assign a unique Unit Address (1 to 65535) to each unit in the system

108 - Output Power Level

The Output Power Level determines at what power the SR900 transmits. The super-sensitive SR900 can operate with very low power levels, so it is recommended that the lowest power necessary is used; using excessive power contributes to unnecessary “RF pollution”.

The allowable settings are:

0 1 mW
1 10 mW
***2 100 mW**
3 1000 mW

Ideally, you should test the communications performance between units starting from a low power level and working upward until the RSSI is sufficiently high and a reliable link is established. Although the conditions will vary widely between applications, typical uses for each setting are described below:

Power	Use
1 mW	For in-building use, typically provides a link up to 300 feet on the same floor or up/down a level. Outdoors, distances of 10 km can be achieved if high-gain (directional) antennas are placed high above ground level and are in direct line-of-sight.
10 mW	200-500 ft indoors, 8-15 km outdoors.
100 mW	400-800 ft indoors, 15-25 km outdoors.
1000 mW (1 W)	Typically provides communications up to a distance of 1000 feet or more in-building on the same floor or up/down a few levels, depending on building construction (wood, concrete, steel, etc.). In ideal line-of-sight conditions, up to 30 km or more can be achieved. Note that only an antenna

	with a gain of no more 6 dBi may be used. Any higher is a violation of FCC rules. See IMPORTANT warning below.

IMPORTANT:

FCC Regulations allow up to 36 dBi effective radiated power (ERP). Therefore, the sum of the transmitted power (in dBm), the cabling loss and the antenna gain cannot exceed 36 dBi.

1 mW = 0 dBm

10 mW = 10 dBm

100 mW = 20 dBm

1000 mW = 30 dBm

For example, when transmitting 1 Watt (30 dBm), with cabling losses of 2 dB, the antenna gain cannot exceed 36 - 30 + 2 = 8 dBi. If an antenna with a gain higher than 8 dBi were to be used, the power setting must be adjusted appropriately. Violation of FCC regulations can result in severe fines.

110 - Data Format

This register determines the format of the data on the serial port. Selection can be made via menu selection: Port. Allowable selections are:

***1 8 bits, No Parity, 1 Stop**
2 8 bits, No Parity, 2 Stop
3 8 bits, Even Parity, 1 Stop
4 8 bits, Odd Parity, 1 Stop
5 7 bits, No Parity, 1 Stop
6 7 bits, No Parity, 2 Stop
7 7 bits, Even Parity, 1 Stop
8 7 bits, Odd Parity, 1 Stop
9 7 bits, Even Parity, 2 Stop
10 7 bits, Odd Parity, 2 Stop
11 9 bits, No Parity, 1 Stop

Note: This affects online operation.

118 - Roaming

This mode is activated on slaves and repeaters by setting register S118=1. In this mode, a slave/repeater looks for synchronization with a Master having the same network address and encryption key, but without regard for the hopping pattern S106. Once the slave/repeater finds such a master, it tunes to that master's hopping pattern. If synchronization is lost, the slave/repeater will again begin searching for a new master. Using this algorithm, a mobile unit can 'roam' and automatically synchronize with a new master once it loses communication with the previous one. It is essential that all Masters with which a roaming slave/repeater will be communicating with use a hopping pattern from within the same group. See Appendix F. The allowable settings for this register are:

*0 Disabled
1 Enabled

4.5 Advanced Setup Items

Note: Accessable in configurator via menu: 'Advanced', 'Setup'.

111 - Packet Minimum Size
112 - Packet Maximum Size
116 - Packet Character Timeout
Auto Power up to data (online) mode

Auto Power up to data (online) mode

This parameter is normally selected. It will cause the unit to immediately go into online data mode on power up. This is required for unmanned sites which may occasionally experience power loss.

The following settings determine the conditions under which the modem will transmit accumulated data over the air.

111 - Minimum Size

Valid entries for this register are 1 to 255 bytes, which defines the minimum number of bytes to receive from the DTE before encapsulating them in a packet and transmitting over the air.

Note that the minimum packet size for all modems in the network is determined by the Master only. This setting is ignored in all Slave and Repeater modems. The default is 1 byte.

112 - Maximum Size

This setting has a range of 2 to 255, and defines the maximum number of bytes from the DTE which should be encapsulated in a packet. This value should be greater than the minimum packet size, but not smaller than is necessary for reliable communications. If the wireless link is consistently good and solid, a maximum size of 255 will yield the best throughput (depending on the higher level protocols of the connected equipment). However, if the link is poor (*e.g.*, experiencing excessive interference) and data is frequently retransmitted, the maximum packet size should be reduced. This decreases the probability of errors within packets, and reduces the amount of traffic in the event that retransmissions are required.

Note that the maximum packet size for all modems in the network is determined by the Master only. This setting is ignored in all Slave and Repeater modems. The default is 255 bytes.

116 - Packet Character Timeout

This register has valid entries of 0 to 254 milliseconds. The Packet Character Timeout timer looks for gaps in the data being received from the DTE. The timer is only activated after the Minimum Packet Size has been accumulated in the modem. After which, if the timer detects a gap in the data exceeding the Packet Character Timeout value, the modem will transmit the data.

The SR900 will accumulate data in its buffers from the DTE until one of the following requirements is met (whichever occurs first):

- The Maximum Packet Size (in bytes) has been accumulated;
- The Minimum Packet Size has been accumulated AND the Packet Character Timeout interval has elapsed.

The default for the Packet Character Timeout is 9 ms. If set to 0 ms, the unit will buffer exactly the minimum packet size before transmitting.

113 - Packet Retransmissions

This register applies to both Master and Repeater operation. It does not apply to Slave operation. The Master will retransmit each data packet exactly the number of times defined by the Packet Retransmissions parameter. The Master retransmits once at the beginning of each hopping interval until the limit is reached. This parameter is not necessary in Slave units since all Slaves receive acknowledgement from the Master. As discussed previously, the Repeater effectively behaves as both a Master and a Slave. When the Repeater is tuned to its Secondary Hopping Pattern (acting as a Master), the Packet Retransmissions Parameter comes into play. The Repeater will re-send packets of data on to Slaves or other Repeaters exactly the number of times defined by the Packet Retransmissions parameter.

Recipients of the packet will discard any duplicates The valid settings for this parameter are 0 to 255 retransmissions. The default is 2.

213 - Packet Retry Limit

Packet Retry Limit is analogous to Packet Retransmissions, but specifically applies to Slaves and Repeaters. This parameter is not used by the Master. Because the Slave has the advantage of receiving acknowledgements from the Master, it is not necessary to blindly retransmit each packet. If the Slave does not get an acknowledgement on the next hop, it will retransmit its packet. This will continue until the Packet Retry Limit is reached or an acknowledgement is received. If the limit is reached, the modem will give up and discard the data. Valid settings are 0 to 255 retries. The default value is 2.

The Repeater makes use of this parameter when it is tuned to its Primary Hopping Pattern and is acting like a Slave.

115 - Packet Repeat Interval

A parameter that is specific to Slaves and Repeaters is the Packet Repeat Interval.

The allowable settings are 1 through 255. The default is 1.

This parameter defines a range of random numbers that the Slave will use as the next slot in which it will attempt to send the packet. For example, if this register is set to 7, the Slave will choose a number between one and seven as the next slot in which to transmit. Suppose the random number generator picks 5, then the Slave will transmit in the fifth time slot. A Slave will transmit a maximum of once per hopping interval, however, depending on the duration of the hopping interval and the maximum packet size, more than one slot per hop is potentially available. The Slave will transmit more frequently when a Repeat Interval with a smaller range is selected. Choose 1 to have the Slave transmit in the first available slot. Choose higher intervals for less frequent transmission, or to avoid collisions between many Slaves in the system.

4.5.1 Handshaking Modes/ Handshaking lines control

DTR Control Modes
DCD Control Modes
RTS Control Modes

DTR Control Modes

Action on DTR toggle: Ignored
Disconnect/Command Mode
Disconnect/Reset

RTS Control Modes (Output data framing)

Action of RTS: Ignored
Handshake
Data Framing

DCD Control Modes (Input data framing)

Action of DCD: Always ON
On when in Online Mode
Input data framing

122 - Link Handshaking

Link Handshaking is controlled only by the Master unit. If the Master runs out of free buffers, it will command all Slaves and Repeaters to hold their data. Once the Master is ready to receive data it will allow the Slaves and Repeaters to transmit. Possible values are '1' - Enabled and '0' - Disabled. The default is 1. This register is ignored by all Slave and Repeater units.

117 - Modbus Mode

Modbus Mode allows for the SR900 to be fully Modbus compatible. (not required for NBT RTU's) For Modbus operation, the general requirement is to get the packet of data to the receiving serial port with no gaps in the data. The SR900 incorporates a "Modbus Mode" which implements a delay at the receiving modem to ensure that no gaps are introduced. For most applications, the following settings are suitable for Modbus operation:

1. Set Modbus Mode parameter S117 = 1
2. Set the minimum packet size (S111) to 1 byte
3. Set the character timeout S116 (rounded to the nearest ms) to roughly 2.5 byte lengths. For example, at 9600 baud,
   S116 = 1/9600 x 10 x 2.5 x 1000 = 2.6ms
   Rounded up, S116 = 3ms
4. Set parameter S121 = 3 byte lengths. For example, at 19200 baud
   S121 = 1/19200 x 10 x 3 x 1000 = 1.56ms.
   Rounded up, S121 = 2ms
5. Set S120 as follows:
   <u>Slave Side</u>
   S120 = (Hop Interval in ms) x (1 + # of Master retransmissions) x (1 + # of Repeaters over 1)
   eg. Hop Interval S109=4 (20 ms),
   Master Retransmissions S113=1

Number of Repeaters in system = 2; then,
S120 = 20 x (1 + 1) x (1 + 1) = 80 ms
Master Side
S120 = (Hop Interval in ms) x (1 + # of Repeaters over 1)

6. Try to set the hop interval as short as possible while still ensuring adequate throughput. It is recommended to set the Hop Interval and Maximum Packet Size as specified in Appendix E. Performance Tables. For example, for Master to Slave communication with no FEC, If a throughput of 60kbps is required, set the Hop Interval S109=3, and set the Maximum Packet Size S112=110.

The allowable settings for this register are:

***0 Disabled**
1 Enabled

120 - RTS/DCD Framing

121 - DCD Timeout

The SR900 supports two special types of data framing:

- Output (or RTS/CTS) Data Framing; and,
- Input (or DCD) Data Framing

Input Data Framing is enabled by DCD selection. This type of framing makes use of the RTS/DCD Delay parameter as illustrated in Figure 5. RTS/DCD Delay can be set to any value between 0 and 254 ms.

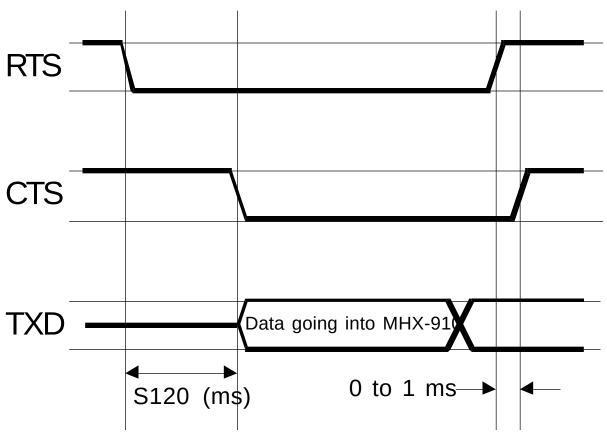
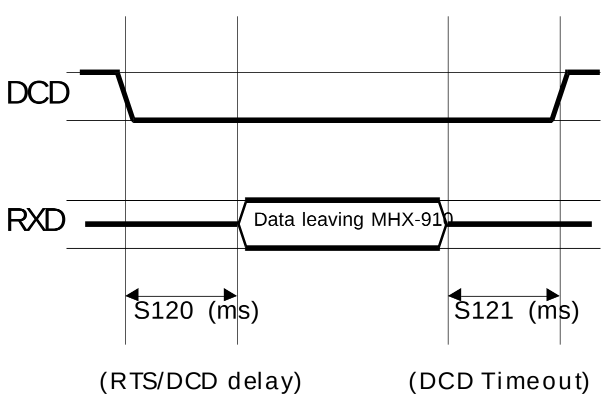


Figure 5 - Output Data Framing (Tx data)

To enable input (DCD) data framing, set the Data Carrier Detect parameter to “Input data framing”. This type of framing uses both S120 and S121 registers as shown in Figure 6. Valid ranges for each parameter are 0 to 254 ms.



4.5.2

Figure 6 - Input Data Framing (Rx Data)

4.5.3 **122 - Remote Control**

This register either disables or enables remote control at a repeater or slave unit. When disabled, a slave/repeater's settings may be remotely read by the master, but may not be remotely modified. When enabled, the slave/repeater allows the network master full remote control access. See Section 4.4.3 for details. The default is 0 - disabled.

4.5.4 Maintenance Functions

123 - RSSI Reading

This register displays the average signal strength in dBm over the previous four hop intervals. Valid RSSI readings apply only to units configured as Slave or Repeater.

4.5.4.1 Monitor Modes (Terminal screens)

This 'terminal' screen allows manual interaction with a radio (Command mode) or with remote site DTE equipment (Online mode). See Appendix for information about Command mode AT commands.

4.5.4.2 Hex mode display of received data

Similar to above, except received data is displayed in Hex format. Useful for deciphering messages from remote DTE equipment.

5 Diagnostics

The SR900 provides several features which are very useful for troubleshooting and analyzing the performance of the radio system.

5.1 Spectrum Analyzer Feature

Go to the spectrum analysis screen via the Advanced menu selection. The spectrum data (a sweep of the entire operating spectrum) from the radio can be read or read multiple times (averaged) to display a signal strength read-out in dBm for each channel. The spectrum data can be viewed as shown below:

```
Noise level, '*'- mean value, '.'- max value
ch 1  -138dBm   *
ch 2  -139dBm   *
ch 3  -139dBm   *
ch 4  -139dBm   *
ch 5  -139dBm   *
ch 6  -139dBm   *
ch 7  -130dBm   *
ch 8  -116dBm   *
ch 9  -135dBm   *
...
ch 127 -135dBm  *
Paging -135dBm  *
```

In addition, the program will display channels in increasing order of signal strength (best to worst). This information can be used to automatically create a custom hop pattern to minimize the use of the worst channels. The best channel display will also show which of the standard hop patterns best avoids the worst channels.

Channel 1 is at frequency 902.4 MHz, with all subsequent channels in 200 kHz increments. This feature also displays average received signal strength for 12 channels above the 902-928 MHz ISM band. This area of the spectrum is used by paging networks.

When deploying a network, the spectrum analyzer feature is useful for determining which parts of the ISM band may be noisy. This knowledge can be used to select an appropriate hopping pattern, or for creating a custom hopping pattern which avoids those frequencies.

In addition, the presence of extremely high paging noise (> -25dBm) may indicate a need to install NBT's external cavity filter in line with the antenna. See Chapter 5 for details.

In addition to viewing

5.2 Statistics (ATP)

GO TO MONITOR Screen. Command Mode.

The ATP <return> command provides a list of several statistics as follows:

```
# of data packets sent = 0
```

```
# of data packets received = 0
# of Slave's retries = 0
# of Slave's packets dropped = 0
# of Slave's sync errors = 0
# of CRC errors = 0
OK
```

The SR900 starts the statistics count at zero each time the unit is powered up, or after the ATP command has been issued. By entering the ATP command, all statistics are cleared back to zero. The maximum limit for each statistic is 65535.

5.3 Remote Control

4.4.3 Remote Control and Diagnostics (S101=5)

This is a very powerful tool which allows user to remotely configure and interrogate all units in a multipoint system from the Master unit. Simply by having knowledge of the unit address of each slave/repeater in the system, users can set the unit address of the master to match that of the slave/repeater of interest, set S101=5, go online, and interrogate/modify virtually all parameters of the remote repeater/slave unit. It should be noted that when the master goes online, all other units belonging to the network will synchronize with the master, but only the unit whose unit address matches the master's will respond to the master's diagnostic commands.

In addition, in diagnostics mode, the master can change its unit address 'on-the-fly,' avoiding the delays of going into command mode, modifying the unit address, going back online and re-synchronizing with the entire network, before interrogating a new slave/repeater. The master's unit address can be changed while still maintaining synchronization with the entire network, allowing for quick and efficient diagnostic sessions with all remote units. Ensure that register S122=1 on any slave/repeater that you wish to remotely modify.

Table 4 provides a diagnostics command summary. The first column is a list of commands that may be issued at the master. The second column is the corresponding remote register. In general, any command issued without any additional parameters is a read command. For example, if you type:

0 <return>

The remote slave/repeater will send back the value if its S101 register. On the Master terminal screen, you would see:

0 (this is the 0 that you typed, echoed back locally)
3 (this indicates that the remote's S101=3)

If you type:

04 <return>

This command would change the remote's operating mode to S101=4 (repeater). The remote unit should return 'OK'. Remember, if the remote's S122=0 (remote control disabled), the remote will respond with 'ERROR'. In Table 4, Column 1, the meanings of the format is as follows:

COMMAND	A command without (x) indicates that you may not add any additional parameters. i.e., you may only read back the value of the remote's register. You may not modify that register. The only exception to this is the WRITE command '**e**'. Type '**e**' to force the write command (&W) at the remote modem.
COMMAND(x)	Indicates this command may be sent with or without a parameter. Issuing this command without a parameter reads the corresponding remote's register. Issuing this command with the

	additional parameter 'x' changes the corresponding remote's register to 'x'. Remember, any changes you wish to retain in the event of a powerdown or reset should be stored to non-volatile memory by issuing the write command 'e'.

Table 4 - Remote Control and Diagnostics

Command	Remote Register	Description
0(x)	S101	Operating Mode
1(x)	S102	Baud Rate
2(x)	S108	Output Power
3(x)	S110	Data Format
4(x)	S115	Repeat Interval
5(x)	S116	Character Timeout
6(x)	S120	RTS/DCD Framing
7(x)	S121	DCD Timeout
8(x)	S117	Modbus Mode
9(x)	S213	Retry Limit
a	test string	Read back 'OK' from remote
a1	test string	Read back 'Microhard Systems, Inc.' from remote
a2	test string	Read back 64 character test string from remote
a3	test string	Read back 255 character test string from remote
b(x)	&E	Framing
c(x)	&C	DCD
d(x)	&K	Handshaking
e	&W	Write
f	S123	RSSI
g(x)	S104	Network Address
h(x)	S106	Hopping Pattern
I(x)	S206	Secondary Hopping Pattern
j(x)	S113	Retransmissions
k1	statistics	Read # of data packets sent
k2	statistics	Read # of data packets received
k3	statistics	Read # of Slave's retries
k4	statistics	Read # of Slave's packets dropped
k5	statistics	Read # of Slave's sync errors
k6	statistics	Read # of CRC errors
k255	statistics	Clear statistics
l(x)	S119	Quick Enter to Command Mode
m(x)	S118	Roaming
n(x)	S114	Packet Size Control
o(x)	S111	Min Packet Size
p(x)	S112	Max Packet Size

As mentioned previously in this section, there are some settings that can be changed to the master's own registers while in diagnostics mode. The most useful is the unit address. By changing the master's unit address to that of another slave in the network while in diagnostics mode, users can quickly interrogate/modify many different slave's settings without the delays associated with switching between command and data modes. The commands which apply to the master's own registers are shown in Table 5.

Table 5 - Master Diagnostics Commands

Command	Master Register	Description
r(x)	S105	Unit Address
s	S101	back to normal operating mode
t(x)	S109	Hopping Interval
u(x)	S104	Network Address
v(x)	S106	Hopping Pattern

6 Appendix

6.1 Technical Specs

Electrical/Physical

Data Interface	Asynchronous Serial Port, TTL Levels
Signals	Sig. Gnd, TX, RX, DCD, DSR, DTR, RTS, CTS
Bandwidth / Data Rate	2,400 - 115,200 bps, uncompressed half-duplex, Approx. 100 kbps sustained in intelligent asymmetrical full-duplex transmission mode
Communications Range[1]	30 kilometres (19 miles)
Power Requirements	12 VDC, 700 milliAmp
Power Consumption	700 mA max, 450 mA typical at 1W transmit; 200 mA receive
Operating Frequency	902 - 928 MHz
System Gain	135 dB
Sensitivity	-105 dBm
Output Power	1mW, 10mW, 100mW, 1W (user-selectable or adaptive)
Spreading Code	Frequency Hopping
Hopping Patterns	64 pseudo-random, user-selectable
Error Detection	CRC-16 with auto re-transmit
Error Correction	User-selectable Forward Error Correction (FEC)
Adjacent Channel	> 60 dB

Rejection	
Weight	200 grams
Operating Environment	Temperature: -40 to +70°C Humidity: 5 to 95%, non-condensing
Storage Temperature	-40 to 90°C

1. Clear line-of-sight, elevated high-gain antennas.

6.2 Terminal Commands

Modem Command Summary

The following provides a command summary for the SR900 module. Factory settings are denoted with a '*'. Note: These are provided for reference only and terminal screen interaction.

AT Commands

A Answer

E Command Echo

E0 No Echo

* E1 Command Echo

I Identification

I0 Product Code

I2 ROM Checksum test

I3 Firmware Version

I4 Firmware Date

I5 Copyright

I6 Firmware Time

O On-line Mode

Q Quiet Mode

* Q0 Enables Result Codes

Q1 Disables Result Codes

V Result Codes Display

V0 Display as Numbers

* V1 Display as Words

W Connection Result

* W0 Reports DTE as CONNECT xxxx

W1 Reports computer (DTE) rate and wireless rate between modems as CARRIER xxxx.

W2 Reports DCE as CONNECT xxxx

Z Reset and load stored configuration

&C DCD (Data Carrier Detect)

&C0 DCD is always on

* &C1 DCD is on when modems are synchronized

&C2 DCD used for output data framing

&D DTR (Data Terminal Ready)

&D0 DTR ignored

* &D2 DTR disconnects and switches to command

&D3 DTR disconnects and resets modem

&F Load Factory Default

&F1 Master

&F2 Slave

&F3 Repeater

&F4 Slave through Repeater

&K Handshaking

&K0 Disable Handshaking

&K2 RTS/CTS Input Framing

* &K3 Enable Handshaking

&S DSR (Data Set Ready)

&S0 DSR is always on

* &S1 DSR on in data, off in command mode

&V View Configuration

&W Write configuration to memory

Sxx? Read S register value

Sxx=yy Set S register value

Result Codes

0	OK	12	CONNECT 9600
3	NO CARRIER	13	CONNECT 14400
4	ERROR	14	CONNECT 19200
7	CONNECT 2400	15	CONNECT 28800
8	CONNECT 3600	17	CONNECT 38400
9	CONNECT 4800	18	CONNECT 57600
10	CONNECT 7200	33	CONNECT 115200
64	CARRIER 20000	62	CARRIER 45000

S Registers

S0 Auto Answer [0...255]

0 = power up in Command Mode,

non-zero = power up in Data Mode

S2 Escape code [0...255] default '+'

S3 CR character [0...255] default <cr>

S4 Line Feed [0...255] default <lf>

S5 Backspace [0...255] default <bs>

S101 Operating Mode:

1 - Master Point to Multipoint

2 - Master Point to Point

3 - Slave

4 - Repeater

S102 Serial Baud Rate:

*1 = 115200, 2 = 57600, 3 = 38400

4 = 28800, 5 = 19200, 6 = 14400

7 = 9600, 8 = 7200, 9 = 4800,

10 = 3600, 11 = 2400

S103 Wireless Link Rate:

2 = Fast w/o FEC

*4 = Fast with FEC

S104 Network Address [0...65535]

S105 Unit Address [1...65535]

S106 Primary Hopping Pattern [0...61]

S206 Secondary Hopping Pattern [0...61]

S107 Encryption Key [0...65535]

S108 Output Power Level:

0 = 1 mW, 1 = 10 mW, *2 = 100 mW, 3 = 1000 mW

S109 Hopping Interval:

1 = 8 msec, 2 = 12 msec, 3 = 16 msec,

4 = 20 msec, 5 = 30 msec, 6 = 45 msec,

7 = 80 msec, *8 = 120 msec

S110 Data Format:

* 1 = 8N1, 2 = 8N2, 3 = 8E1, 4 = 8O1

5 = 7N1, 6 = 7N2, 7 = 7E1, 8 = 7O1

9 = 7E2, 10 = 7O2, 11 = 9N1

S111 Packet Minimum Size [1...Maximum Size]

S112 Packet Maximum Size [2...255]

S113 Packet Retransmissions [0...255]

S213 Packet Retry Limit [0...255]

S115 Packet Repeat Interval [1..255]

Default = 1

S116 Packet Character Timeout [0...254 ms]

S117 Modbus Mode:

*0 = Disabled, 1 = Enabled

S120 RTS/DCD Framing Interval [0...254 ms]

S121 DCD Timeout [0...254 ms]

S122 Link Handshaking [0=Disabled, *1=Enabled]

S118 Roaming

This mode is activated on slaves and repeaters by setting register S118=1. In this mode, a slave/repeater looks for synchronization with a Master having the same network address and encryption key, but without regard for the hopping pattern S106. Once the slave/repeater finds such a master, it tunes to that master’s hopping pattern. If synchronization is lost, the slave/repeater will again begin searching for a new master. Using this algorithm, a mobile unit can ‘roam’ and automatically synchronize with a new master once it loses communication with the previous one. It is essential that all Masters with which a roaming slave/repeater will be communicating with use a hopping pattern from within the same group. The allowable settings for this register are:

*0	Disabled
1	Enabled

S119 - Quick Enter to Command

By setting this register to 1, a delay of 5 seconds is introduced at power-up before the modem goes into data mode. If, during these 5 seconds, the user enters ‘mhx’ the modem will instead go into Command Mode, and reply with ‘OK’. The terminal baud rate must be set to 9600 baud. If an incorrect character is entered, the modem will immediately go into Data Mode. The default setting is 1 - Enabled.

6.3 Performance Tables

The scope of this appendix is to find the best possible performance and maximum packet size at different modes of operation. The setup assumes a baud rate of 115k, no retries and no retransmissions.

	Hop Interval	**Optimal Packet Size (bytes)**	**Throughput (kbps) ***
Master to Slave Communication. (No Repeater) Link Rate = Fast NO FEC	**1 (8 ms)**	14	20
	2 (12 ms)	66	52
	3 (16 ms)	110	66
	4 (20 ms)	154	74
	5 (30 ms)	255	83
	6 (45 ms)	255	56
	7 (80 ms)	255	31
	8 (120 ms)	255	21
Master to Slave Communication. (No Repeater) Link Rate = Fast WITH FEC	**1 (8 ms)**	5	4
	2 (12 ms)	34	22
	3 (16 ms)	54	28
	4 (20 ms)	76	32
	5 (30 ms)	130	38
	6 (45 ms)	210	43
	7 (80 ms)	255	30
	8 (120 ms)	255	20
Master to Repeater Direct Communication. Link Rate = Fast NO FEC	**1 (8 ms)**	N/A	N/A
	2 (12 ms)	3	1
	3 (16 ms)	22	13
	4 (20 ms)	44	21
	5 (30 ms)	101	32
	6 (45 ms)	178	39
	7 (80 ms)	255	31
	8 (120 ms)	255	21
Master to Repeater Direct Communication. Link Rate = Fast WITH FEC	**1 (8 ms)**	N/A	N/A
	2 (12 ms)	N/A	N/A
	3 (16 ms)	5	2
	4 (20 ms)	16	6
	5 (30 ms)	43	12
	6 (45 ms)	80	16
	7 (80 ms)	174	20
	8 (120 ms)	255	20
Master to Slave	**1 (8 ms)**	N/A	N/A
	2 (12 ms)	3	1

Through One or More Repeaters. Link Rate = Fast NO FEC	3 (16 ms)	22	13
	4 (20 ms)	43	21
	5 (30 ms)	93	31
	6 (45 ms)	174	38
	7 (80 ms)	255	31
	8 (120 ms)	255	21
Master to Slave Through One or More Repeaters. Link Rate = Fast WITH FEC	1 (8 ms)	N/A	N/A
	2 (12 ms)	N/A	N/A
	3 (16 ms)	N/A	N/A
	4 (20 ms)	14	6
	5 (30 ms)	40	12
	6 (45 ms)	80	16
	7 (80 ms)	174	19
	8 (120 ms)	255	20

6.4 Hopping Patterns

This Appendix provides a guide for selecting appropriate hopping patterns (S106,S206). There are 62 hopping patterns: 31 in Group A and 31 in Group B. When deploying a network, it is recommended that you use choose hopping patterns all belonging to the same group. Patterns have been designed to notch out certain segments of the ISM band.

	Pattern Number	Spectrum Used
Group A Patterns 0,2,4...60	0, 2, 4, 6, 8, 10, 12	902.4 - 927.6 MHz
	14, 16, 18, 20	902.4 - 907.2, 913.2 - 927.6 MHz
	22, 24, 26, 28	908.0 - 927.6 MHz
	30, 32, 34, 36	902.4 - 912.4, 918.4 - 927.6 MHz
	38, 40, 42, 44	902.4 - 917.6, 923.6 - 927.6 MHz
	46, 48, 50, 52	902.4 - 917.6, 923.6 - 927.6 MHz
	54, 56, 58, 60	902.4 - 922.0 MHz
Group B Patterns 1,3,5...61	1, 3, 5, 7, 9, 11, 13	902.6 - 927.4 MHz
	15, 17, 19, 21	905.4 - 925.0 MHz
	23, 25, 27, 29	907.8 - 927.4 MHz
	31, 33, 35, 37	902.6 - 907.4, 913.0 - 927.4 MHz
	39, 41, 43, 45	902.6 - 912.6, 918.2 - 927.4 MHz
	47, 49, 51, 53	902.6 - 917.8, 923.4 - 927.4 MHz
	55, 57, 59, 61	902.6 - 922.2 MHz

6.5 Glossary

Terminology Used in the SR900 Reference Manual

Asynchronous communications A method of telecommunications in which units of single bytes of data are sent separately and at an arbitrary time (not periodically or referenced to a clock). Bytes are "padded" with start and stop bits to distinguish each as a unit for the receiving end, which need not be synchronized with the sending terminal.

Attenuation The loss of signal power through equipment, lines/cables, or other transmission devices. Measured in decibels (dB).

Bandwidth The information-carrying capacity of a data transmission medium or device, usually expressed in bits/second (bps).

Baud Unit of signaling speed equivalent to the number of discrete conditions or events per second. If each signal event represents only one bit condition, then baud rate equals bits per second (bps) – this is generally true of the serial data port, so *baud* and *bps* have been used interchangeably in this manual when referring to the serial port; this is not always the case during the DCE-to-DCE communications, where a number of modulation techniques are used to increase the bps rate over the baud rate.

Bit The smallest unit of information in a binary system, represented by either a 1 or 0. Abbreviated "b".

Bits per second (b/s or bps) A measure of data transmission rate in serial communications. Also see *baud*.

Byte A group of bits, generally 8 bits in length. A byte typically represents a character of data. Abbreviated "B".

Characters per second (cps) A measure of data transmission rate for common exchanges of data. A character is usually represented by 10 bits: an 8-bit byte plus two additional bits for marking the start and stop. Thus, in most cases (but not always), *cps* is related to *bits per second (bps)* by a 1:10 ratio.

CRC (Cyclic Redundancy Check) An error-detection scheme for transmitted data. Performed by using a polynomial algorithm on data, and appending a checksum to the end of the packet. At the receiving end, a similar algorithm is performed and checked against the transmitted checksum.

Crossover cable (Also known as rollover, null-modem, or modem-eliminator cable) A cable which allows direct DTE-to-DTE connection without intermediate DCEs typically used to bridge the two communicating devices. Can also be used to make cabled DCE-to-DCE connections. The name is derived from "crossing" or "rolling" several lines, including the TX and RX lines so that transmitted data from one DTE is received on the RX pin of the other DTE and vice-versa.

Data Communications Equipment (DCE, also referred to as Data Circuit-Terminating Equipment, Data Set) A device which facilitates a communications connection between *Data Terminal Equipment* (DTEs). Often, two or more compatible DCE devices are used to "bridge" DTEs which need to exchange data. A DCE performs signal encoding, decoding, and conversion of data sent/received by the DTE, and transmits/receives data with another DCE. Common example is a modem.

Data Terminal Equipment (DTE) An end-device which sends/receives data to/from a DCE, often providing a user-interface for information exchange. Common examples are computers, terminals, and printers.

dBm Stands for "Decibels referenced to one milliwatt (1 mW)". A standard unit of power level commonly used in RF and communications work. *n* dBm is equal to $10^{(n/10)}$ milliwatt, so 0dBm = 1mW, -10dBm = 0.1mW, -20dBm = 0.01mW, etc.

DCE See *Data Communications Equipment*.

DTE See *Data Terminal Equipment*.

Flow Control A method of moderating the transmission of data so that all devices within the communications link (DTEs and DCEs) transmit and receive only as much data as they can handle at once. This prevents devices from sending data which cannot be received at the other end due to conditions such as a full buffer or hardware not in a ready state. This is ideally handled by hardware using flow-control and handshaking signals, but can be controlled also by software using X-ON/X-OFF (transmitter on/off) commands.

Frequency-hopping A type of *spread spectrum* communication whereby the carrier frequency used between transmitter and receiver changes repeatedly in a synchronized fashion according to a specified algorithm or table. This minimizes unauthorized jamming (interference) and interception of telecommunications.

Full-duplex Where data can be transmitted, simultaneously and independently, bi-directionally.

Half duplex Exists when the communications medium supports bi-directional transmission, but data can only travel in one direction at the same time.

Handshaking A flow-control procedure for establishing data communications whereby devices indicate that data is to be sent and await appropriate signals that allow them to proceed.

Line-of-sight Condition in which a transmitted signal can reach its destination by travelling a straight path, without being absorbed and/or bounced by objects in its path.

Master The station which controls and/or polls one or more Slave stations in a point-to-point or point-to-multipoint network. Often functions as a server or hub for the network.

Non-volatile memory Memory which retains information which is written to it.

Null modem cable See *Crossover cable*.

Point-to-point A simple communications network in which only two DTEs are participants.

Point-to-multipoint A communications network in which a *Master* DTE communicates with two or more *Slave* DTEs.

Repeater A device which automatically amplifies or restores signals to compensate for distortion and/or attenuation prior to retransmission. A repeater is typically used to extend the distance for which data can be reliably transmitted using a particular medium or communications device.

RS-232 (Recommended Standard 232; more accurately, RS-232C or EIA/TIA-232E) Defined by the EIA, a widely known standard electrical and physical interface for linking DCEs and DTEs for serial data communications. Traditionally specifies a 25-pin D-sub connector, although many newer devices use a compact 9-pin connector with only the essential signaling lines used in asynchronous serial communications. Lines have two possible states: "high" (on, active, asserted, carrying +3 to +25 V) or "low" (off, inactive, disasserted, carrying -3 to -25 V).

RTU (Remote Terminal Unit) A common term describing a DTE device which is part of a wide-area network. Often a RTU performs data I/O and transmits the data to a centralized station.

Serial communications A common mode of data transmission whereby character bits are sent sequentially, one at a time, using the same signaling line. Contrast with parallel communications where all bits of a byte are transmitted at once, usually requiring a signal line for each bit.

Shielded cable Interface medium which is internally shrouded by a protective sheath to minimize external electromagnetic interference ("noise").

Slave A station which is controlled and/or polled by the Master station for communications. Typically represents one end of a point-to-point connection, or one of the terminal nodes in a point-to-multipoint network. Often a RTU is linked by a Slave DCE.

Spread spectrum A method of transmitting a signal over a wider bandwidth (using several frequencies) than the minimum necessary for the originally narrowband signal. A number of techniques are used to achieve spread spectrum telecommunications, including *frequency hopping*. Spread spectrum provides the possibility of sharing the same band amongst many users while increasing the tolerance to interference and noise, and enhancing privacy of communications.

Throughput A measure of the rate of data transmission passing through a data communication system, often expressed as bits or characters per second (bps or cps).