Operating Manual

Model: ENC-900
900 MHz Spread Spectrum OEM Transceiver
Revision 1.00, February 23, 2005

Encom Wireless Data Solutions Inc.
#7-640, 42nd Ave. N.E.
Calgary, Alberta T2E 7J9
Phone: (403) 230-1122
Fax: (403) 276-9575
http://www.encomwireless.com/

RF EXPOSURE

This module has been designed to comply with FCC RF exposure requirements outlined in Parts 2.1091, 2.1093, and 15.247(b)(4). Deviation from the recommended installation may violate RF exposure requirements.

The manual for end users of the final product which incorporates the ENC-900 module must contain the following statement in a prominent location:

To comply with FCC RF exposure requirements for mobile transmitting devices, this transmitter should only be used or installed at locations where there is at least 20cm separation distance between the antenna and all persons.

FCC NOTIFICATIONS

The ENC-900 module generates radio frequency energy. It must be installed according to the manufacturer's guidelines or it has the potential to cause interference with other radio devices. Testing has been performed to assure that it conforms with the FCC Part 15 rules for intentional and unintentional radiators.

No further EMI compliance testing of the *transmitter* is required as long as the 20 cm separation and co-location requirements are observed. Each new use of the module will, however, always need to be scanned for unintentional radiation from digital clocks, etc.

All necessary calibration has been performed at the time of manufacture. Any modification of the device after it leaves the factory is a violation of FCC rules.

Compliance Statement (Part 15.19)
This device complies with Part 15 of the FCC Rules and with RSS-210 of Industry Canada. 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.

Warning (Part 15.21)
Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

RF Exposure (OET Bulletin 65)
To comply with FCC RF exposure requirements for mobile transmitting devices, this transmitter should only be used or installed at locations where there is at least 20cm separation distance between the antenna and all persons.

LABELING REQUIREMENTS

The FCC requires that the Part 15 statement be installed on the outside of the final product in a manner which allows it to be seen and read. The accepted statement and a sample label format are as follows:

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.

Contains TX FCC ID: PLQENC900
Canada: 3966A-ENC900
S/N: XXXYYYZZZ
MODEL: ENC-900

ENCOM™ Wireless Data Solutions

Made in Canada

The label should be printed or molded into the case using a type front and size that is readable with the unaided eye. The FCC identification number is required.

Industry Canada Statement
The term "IC" before the certification / registration number only signifies that the Industry Canada technical specifications were met.

900 MHz

Spread-Spectrum OEM
Radio Modem

WARNING

In order to comply with the FCC/IC adopted RF exposure requirements, this transmitter system will only be installed according to manufacturer's Installation Guidelines. Installation of all antennas must be performed in a manner that will provide at least 20cm clearance from the front radiating aperture, to any user or member of the public.

EQUIPMENT LABELING

The manufacturer, product name, and FCC and Industry Canada identifiers of this product must appear on the outside label of the end-user equipment.

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Encom' products are appropriate for home, office, or industrial use, but are not authorized for utilization in applications where failure could result in damage to property or human injury or loss of life.

The electronic equipment described in this manual generates, uses, and radiates radio frequency energy. Operation of this equipment in a residential area may cause radio interference, in which case the user, at his own expense, will be required to take whatever measures necessary to correct the interference.

FCC Declaration of Conformity

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.

Encom Wireless Data Solutions Inc., products are warranted against all failures which occur as a result of defective material or workmanship within 24 months of purchase by the user. This warranty does not extend to products that, in the opinion of Encom Wireless Data Solutions Inc.., have been subject to misuse, accidents, lightning strikes, improper installation or application, nor shall it extend to units which have, in Encom Wireless Data Solutions Inc.'s opinion, been opened, tampered with or repaired by an unauthorized facility.

Revision 1.00, August 27, 2004

1. INTRODUCTION

1.0 Product Overview

The ENC-900 is a high-performance embedded wireless data transceiver. Operating in the 902 - 928 MHz ISM band, this frequency-hopping spread-spectrum module is capable of providing reliable wireless data transfer between almost any type of equipment which uses an asynchronous serial interface. The small-size and superior RF performance of this module make it ideal for many applications. Typical uses for this module include:

- SCADA
- Traffic Control
- Remote Monitoring
- Fleet Management;
- Telemetry;
- Remote Camera/Robot Control;
- Security Systems; and,
- Display Signs.

While a pair of ENC-900 modules can link two terminal devices ("point-to-point" operation), multiple 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 to take place in the same or a nearby area without sacrificing privacy or reliability.

1.1 Features

Key features of the ENC-900 include:

- transmission within a public, license-exempt band of the radio spectrum[1] – this means that it can be used without access fees (such as those incurred by cellular airtime);
- a serial I/O data port with handshaking and hardware flow control, allowing the ENC-900 to interface directly to any equipment with an asynchronous serial interface.
- 64 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 – the ENC-900 module uses a subset of standard AT style commands, very similar to those used by traditional telephone line modems.

While the typical application for the ENC-900 is to provide a short- to mid-range wireless communications link between DTEs, it can be adapted to

[1] 902-928 MHz, which is license-free within North America; may need to be factory-configured differently for some countries.

almost any situation where an asynchronous serial interface is used and data intercommunication is required.

1.2 About this Manual

This manual has been provided as a guide and reference for installing and using ENC-900 wireless modem modules. The manual contains instructions, suggestions, and information which will help you set up and achieve optimal performance from your equipment using the ENC-900 module.
It is assumed that users of the ENC-900 module have either system integration or system design experience. Chapter 2 details the electrical/physical attributes of the module. Chapter 3 explains the different modes of operation, and Chapter 4 provides complete details of all configuration parameters. The Appendices, including the Glossary of Terms, are provided as informational references which you may find useful throughout the use of this manual as well as during the operation of the wireless modem.

Throughout the manual, you will encounter not only illustrations that further elaborate on the accompanying text, but also several symbols which you should be attentive to:

Caution or Warning: Usually advises against some action which could result in undesired or detrimental consequences.

Point to Remember: Highlights a key feature, point, or step which is worth noting, Keeping these in mind will make using the ENC-900 more useful or easier to use.

Tip: An idea or suggestion is provided to improve efficiency or to make something more useful.

With that in mind, enjoy extending the boundaries of your communications with the ENC-900 module.

2. ELECTRICAL/PHYSICAL

2.0 Functional Block Diagram

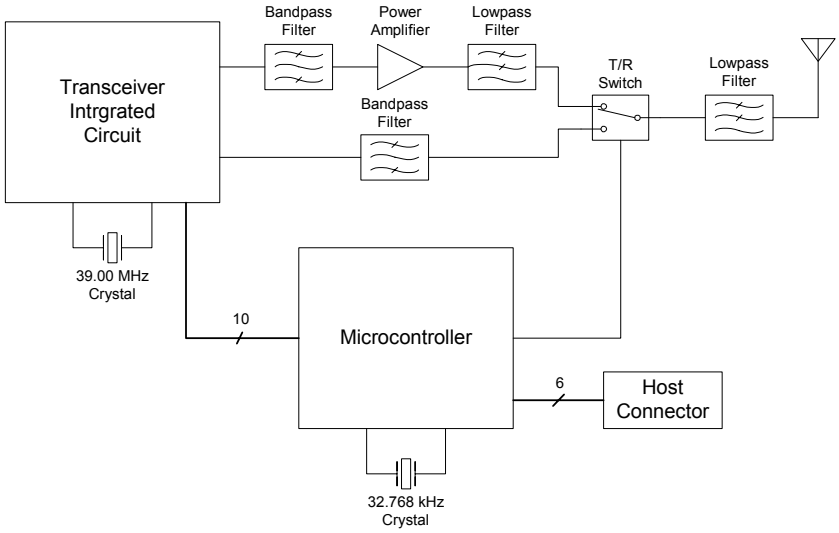


Figure 1. Functional Block Diagram

2.1 Pin-out

Figure 2 provides a top-view pin-out drawing of the ENC-900 module.

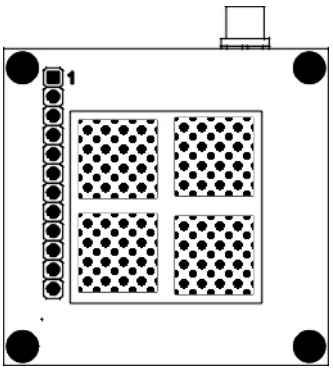


Figure 2 – Pin-out (Top View)

Table 1. Pin Description

No.	Pin Name	Description	I/O
1	GND	Ground reference for logic, radio and I/O pins.	
2	VCC	Positive Supply for Radio Circuitry. See Section 2.3 for DC Characteristics	
3	TXD	Serial Data Input. Active low (TTL Level) input.	I
4	RXD	Serial Data Output. Active low (TTL Level) output.	O
5	DTR	RS-232 Data Terminal Ready. Active low (TTL level) input.	I
6	CTS	RS-232 Clear to Send. Active low (TTL level) output.	O
7	RTS	RS-232 Request to Send. Active low (TTL level) output.	I
8	DSR	RS-232 Data Set Ready. Active low (TTL level) output.	O
9	RSSI1	Receive Signal Strength Indicator 1. This output is the first of the three RSSI indicators to become active high as the signal strength increases.	O
10	RSSI2	Receive Signal Strength Indicator 2. This output is the second of the three RSSI indicators to become active high as the signal strength increases.	O
11	RSSI3	Receive Signal Strength Indicator 3. This output is the third RSSI indicator to become active high as the signal strength increases.	O
12	DCD	RS-232 Data Carrier Detect. Active low (TTL level) output.	O

2.2 Mounting Location

Mounting is accomplished via the 12 pin 0.1" header and 4 mounting holds along the edge of the board.

In order to maintain compliance with the FCC modular certification it is necessary to mount the module in such a way that user is never closer than 20 cm to the antenna.

The manual for end users of the product must contain a warning about the 20 cm separation as outlined in the beginning of this manual.

Additionally, the transceiver may not be co-located with any other antenna or transmitter.

2.3 Antennas and Cabling

This section describes the recommended procedure for installing cabling and antennas for use with ENC-900 module.

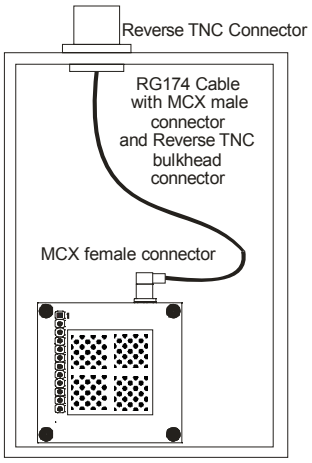
2.3.1 Antennas

Compliance with FCC regulations may only be maintained using the specified antennas and maximum output power cannot be exceeding 36 dBm EIRP.

See appendix A for a list of approved antennas that can be used with the ENC-900 radio modem. All the antennas listed on the appendix A can be purchased from Encom Wireless Data Solutions Inc. If you require another type of antenna, please contact Encom Wireless Data Solutions Inc. The ENC-900 cannot be used with any antenna that does not appear in Appendix A.

2.3.2 Cabling

The most common method for installing the module is to run a short RF Jumper cable from the module's MCX connector to a reverse TNC bulkhead connector on the chassis of the equipment as shown in the following figure. These cables can be purchased from Encom Wireless Data Solutions Inc.



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 connectors.

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

ERP is calculated as follows:
ERP = Tx Power (dBm) – Cable/Connector Loss (dB) +Ant Gain (dBi)

Antenna Gain must be in dBi when calculating the 36dBm ERP limit.
1dBd = 2.15dBi

2.4 LED Operation

LED functionality is dependent on the mode of operation. Lines RX/SYNC, TXMODE, and RSSI1,2 and 3 are designed to drive LED's (active high). Table 2 explains LED operation for the various modes.

MODE	RSSI1,2,3
Power Up (S0=1)	off
Power Up (S0=0)	off
Command Mode	off
Data Mode - Master	RSSI mode based on all received packets See Table 3
Data Mode - Repeater During Sync. Acquisition	alternating 300ms ON
Data Mode - Repeater When Synchronized	RSSI mode based on packets received from Remotes* See Table 3
Data Mode - Remote During Sync. Acquisition	alternating 300ms ON
Data Mode - Remote When Synchronized	RSSI mode based on packets received from the Repeater or Master with which it communicates See Table 3

*If Remote have been silent for 2 seconds, repeater will base its RSSI on packets received from the Master.

Table 2. LED Operation

Signal strength, which is also reported in Register S123, is calculated based on the last four valid received packets with correct CRC, and represented by RSSI1, 2 and 3.
For Remotes, packets are received on every single hop either from a repeater, or the master.
When calculating RSSI, the master takes into consideration all packets received from Remotes and repeaters. Repeaters and Remotes only transmit back to the master when they have information to send. Therefore, if no data is coming back to the master then RSSI will never get updated at the master, and the LED's will be off.

Signal Strength (dBm)	**RSSI1**	**RSSI2**	**RSSI3**
-95	50% duty cycle	off	off
-90	on solid	off	off
-85	on solid	50% duty cycle	off
-80	on solid	on solid	off
-75	on solid	on solid	50% duty cycle
-70	on solid	on solid	on solid

Table 3 - RSSI mode operation

2.5 DC Characteristics

Characteristic	Min	Typ	Max	Units
Supply Voltage		3.80		V
Transmit Current at 1W		900		mA
Receive Current		28		mA
Sleep Current		1		mA

IMPORTANT:
For best performance, it is strongly recommended to use a separate, linearly regulated supply for Vcc Radio. Do not directly feed a switching power supply into Vcc Radio.

Caution: Using any other power supply which does not provide the proper voltage or current could damage the ENC-900 module.

3. MODES OF OPERATION

The ENC-900 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. This port has two functions:
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.
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.

3.1 Data Mode

Data mode is the normal operating mode of the ENC-900. When in data mode, the ENC-900 is communicating with other ENC-900 modules, and facilitating wireless asynchronous serial communication amongst two or more terminal devices. There are three basic elements to any ENC-900 communications network:

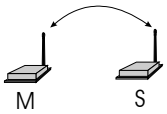
- One module configured as the **Master**
- Zero or more modules configured as **Repeaters**
- One or more modules configured as **Remotes**

The function of the Master is to provide synchronization for the entire network, and to control the flow of data. There is always one Master per network. The Master is the ultimate destination for all data collected at the various Repeater's and Remote's serial ports. With the network set up for Point-to-Multipoint communication, all data received at the Master's serial port is transmitted to every Repeater and Remote in the network. The ENC-900 is a frequency hopping transceiver, meaning that it "hops" to a new frequency after a predetermined time interval. This time interval is a fixed time set by the user, and can range from 8ms to 200ms. The ENC-900 hops according to a pseudorandom pattern of 50 different channels.

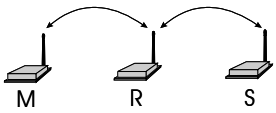
Refer to Appendix A for a summary of the modem commands

Configuration options are not stored in non-volatile memory until the WRITE command (&W) is executed

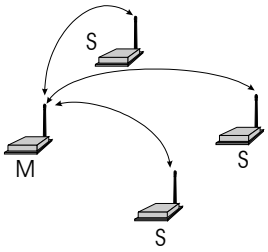
When configured as a Remote, the ENC-900 searches for synchronization with a Master. Network topologies consisting of a single *Master* and virtually any combination of *Remotes* and *Repeaters* may be deployed. The functionality of any particular ENC-900 can be configured as follows:



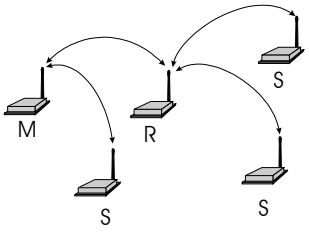
Network 1



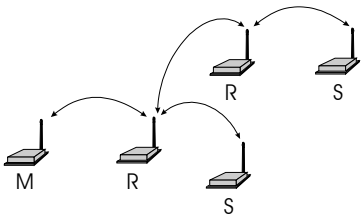
Network 2



Network 3



Network 4



Network 5

Figure 4 - Sample Network Topologies. Virtually any Combination of Remotes and Repeaters May be Used.

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

Examples of different network topologies are shown in Figure 4. Network 1 shows Point-to-Point communication between a Master and Remote. Network 2 makes use of a Repeater to communicate with the Remote. 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 Remotes. There is effectively no restriction to the number of Repeaters and Remotes that can be added to a network. As seen in Network 4, a Master can communicate directly with both Remotes and Repeaters.

3.2 Command Mode

The ENC-900 firmware has been designed to allow the user to customize the operation of the modem through an AT Command Interface. This interface is ideal for direct interface with another microcontroller or for higher level Windows-based software applications, but also contains user-friendly built-in register descriptions. These descriptions make it easy for the user to configure the unit by manually inputting AT Commands and modifying S-Register parameters, using any standard terminal program. The ENC-series development board is a useful tool for familiarizing yourself with the various operating parameters and user interface. Reference schematics for the development board can be found in the development kit user's manual. To access the ENC-900's command mode using the development board:

1. Insert the module into the socket with the antenna connector at the end near the power jack.
2. Attach the supplied antenna.
3. Connect a straight through serial cable between the DB9 connector and the serial port on your PC
4. Run any terminal application program such as Hyperterminal
5. Set the serial port to 9600 baud, 8N1
6. Apply power to the development board
7. While the three RSSI LED's are blinking, type 'ENC' (you have about 5 seconds to do this). The modem should respond with 'OK'.
8. Type 'AT&V <ENTER>'

3.2.1 AT Command Interface

At this point you should see a menu similar to the following appear:

```
BAUD = 9600
 E1 Q0 V1 W0
 DCD &C1    DTR &D0    Framing &E0    Handshaking &K3    DSR &S1
 S0=1 S2=43 S3=13 S4=10 S5=8
Operating Mode          S101=1          Serial Baud Rate        S102=7
Wireless Link Rate      S103=2          Network Address         S104=1
Unit Address            S105=1          Hop Pattern             S106=0
Encryption Key          S107=1          Output Power            S108=2
Hop Interval            S109=4          Data Format             S110=1
Packet Min Size         S111=1          Packet Max Size         S112=43
Packet Retransmissions  S113=1          Quick enter to command  S119=1
Packet Repeat Interval  S115=1          Character Timeout, ms   S116=8
RTS/DCD Framing, ms     S120=0          DCD Timeout, ms         S121=0
Secondary Hop Pattern   S206=2          Packet Retry Limit      S213=2
Average RSSI value      S123= -0 dBm    Buffer Mode             S117=0
Roaming                 S118=0          Packet Size Control     S114=0
Remote Control          S122=0
OK
```

The ENC-900 is controlled through an AT Command line interface using a command set which is very similar to a traditional Hayes telephone modem command set.

All line entries must be preceded by the characters ‘AT’. The characters ‘AT’ are known as the attention characters and must be typed at the beginning of each command line. For example, to change the operating mode, type:

ATS101=2 <ENTER>

The modem should respond with ’OK.’ The above command will set the operating mode to Master Point-to-Point.

Register settings are not immediately stored to non-volatile memory, therefore if the modem is powered down at this point, the Operating Mode would revert to its previous value. To store any recently updated command registers, the following “write” command must be entered.

AT&W <ENTER>

3.3 Switching Between Command and Data Modes

Your modem must be in command mode for it to execute a command. If you send characters when the modem is in data mode, the modem transmits the characters over the air.

Depending on its settings, the modem will either power up in command mode or data mode. Normally, when first received from the factory, the unit will power up into data mode. During the first five seconds after power-up, the user is given the opportunity to avoid entering into data mode but instead enter into command mode by typing ‘enc’.

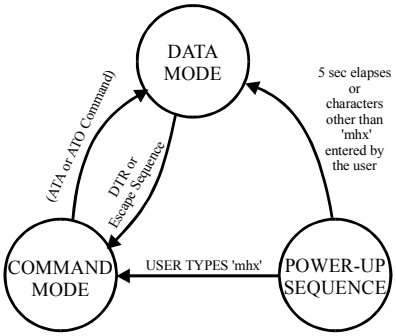


Figure 5A. S0=1, S119=1 (factory default)

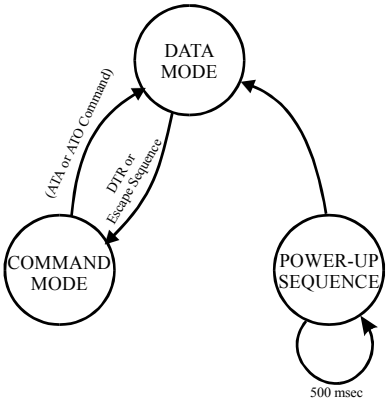


Figure 5B. S0=1, S119=0

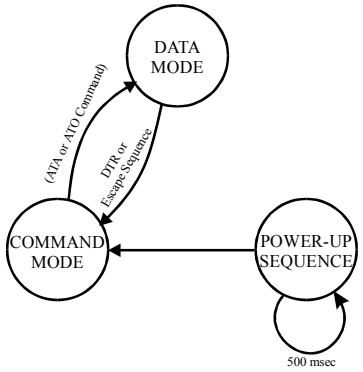


Figure 5C. S0=0

The escape sequence will not be accepted unless both the ENC-900 and the terminal are set to the same baud rate

The terminal must be set for 9600 baud 8N1 in order for the modem to accept these characters. If 'enc' is typed incorrectly, the modem will immediately enter into data mode. If the five seconds elapses without any response from the user, the modem will go into data mode.

In command mode, the module "autobauds," meaning that it will adapt to the baud rate of the DTE equipment to which it is connected. Therefore, when in command mode, you may change the baud rate of your equipment, and the ENC-900 will automatically adjust to this baud rate once an AT string is issued. The new baud rate is stored in register S102. Several baud rates ranging from 1200 to 115200 may be selected.

You can place the modem into Data Mode from Command Mode either by:

- Issuing the answer command (ATA <ENTER>); or,
- Issuing the online command (ATO <ENTER>).

With traditional telephone line modems, these two commands serve different purposes, however, with the ENC-900, these commands are identical. The modem will now attempt to communicate with other ENC-900 modules. While in Data Mode, the modem will communicate through the serial port at the same baud rate as was last used in Command Mode[2].

To return to Command Mode, you can either:

- Send the escape sequence. (The escape sequence consists of 1 second of inactivity, followed by the characters '+++' followed by another second of inactivity.); or,
- Toggle the DTR line (depending on the &D parameter).

The escape sequence must be issued at the baud rate that the modem has been set to. If the modem is set to 19200 baud, and the escape sequence is issued at 9600 baud, for example, the modem will not recognize it, and will not go into Command Mode.

Figure 5 provides a state diagram for power-up, command mode, and data mode. Note that there are three different variants of the state diagram which depend on the values of registers S0 and S119. See the appropriate sections for more details about these registers. The factory defaults are S0=1 and S119=1.

[2] It is possible to enter into Data Mode at a different baud rate from what is currently being used in Command Mode by issuing the command ATS102=x, where x is one of the valid baud rates. Care must be taken when setting the baud rate in this manner. If you issue another AT string after attempting to set the baud rate using ATS102 <ENTER>, the modem will again autobaud and automatically revert to the baud rate of the host equipment. For example, if your equipment is running at 9600 baud and you wish to set up the modem to run at 19200 baud, the following command line entry would be suitable:

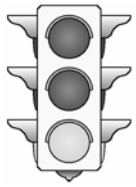
ATS102=5&WA <ENTER>

The first part (S102=5) sets the baud rate to 19200. The next characters (&W) write this baud rate to memory. The last character (A) puts the modem into Data Mode. Once in Data Mode, the modem is unable to autobaud, and is fixed at 19200 baud. By combining several commands into one command line entry, and then immediately putting the modem online, the modem is not given a chance to autobaud back to 9600.

4. CONFIGURATION

This chapter provides a detailed description of the various operating parameters of the ENC-900. Section 4.1 provides a quick-start approach which outlines the minimum requirements for establishing communication between two ENC-900 modules. The settings will not necessarily provide optimal performance for your application, but will verify that the modules are functioning correctly.

Section 4.2 describes the AT Command interface, and the various AT Commands. Section 4.3 covers all S-Register parameters which affect the operation of the modem, and Section 4.4 provides a description of all diagnostic features of the modem.

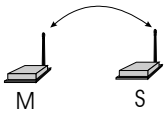


4.1 Quick Start Approach

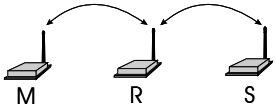
There are several parameters that must be set in order to establish communication between a pair of ENC-900 modules.

The ENC-900 is equipped with four standard factory default settings. Instead of manually configuring each individual operating parameter, a global command may be used to quickly configure the modem for a particular type of operation. For example, to quickly implement Network 1, Factory default 1 would be applied to the Master, and Factory default 2 would be applied to the Remote. To quickly set up Network 2, apply Factory 1 to the Master, Factory 3 to the Repeater, and Factory 4 to the Remote. *These defaults will get you started and only ensure that a link can be established, but do not necessarily provide the best performance.* Optimization of the communications link is discussed in later sections.

Warning: After testing the units for correct operation using the quick-start approach, be sure to modify some of the security parameters such as Network Address and Encryption Key, to avoid unintentional communication with other users of ENC-900 products..



Network 1



Network 2

Figure 6. Basic Networks

To implement the basic network illustrated in Figure 6, Network 1,

1. Insert the module into the development board socket with the antenna connector at the end near the power jack.
2. Attach the supplied antenna.
3. Connect a straight through serial cable between the DB9 connector and the serial port on your PC
4. Run any terminal application program such as Hyperterminal and set the terminal application's serial port settings to 9600 baud, 8N1
5. Apply power to the development board
6. While the three RSSI LED's are blinking, type 'ENC' (you have about 5 seconds to do this). The modem should respond with 'OK'.
7. Configure the unit to Factory Setting 1 by typing AT&F1 <return>. This puts the unit into Master Point-to-point mode.
8. Store these settings to memory by typing AT&W <return>.
9. Put the modem into Data Mode by typing ATA (or ATO) <return>
10. Perform above steps for the second unit, using Factory Setting 2 instead of Factory Setting 1. This will configure the second unit as a Remote.

The units should now be communicating. Remember, the parameters defined by Factory Settings 1 and 2 will likely not be the most ideal for your application, but will quickly allow you to test the units. A complete summary of the settings defined by all four factory settings can be found in Appendix D. Factory Default Settings.

Settings are not immediately stored in non-volatile memory, therefore, the command &W is issued to store the current configuration into non-volatile memory. Settings are retained even after powering down. All user selectable parameters for the ENC-900 are described in detail in Sections 4.2 and 4.3:

4.1.1 Checking the Link

To check if the units are communicating, observe the LED indicators on the development board which houses the Remote unit. If the link is good, up to three RSSI LEDs on the Remote modem should be active along with the RX/Sync LED, and if the link is absent (due to a fault at one end or another, such as misconfiguration), the LED's will be in either "scanning mode" or inactive. See Section 2.2 for complete LED operation.

Characters typed at the Master terminal should appear at the Remote'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 Remote to Master, the RX indicator should blink on as correct packets of data are received. At this point, the Master's RSSI LED's should become active. It is recommended that if the ENC-900 will be deployed in the 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.

4.2 AT Commands

Several AT Commands are supported by the ENC-900. These commands affect the operation of the modem in command mode and the transition between data and command modes. More commands and S-Register settings are discussed in Sections 4.3 and 4.4.

To make the command line more readable, you can insert as many spaces as desired. The command line holds up to 16 characters, not including the AT prefix. If you want to send more than one command line, wait for a response before entering the AT prefix at the start of the next command line. To re-execute the previous command, enter A/. The modem will execute the previous command line.

The escape sequence will not be accepted unless both the ENC-900 and the terminal are set to the same baud rate

When in Command Mode, the modem "autobauds", meaning that it will automatically adjust to the baud rate of the terminal. You may change the terminal baud rate while in Command Mode without losing communication with the modem.

For the AT command protocol, an escape sequence consists of three consecutive escape codes preceded and followed by at least 1 second of inactivity. Typically, the '+' character is used as the escape code.

+++ preceded and followed by 1 second of inactivity

Note that the terminal must be configured to the same baud rate as the modem in order for the modem to recognize the escape sequence. The modem is unable to "autobaud" while in Data Mode.

The following is a description of all available commands. '*' denotes standard factory settings. All of the following commands must be preceded by "AT".

A Answer

The A command puts the modem into data mode, where the modem attempts to communicate with other compatibly configured modems (Type ATA <return>).

Dxxxxx, DTxxxxx, DPxxxxx Dial

The D, DT or DP are identical commands which change the unit address to xxxxx and puts the modem into data mode (Type ATDxxxxx <return>).

E Command Echo

Your modem is preset to return (or echo) commands to the host microprocessor when in Command Mode.

E0 No Command Echo
*E1 Command Echo

I Identification

The I command returns various modem information settings.

I0= String up to 15 characters stored in non-volatile memory
I1 Product Code
I2 Self Test Result
I3 Product Identification (Firmware Version)
I4 Firmware Date
I5 Firmware Copyright
I6 Firmware Time
I7 Serial Number

O On-line Mode

The O command puts the modem into data mode. This command is identical to the A command.

Q Quiet Mode

Your modem is preset to send responses when it executes commands, and there after to keep the host informed of its status.

*Q0 Enable modem responses
Q1 Disable modem responses

V Result Codes display

Your modem can either display result codes as words or numbers.

V0 Display Result Codes as numbers
*V1 Display Result Codes as words

W Connection Result

This parameter determines the modem response at the transition to Data Mode from Command Mode

*W0 Reports computer (DTE) baud rate as CONNECT xxxx
W1 Reports wireless rate between modems as CARRIER xxxx.

Z Reset and load stored configuration

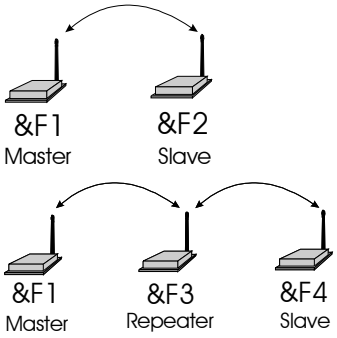
Refer to Appendix A (page 49) for a summary of the modem commands

The Z command resets the modem and loads the stored configuration.

&C DCD (Data Carrier Detect)

The &C command controls the modem's DCD output signal to the host microprocessor. This command determines when the DCD is active.

&C0 DCD is always ON
*&C1 DCD on when modems are synchronized. DCD is always on when unit is configured as Master.
&C2 DCD used for output data framing
&C3 DCD is always ON, but S120 & S121 timing is still valid



&D DTR (Data Terminal Ready)

The &D command controls what action the modem performs when the DTR input line is toggled. The DTR input is controlled by the host microprocessor.

*&D0 DTR line is ignored
&D1 Not Supported
&D2 De-assert DTR to force the modem into command mode from data mode. DTR must be asserted before putting the modem back into data mode (The modem is put back into data mode in the normal manner using ATA or ATO)
&D3 De-asserting DTR disconnects and resets modem. Modem will remain in this state until DTR again goes active.

&F Load Factory Default Configuration

The &F command resets the modem and loads the default factory configuration.

&F1 Master Point-to-Multipoint. Designed to communicate with modems configured as &F2 or &F3.
&F2 Remote. Designed to communicate with another modem configured as &F1.
&F3 Repeater. Designed to communicate with modems configured as &F1 and &F4.
&F4 Remote working with factory default Repeater and factory default Master. Communicates directly with Repeater configured as &F3.

&K Handshaking

The &K command controls the handshaking between the modem and host microprocessor.

&K0 Disable handshaking
&K2 RTS/CTS input data framing.
*&K3 Enable hardware handshaking (RTS/CTS)

&S DSR (Data Set Ready)

The &S command controls the DSR line for the modem, and determines when it is active

&S0 DSR is always ON
*&S1 DSR is ON in Data Mode, OFF in Command Mode

&V View Configuration

The &V command displays all S registers and their current values.

&E Framing Error Check

This command enables or disables Framing Error Check. When enabled, the modem looks for the stop bit. If the stop bit is absent, the byte is thrown out. When enabled, the modem also does a parity check. Note that the data format (number of data bits, parity type, and number of stop bits) is defined by S register 110.

*&E0 Disable Framing Error Check
&E1 Enable Framing Error Check

&W Write Configuration to Memory

Configuration options are not stored in non-volatile memory until the WRITE command (&W) is executed

The &W command stores the active configuration into the modem's non-volatile memory.

Sxxx? Read S register value

This command causes the modem to display the current setting of S register xxx.

Sxxx=yyy Set S register value

This command sets the specified S register to a value specified by yyy.

AT Command Result Codes

The ENC-900 module can display the results of a command as either text strings or numerical data. The following chart shows resulting text string and corresponding numeric result.

0 OK
3 NO CARRIER
4 ERROR

4.3 S Registers

Refer to Appendix A for a summary of the S-Registers.

The S Registers described in this section affect the operating characteristics of the modem.

S Register 0 - Auto Answer

If this register is set to zero, the modem will power up in command mode. If this register is set to one, the modem will power up in data mode.

S Registers 2 cannot be stored to non-volatile memory.

S Register 2 - Escape Code

This register contains the ASCII value of the escape character.

The default value (decimal 43) is equivalent to the ASCII character '+'. Values greater than 127 disable the escape feature and prevent you from returning to the Command Mode. This register cannot be stored to non-volatile memory. If the modem is reset, or powered down, the default value is restored.

Default is '+' (decimal 43).

S Register 101 - Operating Mode

Only one Master can exist for each network.

The Operating Mode (register S101) partly defines the "personality" of the ENC-900 module. Allowable settings for this register are 1 through 6 as follows:.

- S101=1 Master Point to Multipoint
- S101=2 Peer-to-Peer Mode
- S101=3 Remote
- S101=4 Repeater
- S101=5 Master - Diagnostics

The default for this register depends on which factory default is selected as shown below:

- Default for Factory Setting &F1 is 1 (Master Point-to-Multipoint)
- Default for Factory Setting &F2 is 3 (Remote)
- Default for Factory Setting &F3 is 4 (Repeater)
- Default for Factory Setting &F4 is 3 (Remote)

1) Master - Point to Multipoint. In any given network, there is always only one Master. All other units should be configured as either Remotes or Repeaters. When defined as a Point-to-Multipoint Master, the modem broadcasts data to all Remotes and Repeaters in the network, and is also the ultimate destination for data transmitted by all Remotes 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):

- Maximum Packet Size (S112)
- Minimum Packet Size (S111)
- Wireless Link Rate (S103)
- Hop Interval (S109)

2) Master – Point to Point. This mode of operation provides for communication between the master and a single repeater or Remote. The master will communicate only with the Remote or repeater which shares a common unit address with the master. For example, if a Remote has been assigned Unit Address 100, and the Master wishes to communicate with that Remote, the Master's unit address must also be set to 100. If there are Repeaters in the network, they will pass the packet through to the Remote, and vice versa. Because Repeaters also have Remote 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) Remote. Up to 255 Remotes may exist in a network, all of which communicate with the common Master (either directly or via Repeater(s)). Remotes cannot directly communicate with other. Remotes only provide acknowledgement for packets of data sent by the Master when the Master is in Point-to-Point mode. In multipoint mode, multiple Remotes would conflict with one another if they were all trying to acknowledge the Master at the same time. The Master does, however, send acknowledgements to all messages it receives from Remotes. The Master initiates communications by sending a broadcast message to all Remotes. Each Remote can choose one of several windows in which to transmit. If there happens to be two Remotes attempting to talk at the same time, the Master may not receive the data, and the Remotes therefore would not get an acknowledgement. At this point, the Remotes would attempt to get the information through at random time intervals, thus attempting to avoid any more conflicts. Special parameters which control the Remote's response characteristics can be modified with S Registers S115 and S213.

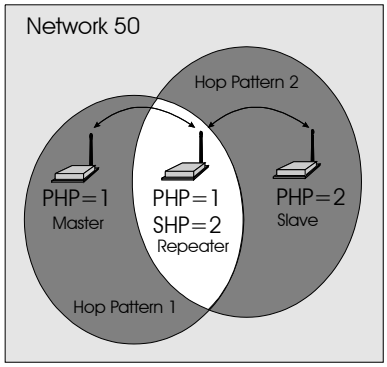


Figure 7 - Repeater Operation

4) Repeater. A more precise title would be Repeater/Remote, because a Repeater also has much of the same functionality as a Remote. 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 7, the Master belongs to Hopping Pattern 1, and communicates with the Repeater on this hopping pattern. The Remote 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 Remotes 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 Remotes (or with another Repeater between itself and the Remotes). Figure 8 shows another example.

If the Repeater is not also being used as a Remote (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.

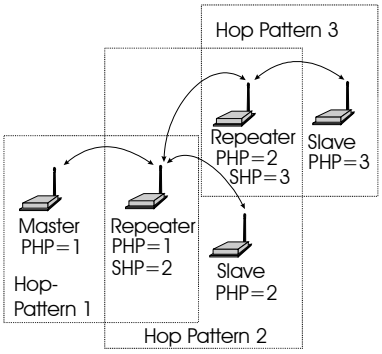


Figure 8 - A Network Utilizing Three Hopping Patterns

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

S Register 102 - Serial Baud Rate

The Serial Baud Rate is the current speed that the modem is using to communicate with the DTE. In command mode, the module "autobauds," meaning that it will adapt to the baud rate of the DTE equipment to which it is connected. Therefore, when in command mode, you may change the baud rate of your equipment, and the ENC-900 will automatically adjust to this baud rate once an AT string is issued. The new baud rate is stored in register S102. If you issue a command to change the value of S102, the instant you issue another command, the baud rate will revert back to that of the DTE equipment. Therefore, it is advisable to operate in Command Mode at the desired baud rate for Data Mode.

The possible values are:

1	115200
2	57600
3	38400
4	28800
5	19200
6	14400
*7	9600
8	7200
9	4800
10	3600
11	2400
12	1200

It is generally advisable to choose the highest rate that your terminal equipment will handle to maximize performance, unless a limitation on the available bandwidth is desired. If the DTE is a personal computer, the port can usually be used reliably at 115200. Issuing the &Fx command (factory default) does not affect the current setting of S102.

S Register 103 - Wireless Link Rate

The Master determines the Wireless Link Rate. This setting on all other modems is ignored..

The Wireless Link Rate is the 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 Remotes will ignore this setting, and adjust automatically to the rate of the Master.

The allowable settings are:

*2	Fast without Forward Error Correction
4	Fast with Forward Error Correction

Depending on the application requirements, each mode will provide different throughput and performance.

In general, Forward Error Correction (FEC) reduces throughput, but in some environments will actually increase throughput. FEC can reduce the number of bad data packets, and hence reduce the need to retransmit.

S Register 104 - Network Address

Select a Network Address and assign it to all units which will be included in the network.

Warning: Encom Wireless strongly recommends changing the Network Address to a value different from the factory default before deploying the network.

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 255, inclusive.

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

Default is 1.

S Register 105 - Unit Address

Use the same Unit Address on both units for point-to-point mode. In multipoint mode, set each Remote and Repeater to a different Unit Address.

In point-to-point operation, the Unit Address on both the Master and Remote (or Repeater) units must be the same. In a multipoint system, the Unit Address uniquely identifies each Remote and Repeater from one another. Each unit in a multipoint system must have a unique Unit Address ranging from 0 to 255.

S Register 106 - Primary Hopping Pattern

S Register 206 - Secondary Hopping Pattern

Valid Unit Addresses are 1 to 65535.

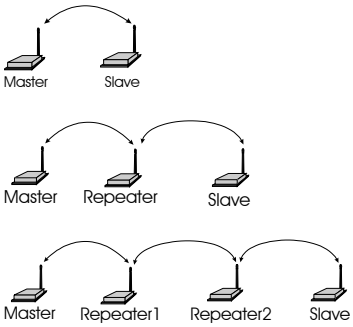
Since the ENC-900 is a frequency-hopping modem, the carrier frequency changes periodically according to one of 64 pseudo-random patterns, defined by the Primary and Secondary Hopping Patterns. Valid entries for each are 0 through 63.

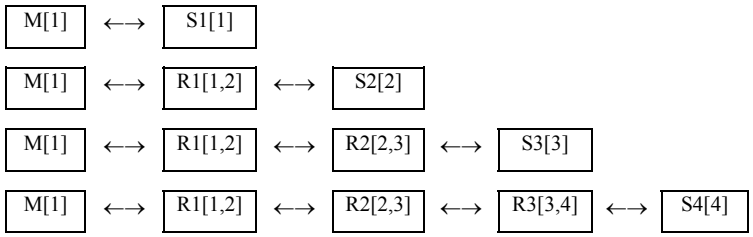
The concept of Primary and Secondary Hopping Patterns was introduced in the discussion of S Register 101 (Operating Mode).

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

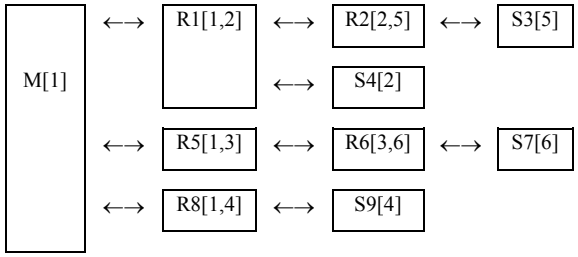
- *M* indicates Master;
- *R* indicates Repeater;
- *S* indicates Remote;
- *x* is the Unit Address;
- *a* is the primary hopping pattern; and,
- *b* is the secondary hopping pattern;

the following diagrams illustrate the methodology for deploying simple to complicated networks:





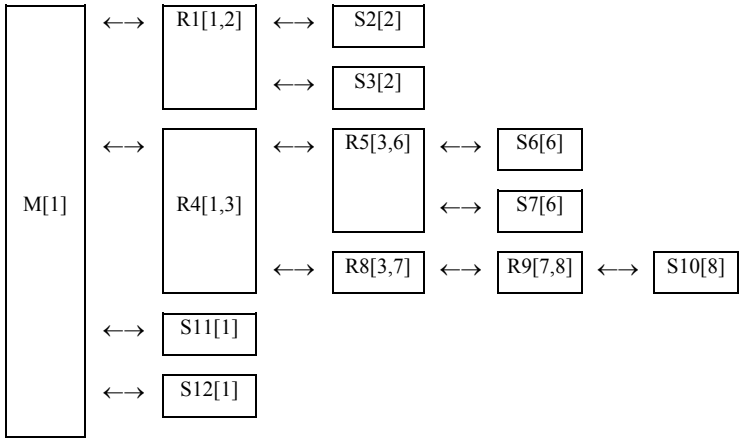
It is reasonable to consider a Repeater as being both a Remote and a Master, alternating between Primary and Secondary Hopping Patterns as the unit changes channel. Consider R1 in the illustration below. When communicating with the Master, R1 is acting like a Remote on Primary Hopping Pattern 1. When communicating with R2 and S4, R1 is acting like a Master on Secondary Hopping Pattern 2. If multiple Repeaters are used, they should have different Secondary Hopping Patterns:



Note that all units have a unique Unit Address.

Remotes and Masters do not use Secondary Hopping Patterns

Networks of any complexity can be created by linking multiple Repeaters and Remotes:



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

With a limitation of 64 hopping patterns, one might suspect that there is a limitation to the number of repeaters in a system. However, if the units are far enough away from one another, hopping patterns may be reused in different sections of the network, without causing interference.

All units within a network must use the same encryption key.

Warning: Encom Wireless strongly recommends changing the Encryption Key to a value different than the factory default before deploying the network.

S Register 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 255.

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

S Register 108 - Output Power Level

Not all the power levels are available on all radio modules.

- Product code (ATI1): ENC-900L, will be factory limited to transmit up to 100mW output power, and will ignore all the level 3 setting.
- Product code (ATI1): ENC-900, will accept the level 3 setting and transmit up to 1W output power

The Output Power Level determines at what power the ENC-900 transmits. The ENC-900's sensitive receiver 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	(not available for ENC-900L model)

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 some of the settings 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	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. **(If the antennas of directional gain greater than 6 dBi (≈3.85 dBd) are used, the peak power from the radio should be reduced by the amount in dB that the directional gain of the antenna exceeds 6 dBi (≈3.85dBd) (see next page for maximum allowed output power calculation example)**

- These outdoor distances assume antennas are mounted at least 100 ft above ground level.

IMPORTANT:

FCC Regulations allow up to 36 dBi effective radiated power (ERP). Therefore, the sum of the transmitted power (in dBm) 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 1000 mW (30 dBm), the antenna gain cannot exceed 36 - 30 = 6dBi (≈3.85dBd). If an antenna with a gain higher than 6dBi (≈3.85dBd) were to be used, the power setting must be adjusted appropriately. Violation of FCC regulations can result in severe fines.

The hopping interval is controlled by the master. The Remote and repeater units will use the hopping interval setting from the master.

S Register 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 Remotes 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

Some of the shorter hop intervals are incompatible in combination with:

- repeaters in the system;
- the value set for link rate (S103); and,
- larger maximum packet sizes (S112).

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

S Register 110 - Data Format

This register determines the format of the data on the serial port. Allowable settings 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

S Register 111 - Packet Minimum Size

S Register 112 - Packet Maximum Size

S Register 116 - Packet Character Timeout

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

S Register 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 if register S114=0 at any particular Repeater or Remote, that Repeater or Remote will ignore its own S111 register and abide by the Master's S111 setting. If S114=1 at any particular Repeater or Remote, that Repeater or Remote will use its own local S111 setting. The default for S111 is 1 byte.

S Register 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 if register S114=0 at any particular Repeater or Remote, that Repeater or Remote will ignore its own S112 register and abide by the Master's S112 setting. If S114=1 at any particular Repeater or Remote, that Repeater or Remote will use its own local S112 setting. The default for S112 is 255 bytes.

S Register 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 ENC-900 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 5 ms. If set to 0 ms, the unit will buffer exactly the minimum packet size before transmitting.

S Register 113 - Packet Retransmissions

This register applies to both Master and Repeater operation. It does not apply to Remote operation. In point-to-multipoint mode, the Master will retransmit each data packet exactly the number of times defined by the Packet Retransmissions parameter. In point-to-point mode, the Master will only retransmit the packet if it does not get an acknowledgement from the Remote with which it is communicating. In this case, the Master will continue to retransmit until an acknowledgement is received, or the retransmission limit is reached. When the retransmission limit is reached, the Master discards the packet. The Master retransmits once at the beginning of each hopping interval until the limit is reached. This parameter is not necessary in Remote units since all Remotes receive acknowledgement from the Master, and needn't blindly retransmit if it has knowledge that the Master has received the packet.. As discussed previously, the Repeater effectively behaves as both a Master and a Remote. 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 Remotes 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 1.

S Register 114 - Sleep Mode

Depend on the level of setting; the radio will turn most of the internal circuit off to save the power consumption. The allowable settings for this register are:

*0	Disabled
1	Level 1- recommend to use in Point-to-Multipoint protocol, radio will turn most of the internal circuit off as well as skip certain hop to save power.
2	Level 2 – recommend to use in Peer-to-Peer protocol, radio will turn off all of the internal circuit except the I/O and Serial Data Input Interrupt.

S Register 115 - Packet Repeat Interval

A parameter that is specific to Remotes 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 Remote 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 Remote 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 Remote will transmit in the fifth time slot. A Remote 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 Remote will transmit more frequently when a Repeat Interval with a smaller range is selected. Choose 1 to have the Remote transmit in the first available slot. Choose higher intervals for less frequent transmission, or to avoid collisions between many Remotes in the system.

This register is always disregarded and taken as S115=1 in Point-to-Point mode.

S Register 117 - Radio Buffer Mode

Radio Buffer Mode controls the ENC-900 TX buffer behaviors.

The allowable settings for this register are:

*0	High Throughput Mode
1	Quick Turn-Around Mode

S Register 118 - Roaming

This mode is activated on Remotes and repeaters by setting register S118=1. In this mode, a Remote/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 Remote/repeater finds such a master, it tunes to that master's hopping pattern. If synchronization is lost, the Remote/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 Remote/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

S Register 119 - 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 'enc' 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 allowable settings for this register are:

*0	Disabled
1	Enabled

S Register 120 - RTS/DCD Framing

S Register 121 - DCD Timeout

The ENC-900 supports two special types of data framing:

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

Input Data Framing is enabled by configuring the Handshaking Parameter as &K2. This type of framing makes use of the S120 parameter as illustrated in Figure 9. Parameter S120 can be set to any value between 0 and 254 ms.

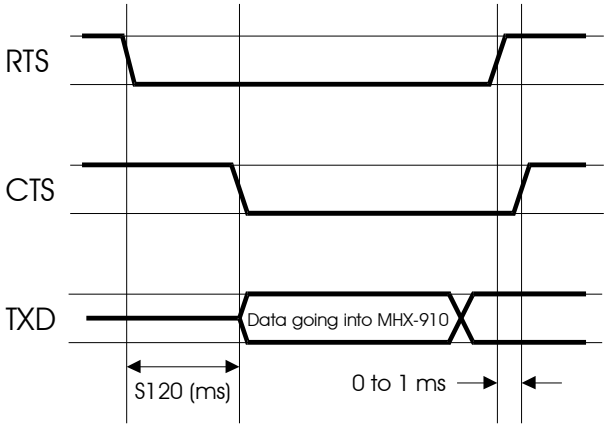


Figure 9 - Input Data Framing

To enable output (DCD) data framing, set the Data Carrier Detect parameter as &C2. This type of framing uses both S120 and S121 registers as shown in Figure 10. Valid ranges for each parameter are 0 to 254 ms

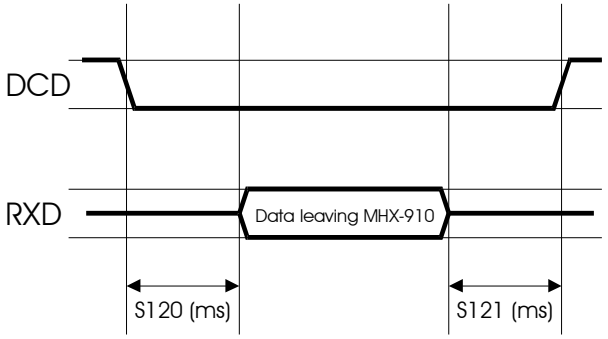


Figure 10 - Output Data Framing

S Register 123 - Remote RSSI Reading

This register displays the average received signal strength in dBm over the previous four hop intervals. In repeater mode, this register is referring the RSSI from last received Remote radios. The value in this register is also reflected in status lines RSSI1,2 and 3.

S Register 124 - Master RSSI Reading

This register will only be used in repeater configuration and display the received signal strength from Master radio.

S Register 213 - Packet Retry Limit

Packet Retry Limit is analogous to Packet Retransmissions, but specifically applies to Remotes and Repeaters. This parameter is not used by the Master. Because the Remote has the advantage of receiving acknowledgements from the Master, it is not necessary to blindly retransmit each packet. If the Remote 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 Remote.

4.4 Diagnostics, Statistics and Remote Control

The ENC-900 provides several commands which are very useful for troubleshooting and analyzing the performance of the radio system.

4.4.1 Spectrum Analyzer Feature (ATG)

Issuing the command ATG <return>,causes the ENC-900 to perform a sweep of the entire operating spectrum, giving a signal strength read-out in dBm for each channel 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  *
```

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.

4.4.2 Statistics (ATP)

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

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

The ENC-900 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.

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 Remote/repeater in the system, users can set the unit address of the master to match that of the Remote/repeater of interest, set S101=5, go online, and interrogate/modify virtually all parameters of the remote repeater/Remote 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 Remote/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 Remote/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 Remote/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 power down 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	Radio Buffer Mode
9(x)	S213	Retry Limit
a	test string	Read back a 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 Remote's retries
k4	statistics	Read # of Remote's packets dropped
k5	statistics	Read # of Remote's sync errors
k6	statistics	Read # of CRC errors
k255	statistics	Clear statistics
l(x)	S124	Master’s RSSI
m(x)	S118	Roaming
o(x)	S119	Quick enter to command
/(x)	S114	Low Current Mode

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 Remote in the network while in diagnostics mode, users can quickly interrogate/modify many different Remote'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
n(x)	-	Remote Hop loading
p	-	Remote IO string read
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
w	S123	Local RSSI
y	-	Remote IO string write
z	S108	Output power level

A. MODEM COMMAND SUMMARY

The following provides a command summary for the ENC-900 module. Factory settings are denoted with a '*'.

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 ModeQ 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
&E	Framing Error Check
	*&E0 Framing Error Check Disabled
	&E1 Framing Error Check Enabled
&F	Load Factory Default
	&F1 Master
	&F2 Remote
	&F3 Repeater
	&F4 Remote 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
3	NO CARRIER
4	ERROR

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 '+'
S101	Operating Mode
	1 - Master Point to Multipoint
	2 - Reserved
	3 - Remote
	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, 12 = 1200
S103	Wireless Link Rate
	*2 = Fast w/o FEC
	4 = Fast with FEC
S104	Network Address [0...255]
S105	Unit Address [1...255]
S106	Primary Hopping Pattern [0...61]
S107	Encryption Key [0...255]
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]
S114	Low Current Mode
	*0 = Disabled, 1 = Enabled
S115	Packet Repeat Interval [1..255]
	Default = 1
S116	Packet Character Timeout [0...254 ms]
S117	Radio Buffer Mode
	*0 = High Throughput, 1 = Quick Turn Around
S118	Roaming
	*0 = Disabled, 1 = Enabled
S119	Quick Enter to Command
	*0 = Disabled, 1 = Enabled
S120	RTS/DCD Framing Interval [0...254 ms]
S121	DCD Timeout [0...254 ms]
S123	Remote RSSI value
S124	Master RSSI value
S206	Secondary Hopping Pattern [0...61]
S213	Packet Retry Limit [0...255]

B. FACTORY DEFAULT SETTINGS

AT&F1 - Master Default Settings

E1, Q0, V1, W0, S0=0, S2=43, S3=13, S4=10, S5=8

DCD	&C2
DTR	&D0
Framing	&E0
Handshaking	&K0
DSR	&S1
Operating Mode	S101=1
Serial Baud Rate	S102=5
Wireless Link Rate	S103=2
Network Address	S104=1
Unit Address	S105=1
Primary Hop Pattern	S106=0
Encryption Key	S107=*****
Output Power	S108=2
Hop Interval	S109=1
Data Format	S110=1
Packet Minimum Size	S111=1
Packet Maximum Size	S112=14
Packet Retransmissions	S113=0
Low Current Mode	S114=0
Packet Repeat Interval	S115=1
Character Timeout (ms)	S116=1
Radio Buffer Mode	S117=0
Roaming	S118=0
Quick Enter to Command	S119=0
RTS/DCD Framing (ms)	S120=5
DCD Timeout (ms)	S121=0
Secondary Hop Pattern	S206=2
Packet Retry Limit	S213=0

AT&F2 - Remote Default Settings

E1, Q0, V1, W0, S0=1, S2=43, S3=13, S4=10, S5=8

DCD	&C2
DTR	&D0
Framing	&E0
Handshaking	&K0
DSR	&S1
Operating Mode	S101=3
Serial Baud Rate	S102=5
Wireless Link Rate	S103=2
Network Address	S104=1
Unit Address	S105=2
Primary Hop Pattern	S106=0
Encryption Key	S107=*****
Output Power	S108=2
Hop Interval	S109=1
Data Format	S110=1
Packet Minimum Size	S111=1
Packet Maximum Size	S112=14
Packet Retransmissions	S113=0
Low Current Mode	S114=0
Packet Repeat Interval	S115=1
Character Timeout (ms)	S116=1
Radio Buffer Mode	S117=0
Roaming	S118=0
Quick Enter to Command	S119=0
RTS/DCD Framing (ms)	S120=5
DCD Timeout (ms)	S121=0
Secondary Hop Pattern	S206=2
Packet Retry Limit	S213=0

AT&F3 - Repeater Default Settings

E1, Q0, V1, W0, S0=1, S2=43, S3=13, S4=10, S5=8

DCD	&C2
DTR	&D0
Framing	&E0
Handshaking	&K0
DSR	&S1
Operating Mode	S101=4
Serial Baud Rate	S102=5
Wireless Link Rate	S103=2
Network Address	S104=1
Unit Address	S105=3
Primary Hop Pattern	S106=0
Encryption Key	S107=*****
Output Power	S108=2
Hop Interval	S109=1
Data Format	S110=1
Packet Minimum Size	S111=1
Packet Maximum Size	S112=14
Packet Retransmissions	S113=0
Low Current Mode	S114=0
Packet Repeat Interval	S115=1
Character Timeout (ms)	S116=1
Radio Buffer Mode	S117=0
Roaming	S118=0
Quick Enter to Command	S119=0
RTS/DCD Framing (ms)	S120=5
DCD Timeout (ms)	S121=0
Secondary Hop Pattern	S206=2
Packet Retry Limit	S213=0

AT&F4 -Remote Through Repeater Default Settings

E1, Q0, V1, W0, S0=1, S2=43, S3=13, S4=10, S5=8

DCD	&C2
DTR	&D0
Framing	&E0
Handshaking	&K0
DSR	&S1
Operating Mode	S101=3
Serial Baud Rate	S102=5
Wireless Link Rate	S103=2
Network Address	S104=1
Unit Address	S105=4
Primary Hop Pattern	S106=2
Encryption Key	S107=*****
Output Power	S108=2
Hop Interval	S109=1
Data Format	S110=1
Packet Minimum Size	S111=1
Packet Maximum Size	S112=14
Packet Retransmissions	S113=0
Low Current Mode	S114=0
Packet Repeat Interval	S115=1
Character Timeout (ms)	S116=1
Radio Buffer Mode	S117=0
Roaming	S118=0
Quick Enter to Command	S119=0
RTS/DCD Framing (ms)	S120=5
DCD Timeout (ms)	S121=0
Secondary Hop Pattern	S206=2
Packet Retry Limit	S213=0

C. TECHNICAL SPECIFICATIONS

Electrical/Physical

Data Interface	Asynchronous Serial Port, TTL Levels
Signals	GND, TX, RX, DCD, DSR, DTR, RTS, CTS
Bandwidth / Data Rate	1200 - 115,200 bps, uncompressed half-duplex, Approx. 50 kbps sustained in intelligent asymmetrical full-duplex transmission mode
Communications Range[1]	30 kilometers (19 miles)
Power Requirements	3.8 VDC, 1 Amp
Typical Power Consumption	900 mA at 1W transmit; 28 mA receive and less than 1mA in sleep
Operating Frequency	902-928 MHz
Sensitivity	-103 dBm
Output Power	1, 10, 100, 1000mW (user-selectable)
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 Rejection	> 40 dB
Out-of-band Rejection	> 80 dB
Dimensions (LxWxH)	1.7” x 1.7” x 0.5” (42 mm x 42 mm x 13 mm)
Operating Environment	Temperature: -40 to +80°C Humidity: 5 to 95%, non-condensing
Storage Temperature	-40 to 90°C

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

D. GLOSSARY

Terminology Used in the ENC-900 Operating 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 Remote 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 *Remote* 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").

Remote 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 Remote 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).

E. APPROVED ANTENNAS

Part Number	Description	Maximum Allowed TX Power
AN-116	2dBi, 900MHz Rubber Duck Antenna Astron, RPTNC	1 W
AN-149	6dBd, 900MHz Omni Directional Antenna Antenex, RPTNC Pigtail	100mW
AN-158	10dBd, 900MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail	100mW

⚠ WARNING:

Change or modifications not expressly approved by Encom Wireless Data Solutions Inc. could void the user's authority to operate the equipment. This device has been tested with MCX and Reverse Polarity TNC connectors with the antennas listed in Appendix A.

Maximum allowed TX power on the radio will be factory reduced if antenna gain higher than 6 dBi is ordered. An ordered antenna will be shipped with the radio module, if a buyer has both modules and substitutes the antennas between the modules or use another type of antenna, EIRP may be exceed. **Violation of FCC regulations can result in severe fines.**