

# Operating Manual

## Pico Series - P900 900MHz Spread Spectrum Modem

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## Important User Information (continued)

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### About This Manual

It is assumed that users of the products described herein have either system integration or design experience, as well as an understanding of the fundamentals of radio communications.

Throughout this 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 noteworthy. Keeping these in mind will simplify or enhance device usage.



#### **Tip**

An idea or suggestion to improve efficiency or enhance usefulness.

## Important User Information (continued)

### Regulatory Requirements

**WARNING**

To satisfy FCC RF exposure requirements for mobile transmitting devices, a separation distance of 23cm or more should be maintained between the antenna of this device and persons during device operation. To ensure compliance, operation at closer than this distance is not recommended. The antenna being used for this transmitter must not be co-located in conjunction with any other antenna or transmitter.

**WARNING**

This device can only be used with antennas designed for use with 900 MHz products. Please contact Microhard Systems Inc. if you need more information or would like to order an antenna.

**MAXIMUM EIRP**

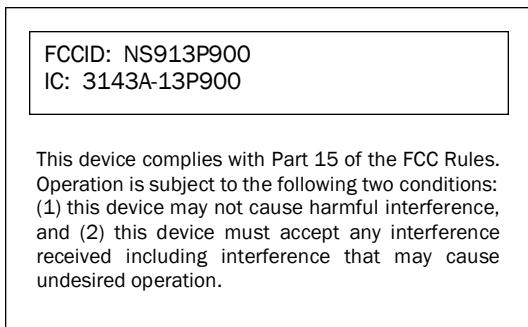
FCC Regulations allow up to 36dBm Effective Isotropic Radiated Power (EIRP). Therefore, the sum of the transmitted power (in dBm), the cabling loss and the antenna gain cannot exceed 36dBm.

**WARNING****EQUIPMENT LABELING**

This device has been modularly approved. The manufacturer, product name, and FCC and Industry Canada identifiers of this product must appear on the outside label of the end-user equipment.

### SAMPLE LABEL REQUIREMENT:

For P900



Please Note: These are only sample labels; different products contain different identifiers. The actual identifiers should be seen on your devices if applicable.

## Revision History

| Revision | Description  | Initials | Date      |
|----------|--|----------|-----------|
| 1.0      | Draft  | PEH      | Mar 2013  |
| 1.1      | Firmware v1.0  | PEH      | Sept 2013 |
| 1.2      | Official Release. Firmware v1.0. Added PTP, PMP Modes  | PEH      | Sept 2013 |
| 1.21     | Added Pad Landing and Solder Mask/Paste diagrams, expanded Mesh description, modified pins descriptions, added AT command firmware upgrade, misc formatting corrections. | PEH      | Sept 2013 |
| 1.22     | Misc Corrections   | PEH      | Feb 2014  |
| 1.3      | Added RS485 Support (S142). Firmware required v1.06.   | PEH      | July 2014 |
| 1.4      | Update for firmware v1.09  | SG/PEH   | Dec 2014  |
| 1.5      | Update for firmware v1.10—Added link rate 57.6 kbps, minor bugs fixed. Added register S225 - Compression (must be set to zero for compatibility with older versions).    | SG/PEH   | Jan 2015  |
| 1.6      | Update for firmware v1.11 - Added link rate 115.2 kbps. Added AT&S3 to enable RS485 driver.  | PEH      | Jan 2015  |
| 1.7      | Update for firmware v1.14 - Removed AT&S3, Added AT&K1 to use CTS to control the Transmitter of RS485 driver chip.   | PEH      | Aug 2015  |
| 1.8      | Added P900-ENC drawings, connectors and LED descriptions   | PEH      | Sept 2015 |
| 1.81     | Added P900-ENC Optional mounting Bracket. Misc updates.  | PEH      | Oct 2015  |
| 1.8.2    | Modified description of S232.  | PEH      | Jan 2016  |
| 1.8.3    | Updated Enclosed DB9 RS232/485 Pins.   | PEH      | Feb 2016  |
| 1.8.4    | Added S159, S177 for AES Encryption  | PEH      | Feb 2016  |
| 1.8.5    | Pin corrections  | PEH      | Feb 2016  |
| 1.8.6    | Added MST reflow and baking instructions, misc corrections.  | PEH      | June 2016 |
| 1.8.7    | Added Pico-MHX Adapter Board   | PEH      | June 2016 |

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## 1.0 Overview

The Pico Series P900 is capable of delivering high-performance wireless serial communications in robust and secure Mesh, Point to Point or Point to Multipoint topologies.

The Pico Series is available as a low cost OEM module, for the ultimate in design integration. When properly configured and installed, long range communications at very high speeds can be achieved.

Pico Series modules operate within the 902-928 MHz ISM frequency band, using frequency hopping spread spectrum (FHSS) technology, providing reliable wireless asynchronous data transfer between most equipment types which employ a serial interface.

The small size and superior performance of the Pico Series makes it ideal for many applications. Some typical uses for this modem:

- SCADA
- remote telemetry
- traffic control
- industrial controls
- remote monitoring
- fleet management
- GPS
- metering
- robotics
- display signs
- railway signaling

### 1.1 Performance Features

Key performance features of the Pico Series include:

- transmission within a public, license-exempt band of the radio spectrum<sup>1</sup> - this means that the modems may be used without access fees or recurring charges (such as those incurred by cellular airtime)
- transparent, low latency link rates up to 276 kbps
- communicates with virtually all serial based devices
- supports a robust true Mesh operation with auto-routing
- wide temperature specification
- maximum allowable transmit power (1 Watt)
- 32 bits of CRC, selectable retransmission and forward error correction
- separate diagnostics port - transparent remote diagnostics and online network control
- ease of installation and configuration - the P900 utilizes a subset of standard AT-style commands, similar to those used by traditional telephone line modems
- 3.3V logic level compatibility

<sup>1</sup>902-928 MHz, which is license-free within North America; may need to be factory-configured differently for some countries, contact Microhard Systems Inc. for details.

## 1.0 Overview

### 1.2 Pico Series P900 Specifications

#### Electrical/General

| <b>Frequency:</b>                  | 902 - 928 MHz   |               |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
|------------------------------------|---|---------------|---------------|---------------|-----------|----------|----------|------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| <b>Spreading Method:</b>           | Frequency Hopping   |               |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| <b>Band Segments:</b>              | Selectable via Freq. Zones  |               |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| <b>Error Detection:</b>            | 32 bits of CRC, ARQ   |               |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| <b>Data Encryption: (Optional)</b> | 128, 196 or 256-bit AES Encryption (Requires export permit outside US and Canada.)  |               |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| <b>Range:</b>                      | 40 miles (60km)   |               |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| <b>Output Power:</b>               | 100mW to 1W (20-30dBm)  |               |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| <b>Sensitivity:</b>                | <table border="1"> <thead> <tr> <th>Link Rate</th> <th><math>10^{-6}</math>BER</th> <th><math>10^{-3}</math>BER</th> </tr> </thead> <tbody> <tr> <td>57.6 kbps</td> <td>-111 dBm</td> <td>-114 dBm</td> </tr> <tr> <td>115.2 kbps</td> <td>-110 dBm</td> <td>-113 dBm</td> </tr> <tr> <td>172 kbps</td> <td>-108 dBm</td> <td>-111 dBm</td> </tr> <tr> <td>230 kbps</td> <td>-107 dBm</td> <td>-110 dBm</td> </tr> <tr> <td>276 kbps</td> <td>-106 dBm</td> <td>-109 dBm</td> </tr> </tbody> </table> | Link Rate     | $10^{-6}$ BER | $10^{-3}$ BER | 57.6 kbps | -111 dBm | -114 dBm | 115.2 kbps | -110 dBm | -113 dBm | 172 kbps | -108 dBm | -111 dBm | 230 kbps | -107 dBm | -110 dBm | 276 kbps | -106 dBm | -109 dBm |
| Link Rate                          | $10^{-6}$ BER   | $10^{-3}$ BER |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| 57.6 kbps                          | -111 dBm  | -114 dBm      |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| 115.2 kbps                         | -110 dBm  | -113 dBm      |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| 172 kbps                           | -108 dBm  | -111 dBm      |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| 230 kbps                           | -107 dBm  | -110 dBm      |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |
| 276 kbps                           | -106 dBm  | -109 dBm      |               |               |           |          |          |            |          |          |          |          |          |          |          |          |          |          |          |



**Caution:** Using a power supply that does not provide proper voltage or current may damage the modem.

#### Environmental

**Operation Temperature:** -40°F(-40°C) to 185°F(85°C)

**Humidity:** 5% to 95% non-condensing

#### Mechanical

|                    |   |
|--------------------|---|
| <b>Dimensions:</b> | Approx: 1.05" (26.5mm) X 1.3" (33mm) X 0.13"(3.5mm) |
| <b>Weight:</b>     | Approx: 5 grams                                     |
| <b>Connectors:</b> | Antenna: UFL<br>Data: 80 Pin/Pad SMT                |

## 2.0 Hardware Description

The Pico Series P900 Modem modules are available as a low cost OEM module. This OEM version supplies all the required raw signals to allow the unit to be tightly integrated into applications to efficiently maximize space and power requirements. The Microhard development board can provide a convenient evaluation platform to test and design with the module. (Contact Microhard Systems for details)

Any P900 Series module may be configured as a Primary Coordinator, Secondary Coordinator, Standby Coordinator or Remote in a Mesh Topology, or a Master, Repeater or Remote in a PP or PMP Topology. This versatility is very convenient from a 'sparing' perspective, as well for convenience in becoming familiar and proficient with using the module: if you are familiar with one unit, you will be familiar with all units.



Image 2-1: Pico P900 Top View

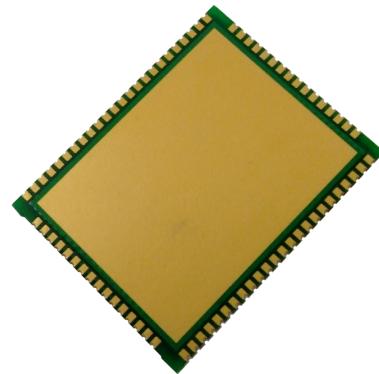
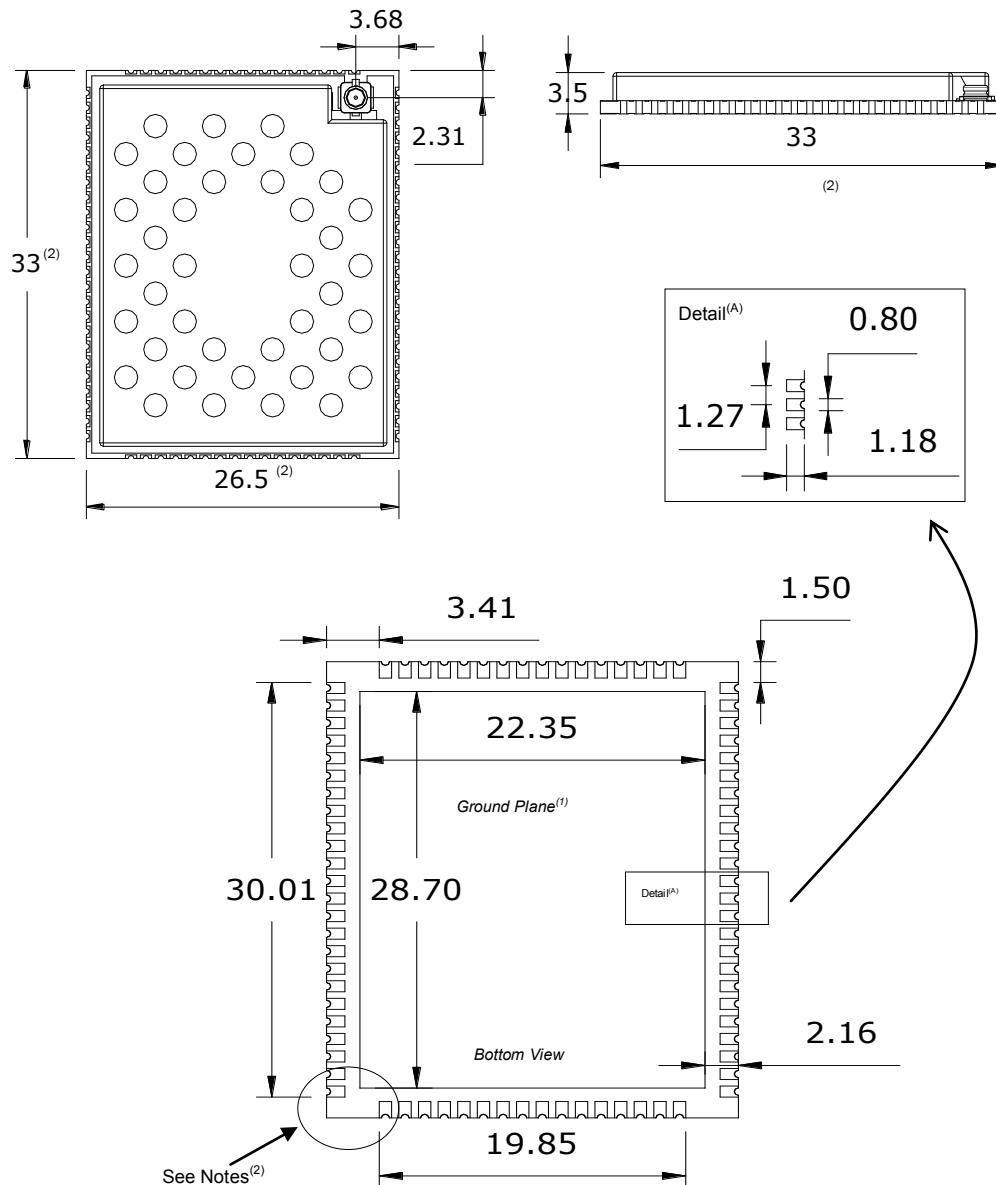


Image 2-2: Pico P900 Bottom View

## 2.0 Hardware Description

### 2.1 Mechanical Drawings

The P900 OEM Modules have an extremely small form factor as seen in *Drawing 3-3 below*.

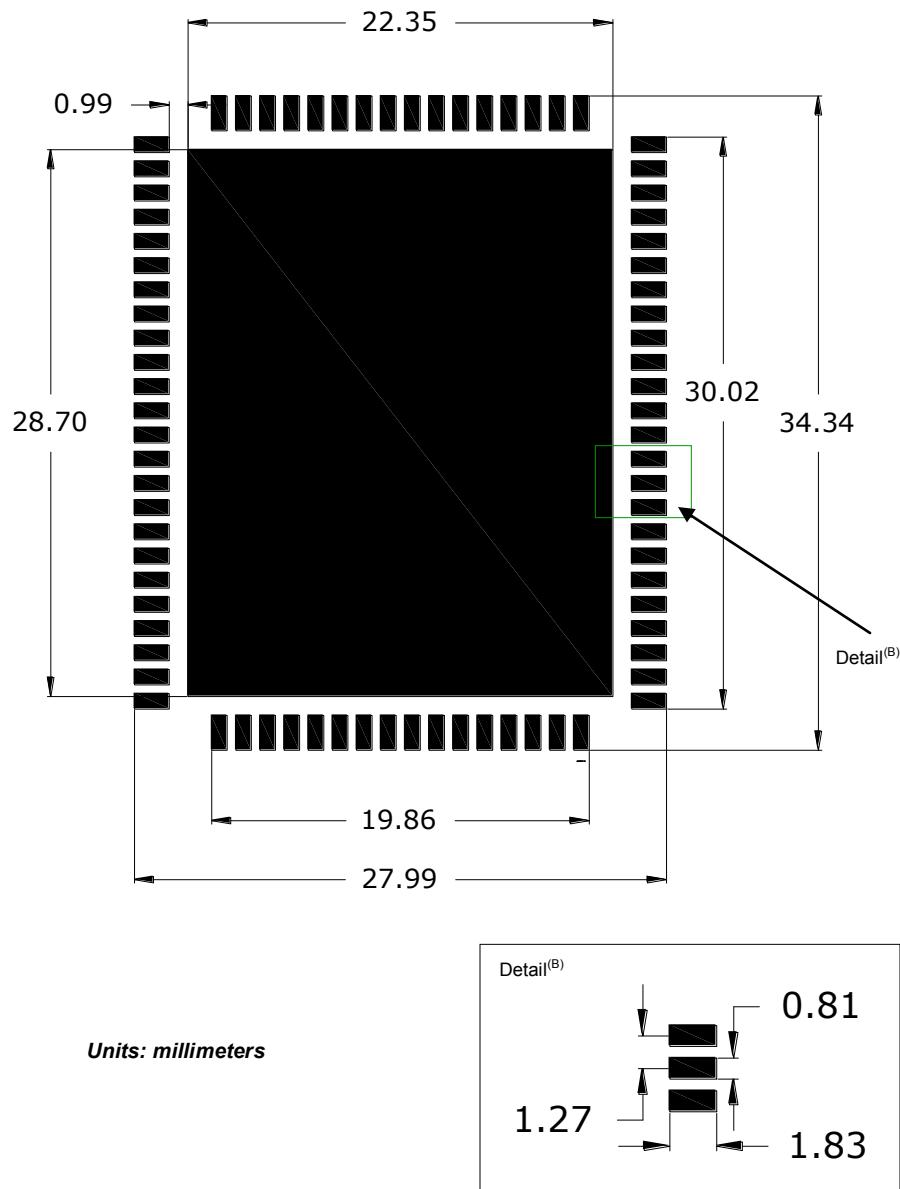


1. Ground plane must be connected to GND for required heat dissipation.
2. Due to manufacturing methods additional PCB material may be present on the corners that cannot be removed. Designs should allow for a small tolerance of this additional material,  $\pm 0.25\text{mm}$ .

*Drawing 2-1: P900 OEM Mechanical*

## 2.0 Hardware Description

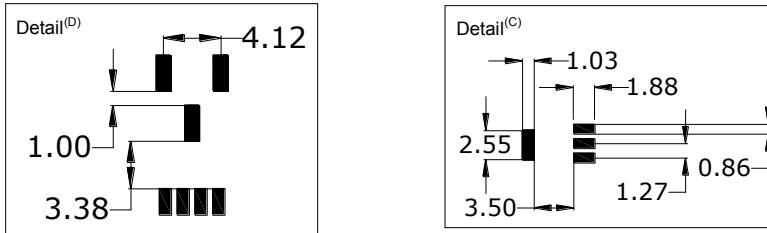
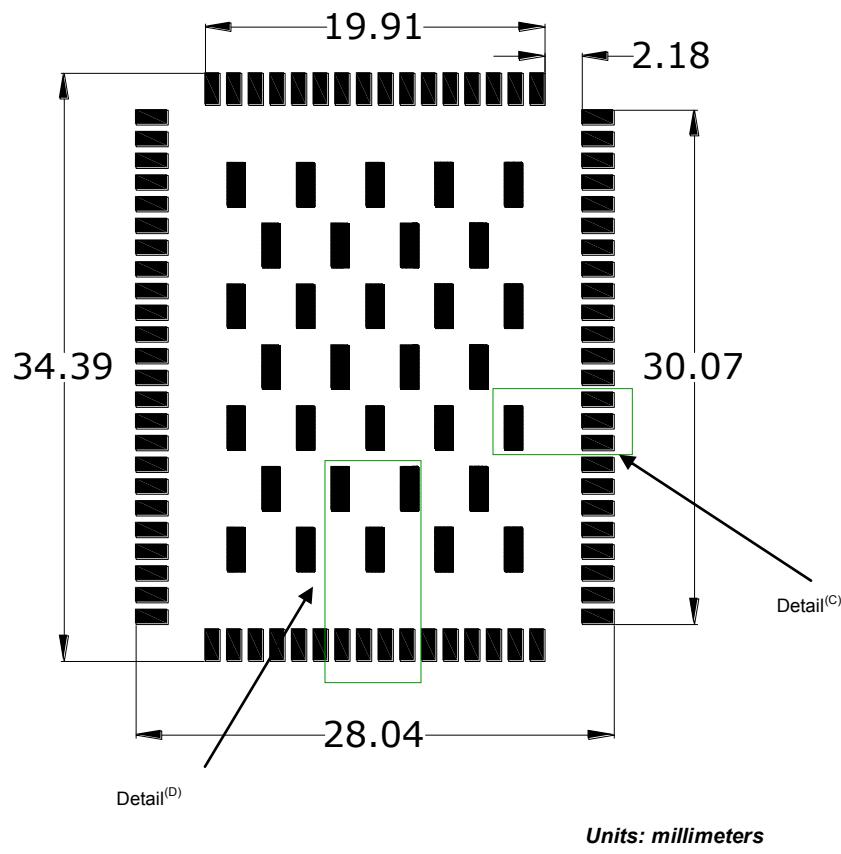
### 2.1.1 Recommended Solder Mask (Pad Landing)



Drawing 2-2: P900 Recommended Solder Mask

## 2.0 Hardware Description

### 2.1.2 Recommended Solder Paste Pattern



Drawing 2-3: P900 Recommended Solder Paste

### 2.1.3 OEM Connectors

#### Antenna

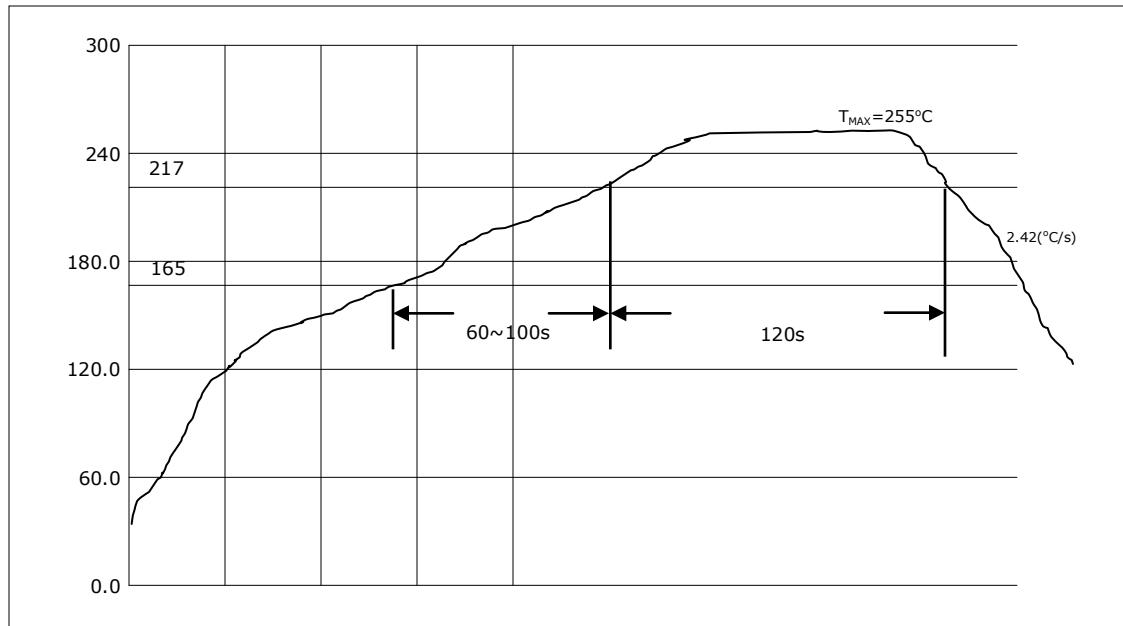
All P900 OEM Modules use an UFL connector for the antenna connection.

#### Data

The interface to the P900 OEM module is a tight integration using 80 pad SMT connections.

## 2.0 Hardware Description

### 2.1.4 SMT Temperature Profile



Drawing 2-4: Reflow Profile

| Temperature Zone                | Time                                | Parameter                      |
|---------------------------------|-------------------------------------|--------------------------------|
| Preheat zone:<br>(40°C - 165°C) | -                                   | Heating rate:<br>0.5°C/s-2°C/s |
| Soak Zone:<br>(165°C - 217°C)   | 60 - 100s                           | -                              |
| Reflow zone:<br>(>217°C)        | 120s                                | Peak reflow:<br>255°C          |
| Cooling zone                    | Cooling rate: 2°C/s ≤ Slope ≤ 5°C/s |                                |

Table 2-1: Reflow Parameters

| Zone | Temperature (°C) |
|------|------------------|
| 1    | 120              |
| 2    | 140              |
| 3    | 160              |
| 4    | 180              |
| 5    | 215              |
| 6    | 255              |
| 7    | 255              |
| 8    | 255              |
| 9    | 250              |
| 10   | 130              |

Chain Speed: 60cm/min

Table 2-2: Oven Temperature Profile

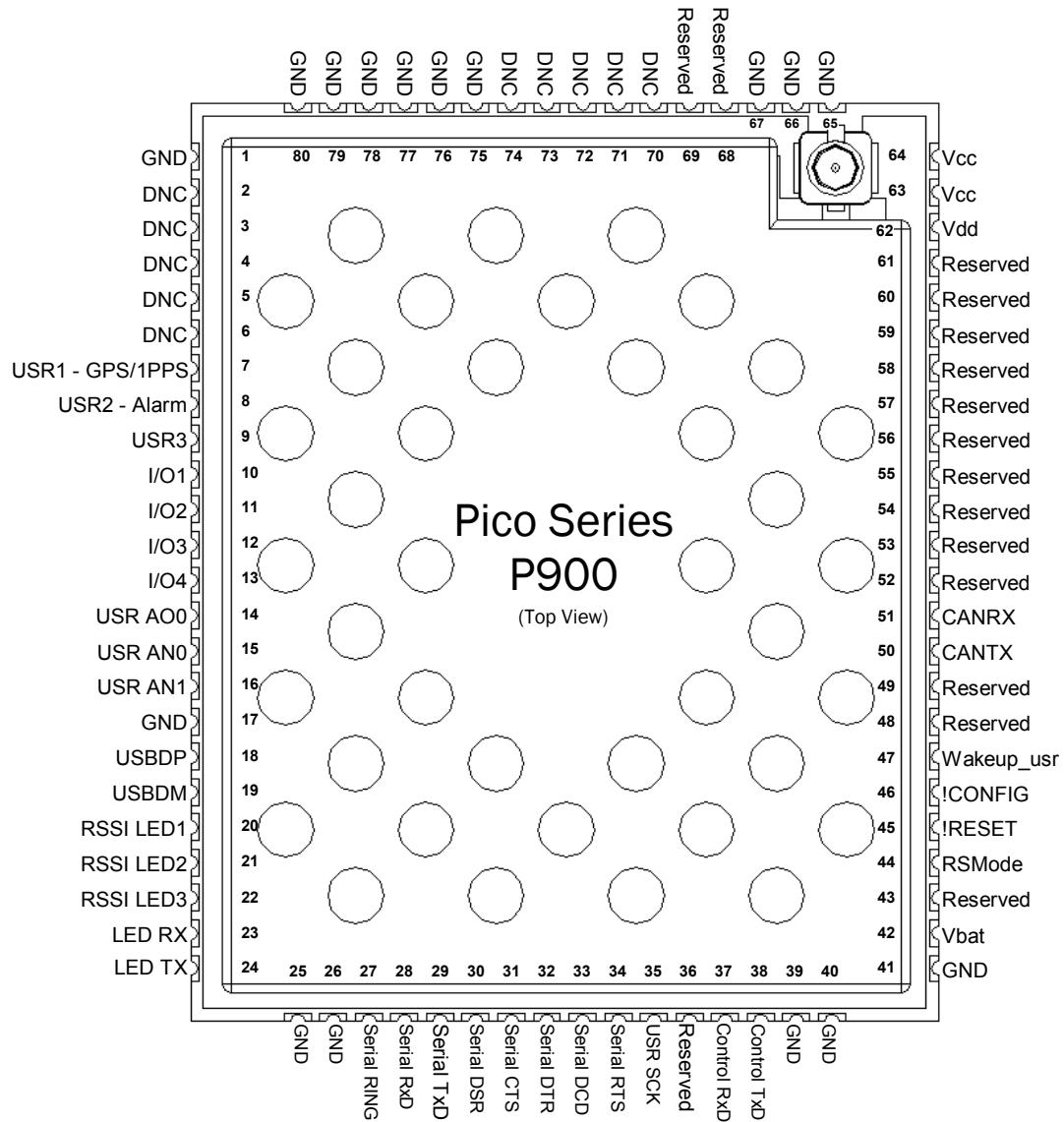
### 2.1.5 SMT Baking Instructions (MSL)

The P900 OEM modules must be baked before mounting, the following baking instruction should be followed for the best results:

- Minimum of 8 to 12 hours at 125°C +/- 5°C for high-temperature device containers.
- Unused modules should be stored at ≤ 10% RH

## 2.0 Hardware Description

### 2.2 Pico OEM Pin Descriptions



Drawing 2-5: Pico P900 80-pin OEM Connection Info

Inputs and outputs are 3.3V nominal (3.0V min — 3.6V max) unless otherwise specified.

The above drawing depicts a top view of the P900-OEM Module. The corner pads (1, 25, 41, and 65) are printed directly on the bottom of the PCB for easy identification.

A full description of the connections and function of each pin is provided on the pages that follow.

## 2.0 Hardware Description



**Caution:** During power up or reset, output pins from the Pico are in an unknown state. It is advised to use pull up or pull down resistors as appropriate.

| Pin Name           | No.                          | Description   | Dir |
|--------------------|------------------------------|---|-----|
| GND                | 1,17,25-26,39-41,65-67,75-80 | Ground reference for logic, radio, and I/O pins.  |     |
| DNC                | 2,3,4,5,6                    | Reserved for factory use only.  |     |
| USR1 – GPS/1PPS    | 7                            | <i>*Currently Not Supported. For Future Expansion*</i>  | I   |
| USR2 - Alarm       | 8                            | <i>*Reserved for future use.*</i>   | O   |
| USR3               | 9                            | <i>*Reserved for future use.*</i>   | O   |
| I/O 1,2            | 10,11                        | Digital Outputs. 3.3 V Output @ 3mA maximum.  | O   |
| I/O3,4             | 12,13                        | Future Use  | I/O |
| USR_ANO0           | 14                           | <i>*Currently Not Supported. For Future Expansion*</i>  | O   |
| USR_AN0<br>USR_AN1 | 15<br>16                     | Analog Inputs. 0 to 3V input, 12 bit.   | I   |
| USBDP              | 18                           | <i>*Currently Not Supported. For Future Expansion*</i>  |     |
| USBDM              | 19                           | <i>*Currently Not Supported. For Future Expansion*</i>  |     |
| LED_1 (RSSI1)      | 20                           | Receive Signal Strength Indicator 1. Active high, cannot drive LED directly. Requires current limiting resistor. 8mA maximum.   | O   |
| LED_2 (RSSI2)      | 21                           | Receive Signal Strength Indicator 2. Active high, cannot drive LED directly. Requires current limiting resistor. 8mA maximum.   | O   |
| LED_3 (RSSI3)      | 22                           | Receive Signal Strength Indicator 3. Active high, cannot drive LED directly. Requires current limiting resistor. 8mA maximum.   | O   |
| LED_RX             | 23                           | Active high output indicates receive and synchronization status. Active high, cannot drive LED directly. Requires current limiting resistor. 8mA maximum.   | O   |
| LED_TX             | 24                           | Active high output indicates module is transmitting data over the RF channel. Active high, cannot drive LED directly. Requires current limiting resistor. 8mA maximum.  | O   |
| Serial RING        | 27                           | Internally connected to GND through a 22kΩ resistor. <i>In RS485 modes the RING line is set high and is normally used to enable the receiver of the RS485 driver.</i>   | O   |
| Serial RxD         | 28                           | Receive Data. Logic level input into the modem. It is recommended to wire this pin out through a zero ohm resistor to a header and jumper block for external access to the serial port for modem recovery procedures.   | I   |
| Serial TxD         | 29                           | Transmit Data. Logic level Output from the modem. It is recommended to wire this pin out through a zero ohm resistor to a header and jumper block for external access to the serial port for modem recovery procedures. | O   |
| Serial DSR         | 30                           | Data Set Ready. Active low output. <i>The DSR line may be used to enable the transmitter of the RS485 driver chip.</i>  | O   |
| Serial CTS         | 31                           | Clear To Send. Active low output. <i>The CTS line may be used to enable the transmitter of the RS485 driver chip.</i>   | O   |
| Serial DTR         | 32                           | Data Terminal Ready. Active low input.  | I   |
| Serial DCD         | 33                           | Data Carrier Detect. Active low output.   | O   |
| Serial RTS         | 34                           | Request To Send. Active low input.  | I   |
| USR SCK            | 35                           | <i>*Currently Not Supported. For Future Expansion*</i>  | I   |

Table 2-3: Pico Series Pin Description

## 2.0 Hardware Description



**Caution:** During power up or reset, output pins from the Pico are in an unknown state. It is advised to use pull up or pull down resistors as appropriate.

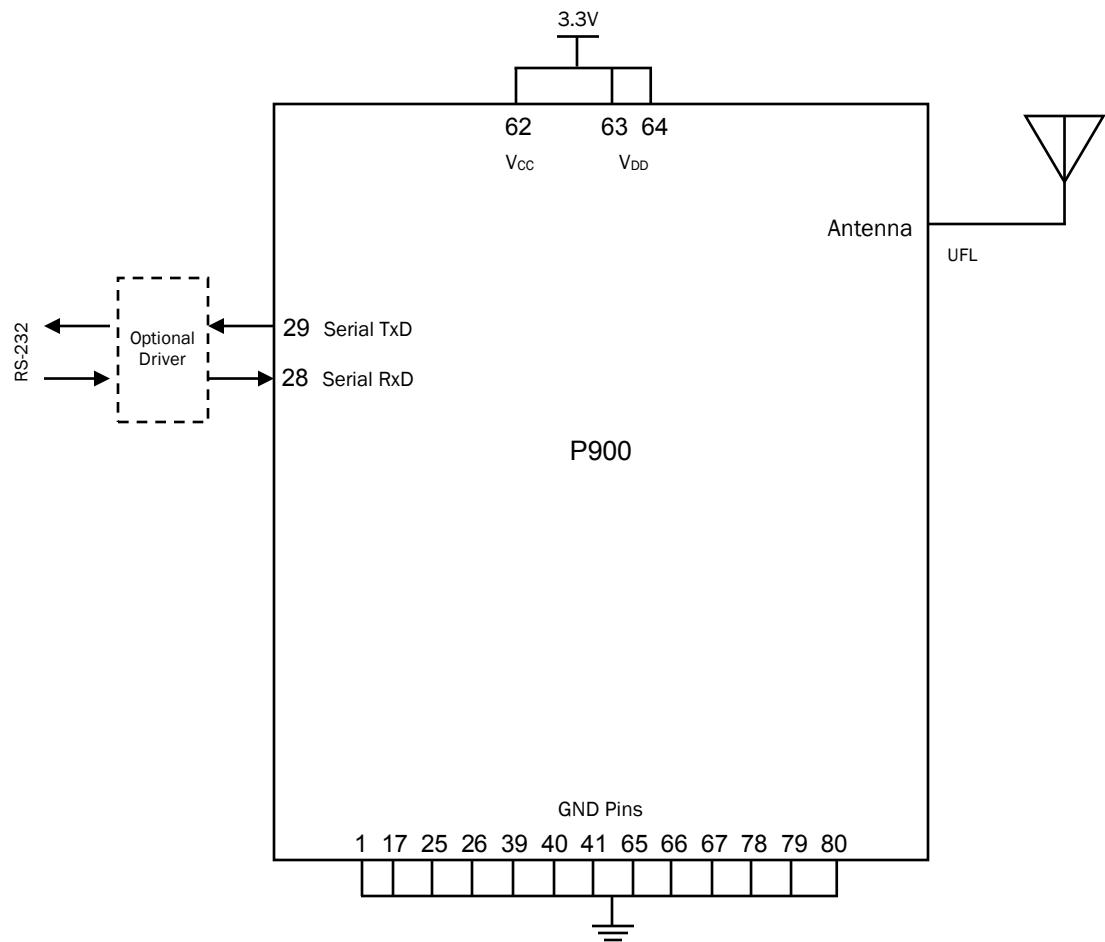
| Pin Name    | No.   | Description   | Dir |
|-------------|-------|---|-----|
| Reserved    | 36    | *Reserved for future use.*  |     |
| Control RxD | 37    | Diagnostics receive data. Logic level input from a PC to the module.  | I   |
| Control TxD | 38    | Diagnostics transmit data. Logic level output from module to a PC.  | O   |
| Vbat        | 42    | Input voltage sensing analog input line, up to 60VDC maximum. Used to measure the main supply voltage. User design must add a 10kΩ 1% 1/16W resistor in series. | I   |
| Reserved    | 43    | *Reserved for future use.*  |     |
| RSMode      | 44    | <i>Internally connected to GND through a 10kΩ resistor. *Reserved for future use.*</i>  | O   |
| !RESET      | 45    | Active low input will reset the module.   | I   |
| !CONFIG     | 46    | Active low input signal to put module into default serial interface (RS232) and default baud rate (9600/8/N/1) during power up. Pull high or leave floating.    | I   |
| !Wakeup_usr | 47    | Active high input used to wake the model from sleep mode.   | I   |
| Reserved    | 48    | *Reserved for future use.*  |     |
| Reserved    | 49    | *Reserved for future use.*  |     |
| CANTX       | 50    | *Currently Not Supported. For Future Expansion*   |     |
| CANRX       | 51    | *Currently Not Supported. For Future Expansion*   |     |
| Reserved    | 52-61 | *Reserved for future use.*  |     |
| Vdd         | 62    | Positive voltage supply voltage for the digital section of the module (3.3V).   | I   |
| Vcc         | 63,64 | Positive voltage supply voltage for the radio module (3.3V). The Vcc lines are internally connected together.   | I   |
| Reserved    | 68,69 | *Reserved for future use.*  |     |
| DNC         | 70-74 | Reserved for factory use only.  |     |

Table 2-3: Pico Series Pin Description (continued)

All serial communications signals are logic level (0 and 3.3V). DO NOT connect RS-232 level (+12, -12VDC) signals to these lines without shifting the signals to logic levels.

## 2.0 Hardware Description

### 2.3 Minimum Connection Requirements



*Drawing 2-6: P900 Minimum Connection Block Diagram*

## 2.0 Hardware Description

### 2.4 Electrical Characteristics

#### 2.4.1 Test Conditions

Unless otherwise specified, all voltages are referenced to  $V_{ss}$ (GND).

#### 2.4.1 Minimum and Maximum Values

Unless otherwise specified the minimum and maximum values are guaranteed in the worst conditions of ambient temperature, supply voltage and frequencies.

Data based on characterization results, design simulation and/or technology characteristics are indicated in the table footnotes and are not tested in production. Based on characterization, the minimum and maximum values refer to sample tests and represent the mean value plus or minus three times the standard deviation (mean $\pm 3\sigma$ ).

#### 2.4.1.2 Typical Values

Unless otherwise specified, typical data are based on  $T_A = 25^\circ\text{C}$ ,  $V_{DD} = 3.3\text{ V}$ . They are given only as design guidelines and are not tested.

Typical ADC accuracy values are determined by characterization of a batch of samples from a standard diffusion lot over the full temperature range, where 95% of the devices have an error less than or equal to the value indicated (mean $\pm 2\sigma$ ).

#### 2.4.1.3 Loading Capacitor

The loading conditions used for pin parameter measurement are shown in **Figure 2-1**.

#### 2.4.1.4 Pin Input Voltage

The input voltage measurement on a pin of the Pico is described in **Figure 2-2**.

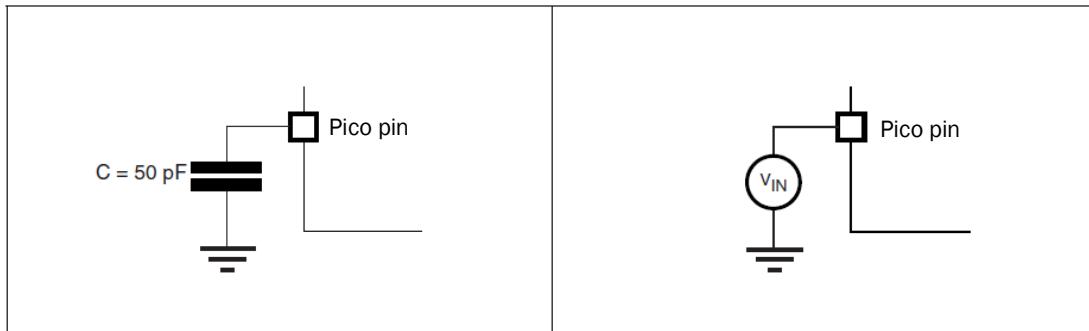


Figure 2-1 Pin Loading Conditions

Figure 2-2 Pin Input Voltage

## 2.0 Hardware Description

### 2.4.2 Absolute Maximum Ratings

Stresses above the absolute maximum ratings listed in **Table 2-2: Voltage Characteristics** and **Table 2-3: Current Characteristics** may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

| Symbol          | Ratings                       | Min  | Max          | Unit |
|-----------------|-------------------------------|------|--------------|------|
| $V_{CC}/V_{DD}$ | External main supply voltage. | 0    | 3.8          | V    |
| $V_{IN}$        | Input voltage on any pin.     | -0.3 | $V_{DD}+0.3$ |      |

Table 2-4 Voltage Characteristics

| Symbol    | Ratings  | Max | Unit |
|-----------|--|-----|------|
| $I_{VDD}$ | Total current into Pico Series (source).           | 70  | mA   |
| $I_{VSS}$ | Total current out of Pico Series (sink).           | 70  |      |
| $I_{IO}$  | Output current sunk by any I/O and control pin.    | 20  |      |
|           | Output Current sourced by any I/O and control pin. | -8  |      |

Table 2-5 Current Characteristics

### 2.4.3 Operating Conditions

#### 2.4.3.1 Operating Conditions at Power-up / Power-down

The parameters given in **Table 2-4: Operating Conditions at Power-up/ Power-down** are derived from tests performed under the ambient temperature ratings of the Pico Series.

| Symbol    | Parameter                | Min | Max      | Unit      |
|-----------|--------------------------|-----|----------|-----------|
| $t_{VDD}$ | $V_{DD}$ rise time rate. | 0   | $\infty$ | $\mu s/V$ |
|           | $V_{DD}$ fall time rate. | 20  | $\infty$ |           |

Table 2-6 Operating Conditions at Power-up/Power-down

#### 2.4.3.2 Operating Conditions Voltage Characteristics

The parameters given in **Table 2-5: Operating Conditions Voltage Characteristics** are derived from tests performed under the ambient temperature ratings of the Pico Series.

| Symbol   | Ratings                          | Min                | Max | Unit |
|----------|----------------------------------|--------------------|-----|------|
| $V_{CC}$ | External radio supply voltage.   | 3.3 <sup>(1)</sup> | 3.6 | V    |
| $V_{DD}$ | External digital supply voltage. | 3.0                | 3.6 |      |

Table 2-7 Operating Conditions Voltage Characteristics

1. The modem will not be able to transit at full power if  $V_{CC}$  is less than 3.3VDC.

## 2.0 Hardware Description

### 2.4.3.3 Operating Conditions Current Characteristics

The parameters given in **Table 2-6: Operating Conditions Current Characteristics** are derived from tests performed under the ambient temperature ratings of the Pico Series. Test conditions measured while  $V_{CC} = 3.3V$ ,  $V_{DD} = 3.3V$ , Frequency 915MHz and ambient temperature of  $25^{\circ}C$ .

| Symbol            | Ratings                       | Min | Typ  | Max  | Unit |
|-------------------|-------------------------------|-----|------|------|------|
| $I_{VCC(TX)}$     | Radio current 100% TX @ 1W    |     | 1250 | 1500 | mA   |
| $I_{VCC(TX)}$     | Radio current 100% TX @ 500mW |     | 375  | 500  |      |
| $I_{VCC(TX)}$     | Radio current 100% TX @ 100mW |     | 180  | 250  |      |
| $I_{VCC(RX)}$     | Radio current 100% RX @ 1W    |     | 75   | 100  |      |
| $I_{VCC(RX-RUN)}$ | Radio RX running              |     | 40   | 75   |      |
| $I_{VCC(IDLE)}$   | Radio Idle current            |     | 2.5  | 3.5  |      |
| $I_{VDD(RUN)}$    | Digital current               |     | 45   | 50   |      |
| $I_{VDD(IDLE)}$   | Digital idle current          |     | 5    |      |      |

Table 2-8 Operating Conditions Current Characteristics

### 2.4.3.4 I/O Port Characteristics

#### General Input / Output Characteristics

The parameters given in **Table 2-7: I/O Static Characteristics** are derived from tests performed under the ambient temperature ratings of the Pico Series. All I/Os are CMOS and TTL compliant. I/O's refer to all input and outputs of the Pico Series.

| Symbol    | Parameter  | Conditions                       | Min           | Typ | Max           | Unit      |
|-----------|--|----------------------------------|---------------|-----|---------------|-----------|
| $V_{IL}$  | Input low level voltage                              | TTL ports                        | -0.5          |     | 0.8           | V         |
| $V_{IH}$  | Input high level voltage                             |                                  | 2             |     | $V_{DD}+0.5$  |           |
| $V_{IL}$  | Input low level voltage                              | CMOS ports                       | -0.5          |     | $0.35 V_{DD}$ | V         |
| $V_{IH}$  | Input high level voltage                             |                                  | $0.65 V_{DD}$ |     | $V_{DD}+0.5$  |           |
| $V_{hys}$ | IO Schmitt trigger voltage hysteresis <sup>(1)</sup> |                                  | 200           |     |               | mV        |
| $I_{lk}$  | Input leakage current                                | $V_{SS} \leq V_{IN} \leq V_{DD}$ |               |     | $\pm 1$       | $\mu A$   |
| $R_{PU}$  | Weak pull-up equivalent resistor <sup>(2)</sup>      | $V_{IN} = V_{SS}$                | 30            | 40  | 50            | $k\Omega$ |
| $R_{PD}$  | Weak pull-down equivalent resistor <sup>(2)</sup>    | $V_{IN} = V_{DD}$                | 30            | 40  | 50            |           |
| $C_{IO}$  | I/O pin capacitance                                  |                                  |               | 8   |               | pF        |

1. Hysteresis voltage between Schmitt trigger switching levels. Based on characterization, not tested in production.
2. Pull-up and pull-down resistors can be used on input/output pins.

Table 2-9 I/O Static Characteristics

## 2.0 Hardware Description

### Output Driving Current

The GPIOs (general purpose input/outputs) can sink or source up to  $+-8$  mA, and sink  $+20$  mA (with a relaxed  $V_{OL}$ ).

In the user application, the number of I/O pins which can drive current must be limited to respect the absolute maximum rating specified in **Section 2.5.2**:

- The sum of the currents sourced by all the I/Os on VDD cannot exceed the absolute maximum rating  $I_{VDD}$  (see **Table 2-3**).
- The sum of the currents sunk by all the I/Os on VSS cannot exceed the absolute maximum rating  $I_{VSS}$  (see **Table 2-3**).

### Output Voltage Levels

Unless otherwise specified, the parameters given in **Table 2-8** are derived from tests performed under ambient temperature and  $V_{DD}$  supply voltage ratings of the Pico Series. All I/Os are CMOS and TTL compliant.

| Symbol            | Parameter   | Conditions                    | Min          | Max | Unit |
|-------------------|---|-------------------------------|--------------|-----|------|
| $V_{OL}^{(1)}$    | Output low level voltage for an I/O pin when 8 pins are sunk at same time     | TTL port<br>$I_{IO} = +8$ mA  |              | 0.4 | V    |
| $V_{OH}^{(2)}$    | Output high level voltage for an I/O pin when 8 pins are sourced at same time |                               | $V_{DD}-0.4$ |     |      |
| $V_{OL}^{(1)}$    | Output low level voltage for an I/O pin when 8 pins are sunk at same time     | CMOS port<br>$I_{IO} = +8$ mA |              | 0.4 | V    |
| $V_{OH}^{(2)}$    | Output high level voltage for an I/O pin when 8 pins are sourced at same time |                               | 2.4          |     |      |
| $V_{OL}^{(1)(3)}$ | Output low level voltage for an I/O pin when 8 pins are sunk at same time     | $I_{IO} = +20$ mA             |              | 1.3 | V    |
| $V_{OH}^{(2)(3)}$ | Output high level voltage for an I/O pin when 8 pins are sourced at same time |                               | $V_{DD}-1.3$ |     |      |

1. The  $I_{IO}$  current sunk by the device must always respect the absolute maximum rating specified in **Table 2-3** and the sum of  $I_{IO}$  (I/O ports and control pins) must not exceed  $I_{VSS}$ .
2. The  $I_{IO}$  current sourced by the device must always respect the absolute maximum rating specified in **Table 2-3** and the sum of  $I_{IO}$  (I/O ports and control pins) must not exceed  $I_{VDD}$ .
3. Based on characterization data, not tested in production.

Table 2-10 Output Voltage Characteristics

### Input / Output AC Characteristics

The values of input/output AC characteristics are given in Table 2-9.

| Symbol          | Parameter   | Conditions   | Min | Max | Unit |
|-----------------|---|--------------|-----|-----|------|
| $t_{f(I/O)out}$ | Output high to low fall time                        | $CL = 50$ pF |     | 125 | ns   |
| $t_{r(I/O)out}$ | Output low to high level rise time                  |              |     | 125 |      |
| $t_{EXTpw}$     | Pulse width of external signals used as interrupts. |              | 1   |     | ms   |

Table 2-11 Input / Output AC Characteristics

## 2.0 Hardware Description

### NRST Pin Characteristics

The NRST pin input driver uses CMOS technology. It is connected to a permanent pull-up resistor, RPU (see **Table 2-7**).

| Symbol          | Parameter                               | Conditions      | Min  | Typ | Max          | Unit       |
|-----------------|---|-----------------|------|-----|--------------|------------|
| $V_{IL(NRST)}$  | NRST Input low level voltage            |                 | -0.5 |     | 0.7          | V          |
| $V_{IH(NRST)}$  | NRST Input high level voltage           |                 | 2    |     | $V_{DD}+0.5$ |            |
| $V_{hys(NRST)}$ | NRST Schmitt trigger voltage hysteresis |                 |      | 200 |              | mV         |
| $R_{PU}$        | Weak pull-up equivalent resistor        | $V_{IN}=V_{SS}$ | 30   | 40  | 50           | k $\Omega$ |
| $V_{NF}$        | NRST Input pulse                        |                 | 300  |     |              | ns         |

Table 2-12 NRST Pin Characteristics

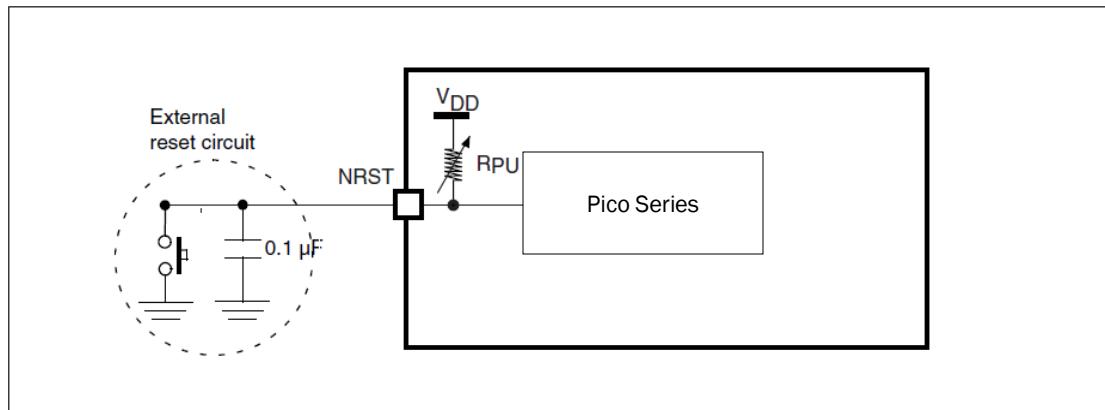


Figure 2-3 Recommended NRST Pin Protection

#### 2.4.3.5 12-bit ADC Characteristics

The parameters given in **Table 2-11: ADC Characteristics** are derived from tests performed under the ambient temperature and supply voltage ratings of the Pico Series.

| Symbol    | Parameter                | Min | Max | Unit       |
|-----------|--------------------------|-----|-----|------------|
| $V_{AIN}$ | Conversion voltage range | 0   | 3.0 | V          |
| $R_{AIN}$ | External input impedance | 0   | 1.2 | k $\Omega$ |

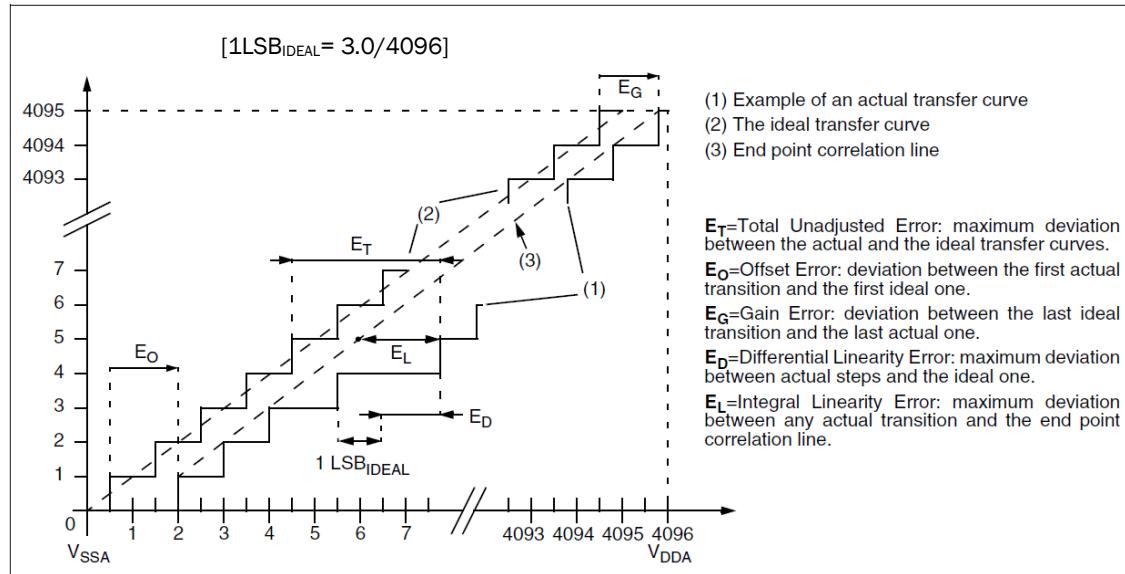
Table 2-13 12-bit ADC Characteristics

| Symbol | Parameter                    | Test Conditions    | Typ | Max | Unit |
|--------|------------------------------|--------------------|-----|-----|------|
| ET     | Total unadjusted error       | $T_A = 25^\circ C$ | 1.3 | 2   | LSB  |
| EO     | Offset error                 |                    | 1   | 1.5 |      |
| EG     | Gain error                   |                    | 0.5 | 1.5 |      |
| ED     | Differential linearity error |                    | 0.7 | 1   |      |
| EL     | Integral linearity error     |                    | 0.8 | 1.5 |      |

Table 2-14 ADC Accuracy

## 2.0 Hardware Description

### ADC Accuracy Characteristics



## 2.0 Hardware Description

### 2.5 P900 to Nano n920 Pin-Outs

The following table shows a pin-out comparison between the P900 and the n920. This table may be useful for customers who current have the n920 who wish to migrate to the P900 platform.



For detailed pin descriptions refer to Section 2.3 Pin Description.

| Pin Name      | P900 Pin No. | n920 Pin No.   | Description   |
|---------------|--------------|----------------|---|
| USR1          | 7            | 35             | *Currently Not Supported. For Future Expansion*                               |
| USR2          | 8            | 37             | *Reserved for future use.*  |
| USR3          | 9            | 39             | *Reserved for future use.*  |
| USR_AN0       | 15           | 9              | Analog Input 0. *Future Use.*   |
| USBDP         | 18           | 25             | *Currently Not Supported. For Future Expansion*                               |
| USBDM         | 19           | 21             | *Currently Not Supported. For Future Expansion*                               |
| LED_1 (RSSI1) | 20           | 30             | Receive Signal Strength Indicator 1.  |
| LED_2 (RSSI2) | 21           | 28             | Receive Signal Strength Indicator 2.  |
| LED_3 (RSSI3) | 22           | 26             | Receive Signal Strength Indicator 3.  |
| LED_RX        | 23           | 22             | Active high output indicates receive and synchronization status.              |
| LED_TX        | 24           | 24             | Active high output indicates module is transmitting RF data.                  |
| Serial RING   | 27           | 38             | *Reserved for future use.*  |
| Serial RxD    | 28           | 42             | Receive Data. Logic level input into the modem.                               |
| Serial TxD    | 29           | 44             | Transmit Data. Logic level Output from the modem.                             |
| Serial DSR    | 30           | 36             | Data Set Ready. Active low output.  |
| Serial CTS    | 31           | 32             | Clear To Send. Active low output.   |
| Serial DTR    | 32           | 40             | Data Terminal Ready. Active low input.  |
| Serial DCD    | 33           | 46             | Data Carrier Detect. Active low output.                                       |
| Serial RTS    | 34           | 34             | Request To Send. Active low input.  |
| USR SCK       | 35           | 50             | *Currently Not Supported. For Future Expansion*                               |
| Control RxD   | 37           | 20             | Diagnostics receive data.   |
| Control TxD   | 38           | 18             | Diagnostics transmit data.  |
| Vbat          | 42           | 17             | Battery Voltage sensing analog input line.                                    |
| RSMODE        | 44           | 19             | *Reserved for future use.*  |
| !RESET        | 45           | 15             | Active low input will reset the module.                                       |
| !CONFIG       | 46           | 13             | Active low input signal to put module into default serial mode.               |
| Wakeup_usr    | 47           | 11             | Active high input used to wake the model from sleep mode.                     |
| !Bootpgm_mode | 48           | 7              | *Reserved for future use.*  |
| CANTX         | 50           | 12             | *Currently Not Supported. For Future Expansion*                               |
| CANRX         | 51           | 10             | *Currently Not Supported. For Future Expansion*                               |
| Vdd           | 62           | 51,53,55,57,59 | Positive voltage supply voltage for the digital section of the module (3.3V). |
| Vcc           | 63,64        |                | Positive voltage supply voltage for the radio module (3.3V).                  |
| Vcc2          | 75,76,77     | N/A            | *Reserved for future use.*  |

Table 2-15: P900 to Nano n920 Pin Description

## 2.0 Hardware Description

### 2.6 P900 Enclosed

The Pico Enclosed provides a standalone P900 with standard interfaces for Data, Power and Antennas. The P900 Enclosed is ideal for base stations or applications where complicated integration of the OEM module is not required, but a modem with a small footprint is still required. The P900 Enclosed can also be used to quickly evaluate the features and performance of the P900 modems.

The P900 Enclosed provides quick access to several of the interfaces of the P900, such as:

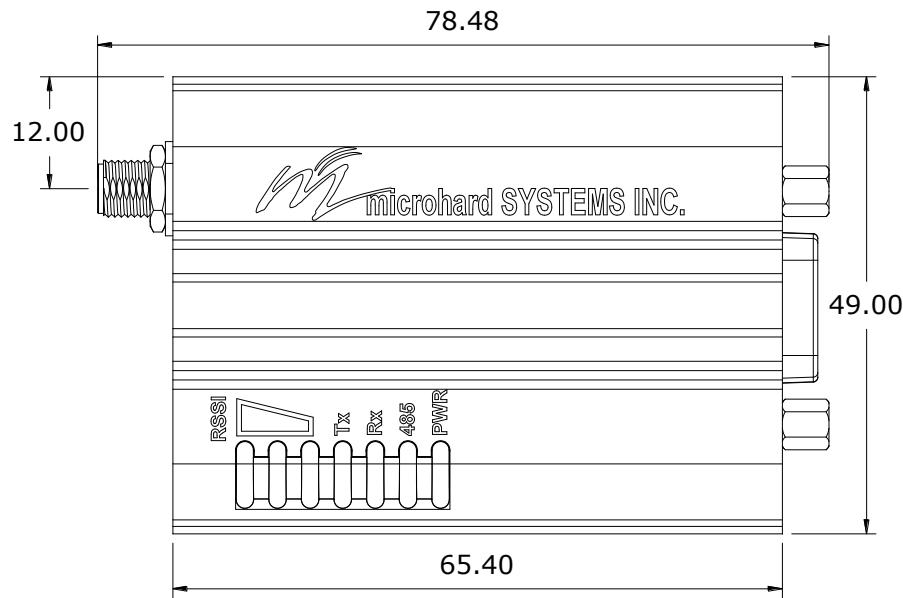
- Input Power (9-30VDC)
- Power LED (Blue)
- RS232/RS485 Data Interface
- RSSI LED Indicators (Green)
- TX/RX LED Indicators (Red/Green)
- CONFIG Button
- Antenna
- USB Port (Diagnostic Port)
- I/O pins (Future Development)



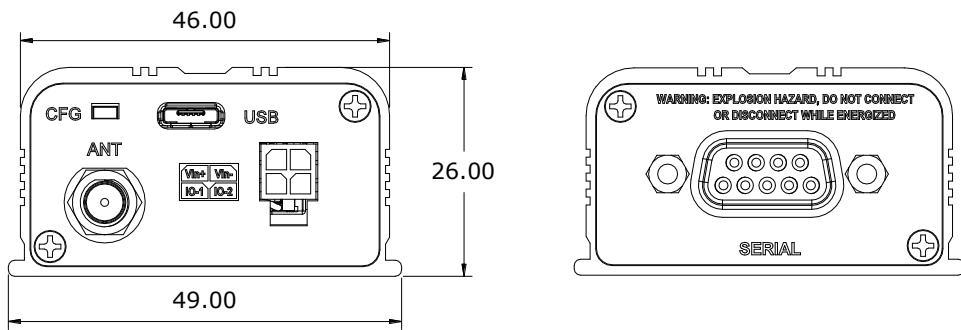
Image 2-4: P900 Enclosed

## 2.0 Hardware Description

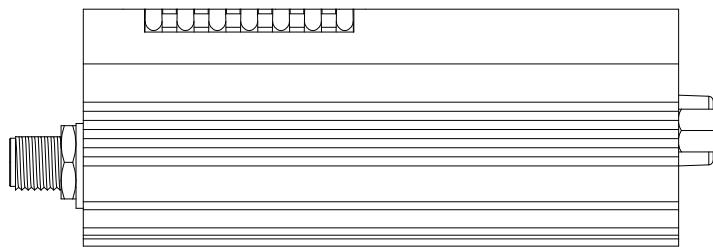
### 2.6.1 P900 Enclosed Dimensional Drawings



Drawing 2-7: P900 Top View



Drawing 2-8: P900 Enclosed End Views

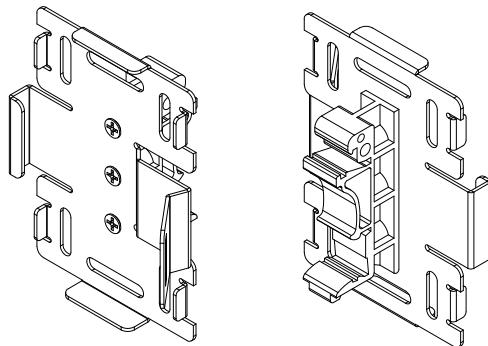


Drawing 2-9: P900 Enclosed Side View

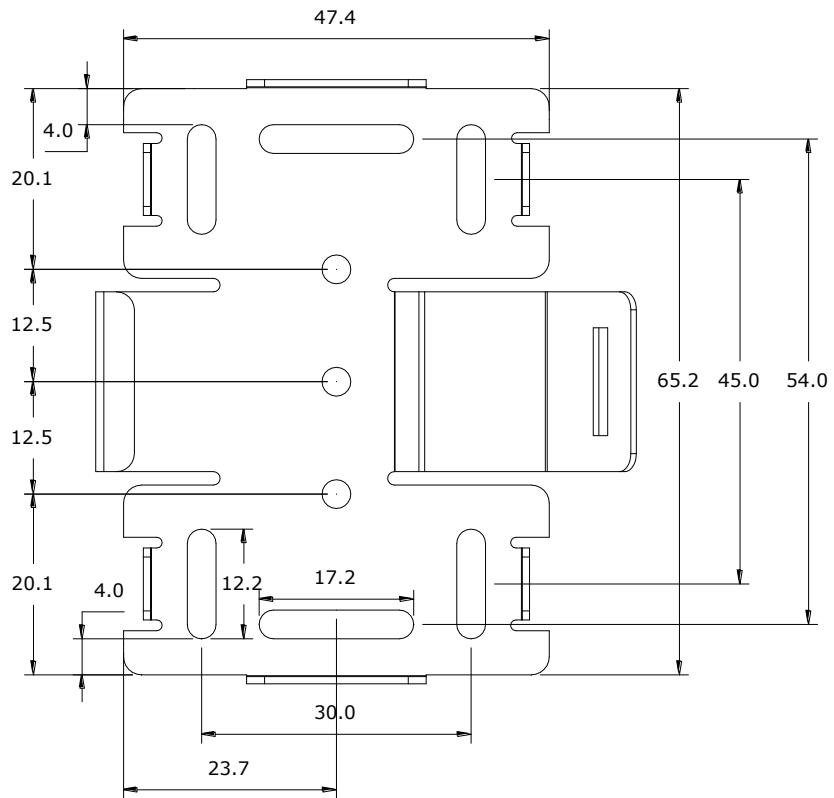
Notes: The dimension unit is mm.

## 2.0 Hardware Description

### 2.6.2 P900 Enclosed Mounting Bracket (Order Option)



*Drawing 2-10: P900 -ENC Mounting Bracket Front/Rear (Shown optional TS35 DIN Rail Mount)*

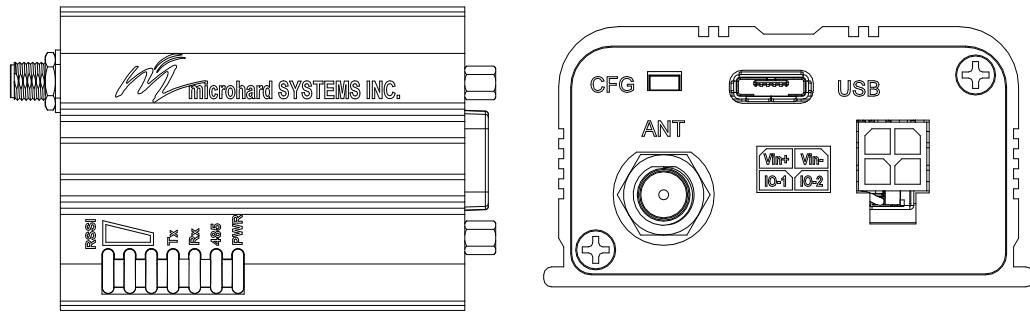


*Drawing 2-11: P900 -ENC Mounting Bracket Top View*

Notes: The dimension unit is mm.

## 2.0 Hardware Description

### 2.6.3 P900 Enclosed Connectors & LED Indicators



Drawing 2-12: Connectors & LED's (Top & End)

#### PWR (Blue)

This LED will illuminate when the P900 Enclosed is connected to a power source (9-30 VDC)

#### 485 (Blue)

This LED will illuminate when the P900 Enclosed Data port is configured as a RS485 port. (Register S142 Serial Channel Mode set to RS485 and Handshaking set to &K1)

#### TX LED (Red)

When illuminated, this LED indicates that the modem is transmitting data over the air.

#### RX LED (Green)

This LED indicates that the modem is synchronized and has received valid packets.

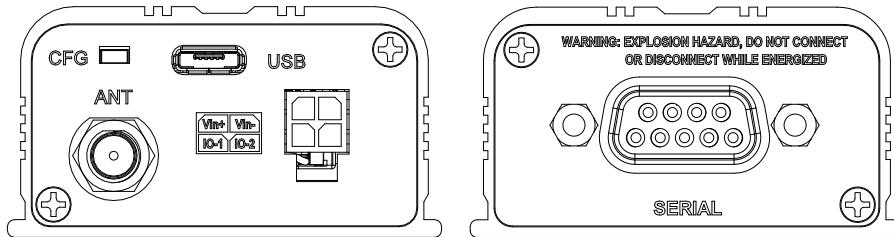
#### Receive Signal Strength Indicator (RSSI) (3x Green)

As the received signal strength increases, starting with the furthest left, the number of active RSSI LEDs increases. Signal strength is calculated based on the last four valid received packets with correct CRC. The value of RSSI is reported in S123.

| MODE                            | Unit Type                            | LED STATUS                    |                            |   |
|---------------------------------|--------------------------------------|-------------------------------|----------------------------|---|
|                                 |                                      | RX/SYNC                       | TX                         | RSSI 1,2,3  |
| COMMAND                         | All                                  | OFF                           | OFF                        | OFF   |
| DATA                            | P.Coordinator<br>S.Coordinator       | ON while receiving valid data | ON while Transmitting data | 1-3 ON in proportion to signal strength received from remotes.    |
| DATA - during sync. acquisition | S.Coordinator<br>Remote/<br>Standby  | OFF                           | OFF                        | Cycling with 300ms ON time  |
| DATA - when synchronized        | S.Coordinator<br>Remotes/<br>Standby | ON while synced               | ON when transmitting       | 1-3 ON in proportion to signal strength received from Coordinator |

Table 2-16: LED Operation

## 2.0 Hardware Description



*Drawing 2-13: Connectors & LED's (Front & Back)*

### CFG Button

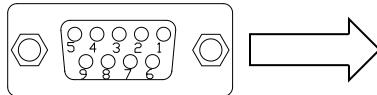
Holding this button while powering-up the modem will boot the unit into COMMAND mode: the default serial interface will be active and temporarily set to operate at its default serial settings of RS232 and 9600/8/N/1.

### USB

Micro-AB USB Port. Internal USB to Serial Converter. Provides access to the Serial Diagnostics Port.

The **SERIAL** (RS232/485 Port (DCE)) on the Enclosed model is for:

- RS232/485 Serial data when in **DATA MODE**, or
- for configuring the modem when in **COMMAND MODE**.



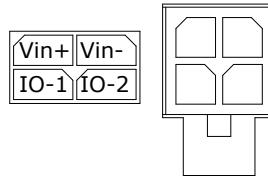
| Pin No. | RS232 | RS485 Full-Dup | RS485 Half-Dup |
|---------|-------|----------------|----------------|
| 1       | DCD   |                |                |
| 2       | RXD   | TX-            | Data-          |
| 3       | TXD   | RX+            |                |
| 4       | DTR   |                |                |
| 5       |       | Ground         |                |
| 6       | DSR   |                |                |
| 7       | RTS   | RX-            |                |
| 8       | CTS   | TX+            | Data+          |
| 9       | N/C   |                |                |

*Table 2-17: Data DB9 Pin Assignments*

**Vin+/Vin-** is used to power the unit. The input Voltage range is 9-30 Vdc.

### IO-1 / IO-2

Programmable I/O. Not currently supported in firmware. Future Development.



### ANT

RP-SMA Female Bulkhead Antenna connector.



**Caution:** Using a power supply that does not provide proper voltage may damage the modem.

## 3.0 Mesh Configuration

To begin configuration, the P900 must be mounted into a either a Microhard supplied development board (with factory attached interface card), or be mounted into a customer designed platform. The P900 is configured using AT commands through the **Data** port, or using special diagnostic commands through the **Diagnostic** Port. Refer to [Section 2: Hardware Description](#) for information related to interfacing to, or powering the module.

To issue AT commands through the **Data** port, the P900 must first be set into **Command Mode** as described below.

### 3.1 Configuration/Unit Modes

#### 3.1.1 Command Mode

- the P900 module is offline (data is not passing through the unit via it's local data lines or RF communications)
- if installed in a Development Board, the only LED illuminated will be the blue power LED.
- the P900's configuration options (registers) may be viewed and modified using AT commands.

Two methods are typically used to place the Pico Series into Command Mode.

#### 1. Force to Command Mode

- Power down off the Development Board assembly.
- Connect a 9-pin straight-through serial cable from the PC serial port to the rear RS-232 port (DATA) of the modem.
- Launch a terminal communications program (e.g. HyperTerminal) and configure for 9600 bps, 8 data bits, No parity, 1 stop bit (8N1), no flow control
- press and hold the CONFIG button
- continue to press the CONFIG button and apply power to the modem
- release the CONFIG button
- On power up the terminal session window should show "NO CARRIER OK" as seen below:

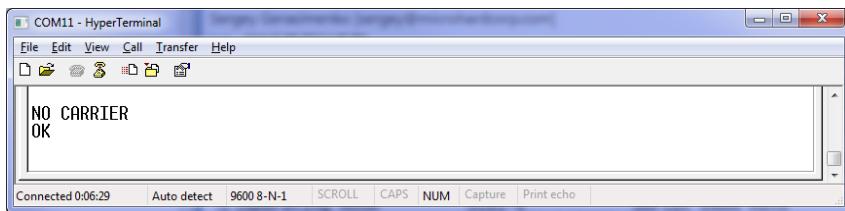


Image 3-1: Command Mode

- the P900 is now in command mode, and AT commands can be used to configure or query the settings. AT&V will display the current configuration, and the registers can be queried using the AT\$XXX=? Command where XXX = the register number. Help is available using the AT\$XXX /? Command.
- Any and all changes must be written to NVRAM using the AT&W command.

## 3.0 Mesh Configuration

### 2. Escape from Data Mode

- With the P900 powered up and 'online', connect a 9-pin straight-through serial cable from the PC serial port to the RS-232 DATA port on the dev board.
- Launch a terminal program (e.g. HyperTerminal) and configure for the P900's established serial baud rate parameters (PC & modem must match).
- Pause 1 second, type '**+++**' , pause 1 second: the monitor should show the module response of 'NO CARRIER OK'

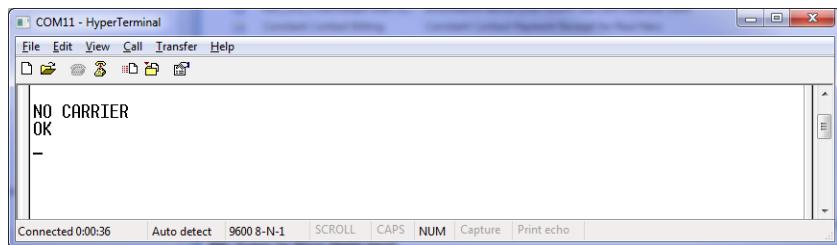


Image 3-2: Command Mode

- The P900 is now in command mode, and AT commands can be used to configure or query the settings.
- Entering the AT&V command as shown will show the current configuration as seen below: (The data displayed varies based on network and unit type.)

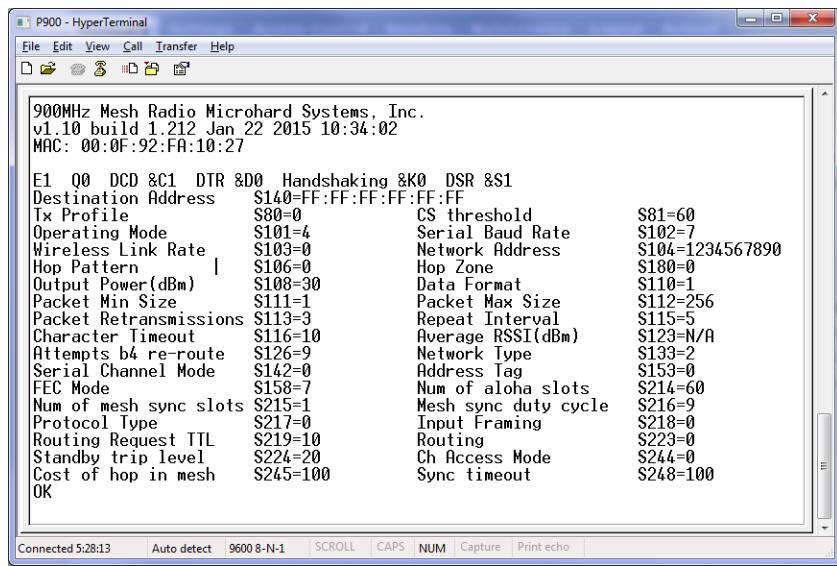


Image 3-3: Command Mode - AT&V Display

#### 3.1.2 Data Mode

Data Mode is the normal operational state of all deployed P900 modules. In this mode the module is prepared to exchange data as per its configuration settings. Available LED indications can provide an indication of the data exchange (TX and RX LEDs).

To enter DATA mode from COMMAND mode, enter the command: **ATA [Enter]**

## 3.0 Mesh Configuration

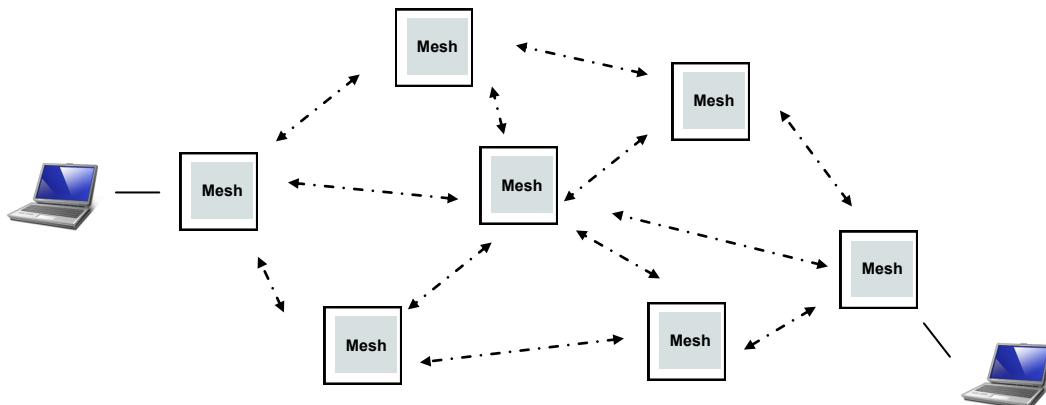
### 3.2 Mesh Network

In a Mesh Network Topology, radios can communicate with each other directly or, if required, through another mesh node. In traditional Point to Multipoint (PMP) and Point to Point (PP or PTP) network topologies a Master is used to not only keep the network synchronized in frequency and time (synchronization), but all data is also routed through the Master. Using Mesh, data can be sent directly between devices without the need to route all data through a single unit, which, when offline, brings down the entire network.

In situations where a direct path is not available between source and destination units, routing can be enabled to find and provide route information to ensure that data is delivered to the required destination. A Mesh network can be designed in such a way that redundant paths are available for data transfer, unknown routes can be auto discovered, and the best path is used to reach the intended destination. If a path or route changes due to a unit going offline, or moving such as in a mobile application, the network can heal itself by finding a new path to the destination. All this is done without data being routed through a single point as seen in traditional PMP and P2P networks. Routing features can be enabled on any unit, coordinators or remotes. Enabling routing on multiple units provides the greatest redundancy, eliminating the risk of any single point of failure.

Any frequency hopping network, even a Mesh Network requires that at least one unit be tasked with the job (primary coordinator) of making sure all units in the network are hopping at the same time, on the same frequency. This is accomplished by sending out synchronization data for all units to hear. If the network grows, or additional coverage is required, additional units can also be tasked with the job of synchronization (secondary coordinators).

As seen in the illustration below, there are many paths that data could take to each any destination in a Mesh network. Mesh Networking generally results in achieving extensive network redundancy. Mesh is enabled by setting register S133 to 2 or 3 (for Mesh with Roaming) (*ATS133=2 or ATS133=3, Network Type*).



*Drawing 3-1: Mesh Network Topology*

## 3.0 Mesh Configuration

### 3.2.1 Operating Modes / Unit Types

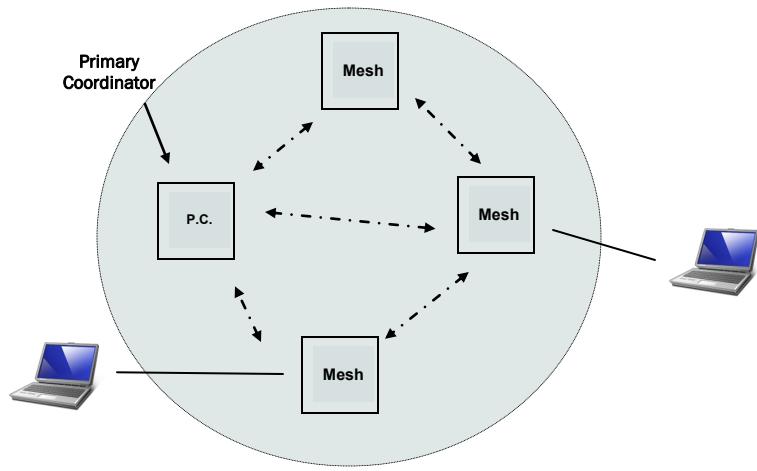
In a Microhard Mesh Network, there are four unit types or operating modes that are available: the Primary Coordinator, the Secondary Coordinator, the Standby Coordinator, and the Remote. Any P900 module can be configured to perform any of these roles, the paragraphs and diagrams that follow attempt to describe the purpose of each unit.

The **Primary Coordinator's** role is to provide network synchronization for the system, which ensures all units are active and able to communicate as required. In any Mesh Network, there can only be a single Primary Coordinator. Additional coordinators can be deployed for redundancy and/or, to extended network coverage to areas not serviced by the Primary Coordinator. For any units to be able to communicate in a Mesh Network, they must be able to hear synchronization data from a coordinator.

What if the Primary Coordinator goes offline or fails? A second unit, called a Standby Coordinator can be deployed to monitor the network synchronization level, and take over the duties of the Primary Coordinator should it ever fail. For this reason the primary coordinator should not be used to interface with an end device, but rather left to perform the duties of network synchronization. If used to interface with an end device, and it fails, the Standby Coordinator will have a unique units address, different from that of the Primary Coordinator. Any data that was destined for the Primary Coordinator will not automatically be routed to the Standby Coordinator.

Although routing can be enabled on a Primary Coordinator, data is not automatically routed through the Primary, or any other coordinator for that matter. This is mentioned to stress that the role of a coordinator of any type is to simply keep the network synchronized in time and frequency.

The diagram below shows a unit configured as a Primary Coordinator. Any other mesh unit that can hear the Primary Coordinator can participate in a Mesh Network.



Drawing 3-2: Primary Coordinator

### 3.0 Mesh Configuration

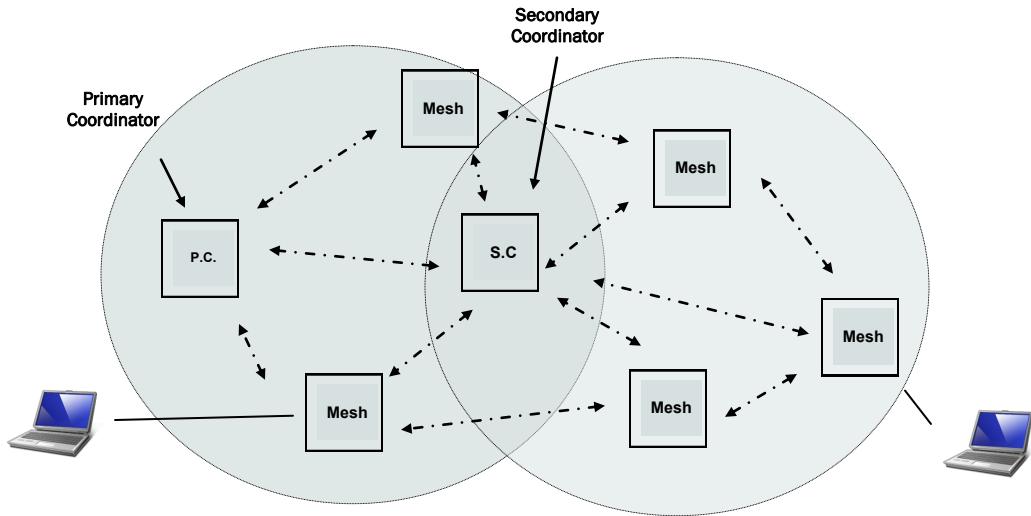
**Secondary Coordinators** are used to extend the coverage of the Primary Coordinator. More than one Secondary Coordinator can be used for redundancy or to ensure adequate network coverage. A Secondary Coordinator must be able to communicate with the Primary Coordinator and/or another Secondary Coordinator to ensure proper synchronization to the units it services.

Although any and all units in a Mesh Network can be designated as a secondary coordinator, the number and placement of coordinators deployed should be taken into consideration. The reason for this is that network synchronization is achieved by occasionally sending synchronization packets. The greater the number of coordinators deployed, the more sync data that will be broadcast on the network, and the higher the potential for collisions. During each Mesh Frame (or hop), a certain number of slots are set aside for network synchronization data, allowing coordinators an opportunity to send their sync data.

Adding a large number of Secondary Coordinators may require changing the values for both the number of sync slots in a mesh frame and the interval at which Secondary Coordinators send sync data. Increasing the number of sync slots gives more opportunity for sync data to be transmitted, but it adds system latency as more time during each frame is spent on synchronization. Decreasing the interval that synchronization packets are sent by each coordinator, results in it taking a long time for units to synchronize with the network once they have been brought online. Ideally a balance between the two can be found which minimizes the impact of the overall system performance. It should also be clear at this point, that adding an excessive number of coordinators may not be the best design practice.

Secondary Coordinators are ideal candidates for being configured for routing. As they are generally positioned to provide coverage for multiple units. More than 1 unit should be configured for routing. Should one unit go offline, another with routing also enabled can continue to provide routing services.

The following illustration shows the previous network coverage being extended by adding a secondary coordinator.



Drawing 3-3: Secondary Coordinator

### 3.0 Mesh Configuration

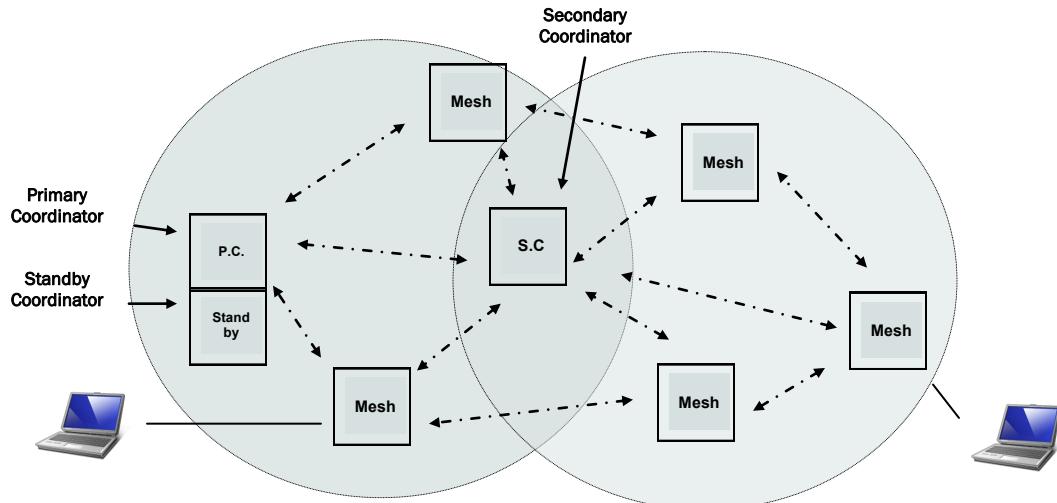
A **Standby Coordinator** monitors the sync level of the network and when it detects that the Primary Coordinator goes offline or is not performing its duties of network synchronization for any reason, the Standby Coordinator can take over.

The Standby Coordinator monitors the Primary Coordinator health by listening for sync packets. When a set number of frames have passed where no sync data is received, the Standby Coordinator can step in and start sending sync data before the network goes offline. This allows a seamless transition to the Standby Coordinator. Waiting for the network to lose sync will impact the network significantly, as the entire synchronization process must begin again.

Only one Standby Coordinator can be used in a Mesh Network. As previously mentioned when discussing the Primary Coordinator, it is not recommended to use either the Primary or Standby Coordinators to interface with end devices. Each unit in a network has a factory assigned MAC address, so even when a Primary Coordinator fails, and the Standby takes over, unicast data will not be automatically rerouted to the new MAC address.

Both the Primary and Standby Coordinators should be located in a location that provides the greatest network coverage, a secure physical location to prevent tampering, and near a reliable, adequate power source.

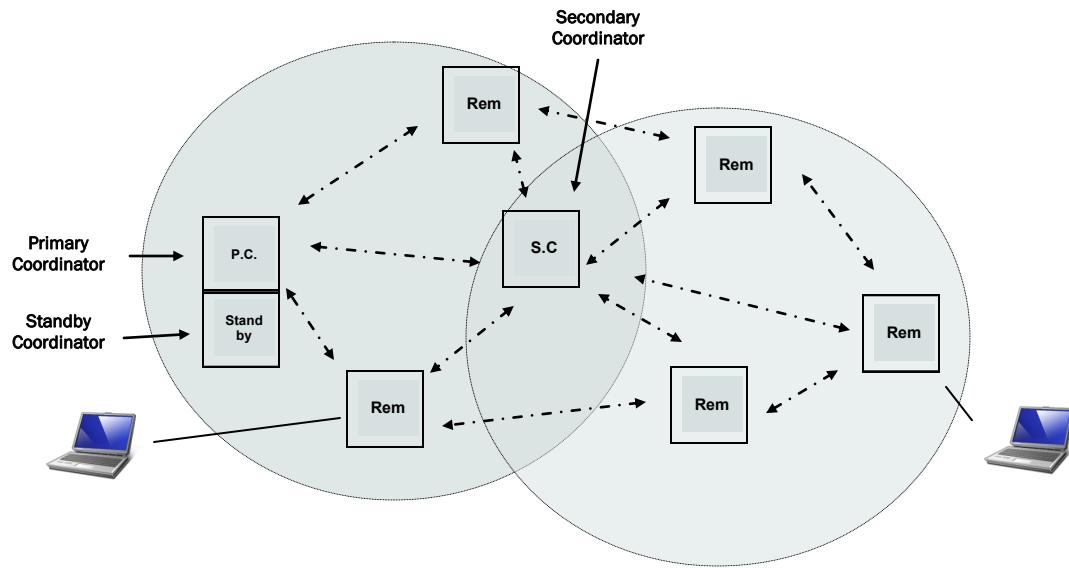
The following illustration shows the Mesh Network with the addition of the Standby Coordinator to provide a backup in an event where the Primary Coordinator cannot perform its duties.



Drawing 3-4: Standby Coordinator

### 3.0 Mesh Configuration

A **remote (slave)** is any unit that is not a coordinator. A remote is generally connected to an end device, but it may also be deployed to provide redundant paths to reach other devices in the network. As with any other device in the network, the remote can be used to provide routing services. Although all units could be configured to provide routing services, it is not efficient to do so since there would be a great deal of overhead consuming network bandwidth.



Drawing 3-5: Remote (Slave)

Units can be configured to perform the various roles discussed by setting register S101 as follows:

- |            |                         |
|------------|-------------------------|
| ATS101 = 2 | - Remote (Slave)        |
| ATS101 = 4 | - Primary coordinator   |
| ATS101 = 5 | - Secondary coordinator |
| ATS101 = 6 | - Standby Coordinator   |

The next section discusses the use of the factory default settings to set all required registers at once based on the unit type or role in the network.



Each Mesh Network must have a unique network ID. This can be changed using register S104: Network Address.

#### 3.2.2 Configuration Using Factory Defaults

To aid in the configuration and deployment of the Pico series modules, the factory default settings can be used as a known starting point for each unit type. Using the factory default commands sets all applicable registers to factory recommended settings and allows initial connectivity between units. For some networks, these commands may be all that is necessary to configure and deploy a Mesh Network.

- |       |   |                            |
|-------|---|----------------------------|
| AT&F1 | - | Mesh Primary Coordinator   |
| AT&F2 | - | Mesh Remote                |
| AT&F3 | - | Mesh Secondary Coordinator |

The following screen shots will illustrate how the commands are used and also highlight the key registers that have been changed, or need to be changed for a successful deployment.

### 3.0 Mesh Configuration

#### AT&F1 Primary Coordinator



Compression (S225) was introduced in firmware v1.10. S225 must be set to 0 for compatibility with older versions.

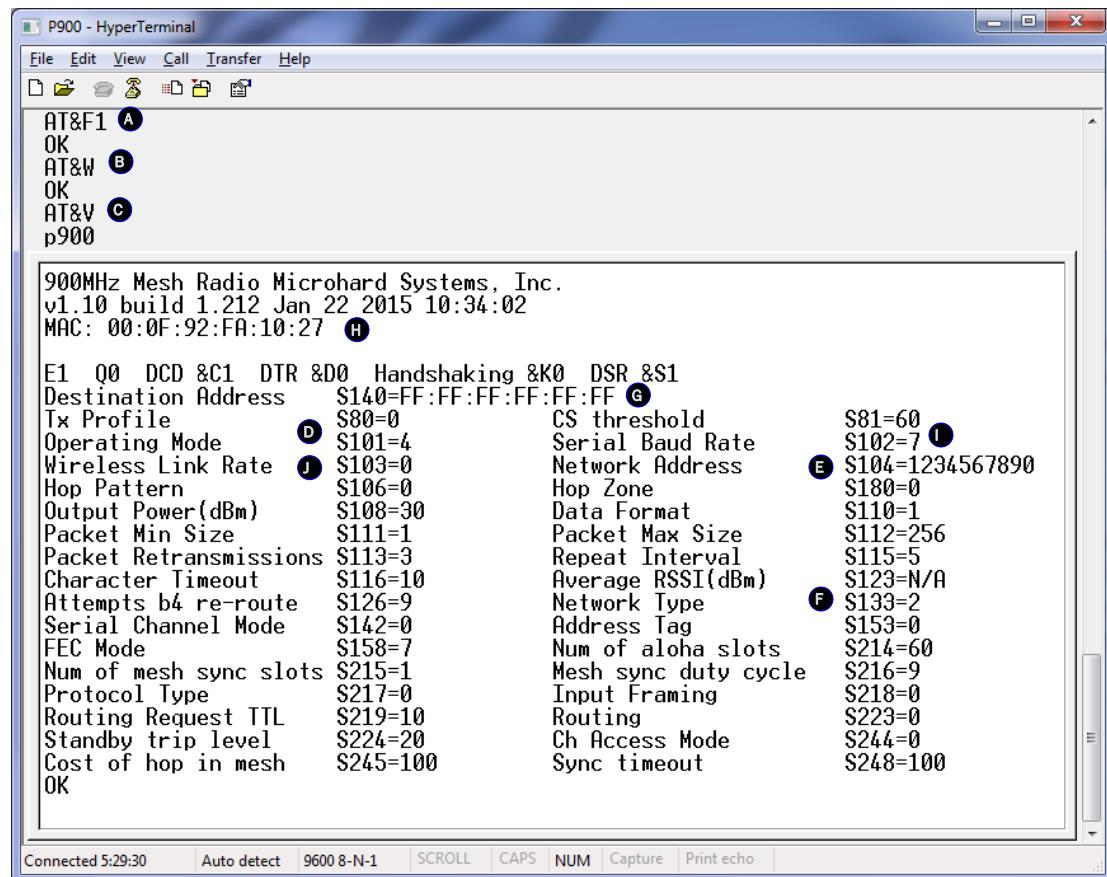


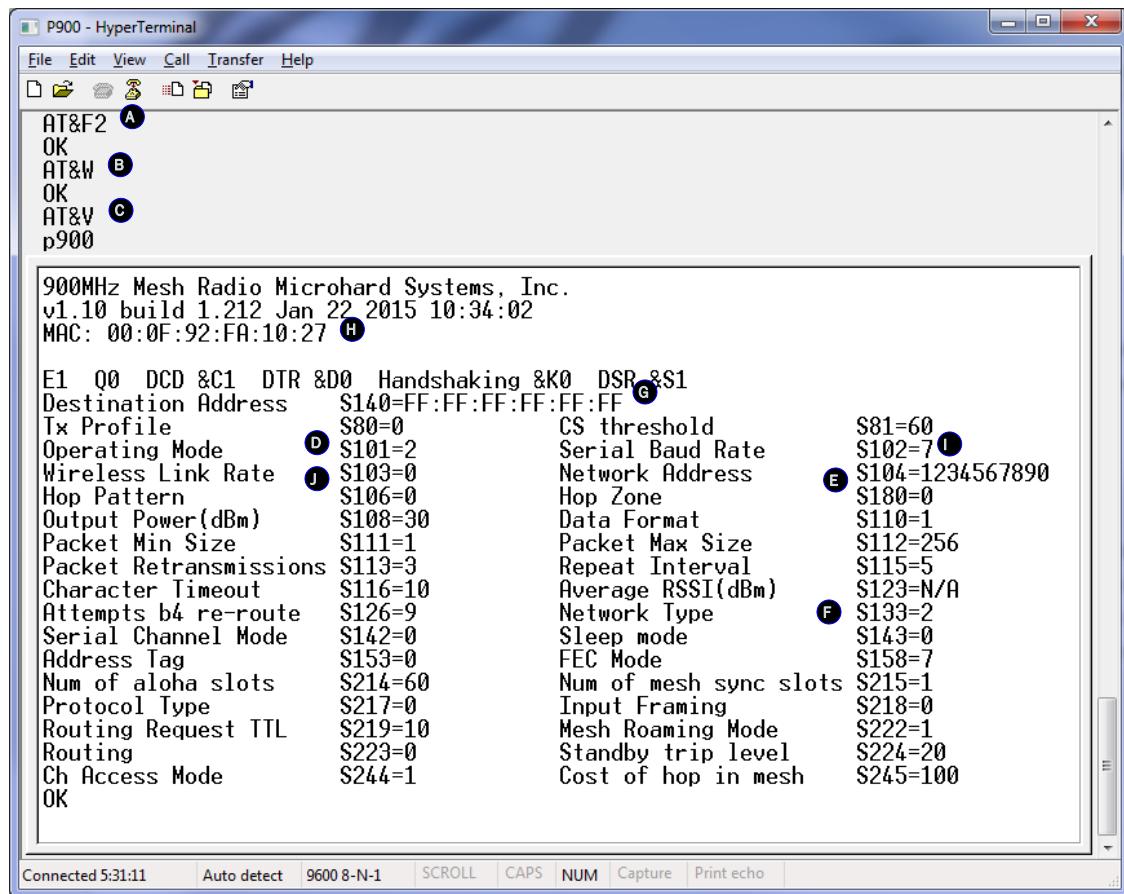
Image 3-4: Factory Defaults AT&F1 - Primary Coordinator

- A) AT&F1 - Sets the factory defaults for a Primary Coordinator.
- B) AT&W - Writes the changes to NVRAM
- C) AT&V - Displays the configuration as seen above.
- D) S101 - The Operating Mode is automatically set to 4, which is the value required for a Primary Coordinator.
- E) S104 - Each unit in a Network must have the same Network Address. It is strongly recommended to never use the default setting of 1234567890. To change the Network Address, the ATS104=XXXXXXX command can be used.
- F) S133 - The network type must be set to 2 or 3 for Mesh.
- G) S140 - Destination Address. By default, the destination address is set to FF:FF:FF:FF:FF:FF which means that any incoming data is broadcast to all devices. For unicast this can be changed to the specific unit MAC Address.
- H) MAC - Each Pico module has a factory set and defined MAC address which can be viewed here.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S103 - Wireless Link Rate must be set to the same value of each unit in the system. Higher link rates may result in higher throughput, but lower link rates usually provide better sensitivity and overall robustness.

Remember, anytime registers are changed the values must be written to NVRAM using the AT&W command. To switch from command mode to data mode (online mode), the ATA command can be issued.

### 3.0 Mesh Configuration

#### AT&F2 Mesh Remote (Slave)



```

P900 - HyperTerminal
File Edit View Call Transfer Help
AT&F2 A
OK
AT&W B
OK
AT&V C
p900

900MHz Mesh Radio Microhard Systems, Inc.
v1.10 build 1.212 Jan 22 2015 10:34:02
MAC: 00:0F:92:FA:10:27 H

E1 Q0 DCD &C1 DTR &D0 Handshaking &K0 DSR &S1
Destination Address $140=FF:FF:FF:FF:FF:FF G
Tx Profile $80=0 CS threshold $81=60
Operating Mode D $101=2 Serial Baud Rate $102=7 I
Wireless Link Rate J $103=0 Network Address $104=1234567890
Hop Pattern $106=0 Hop Zone $180=0
Output Power(dBm) $108=30 Data Format $110=1
Packet Min Size $111=1 Packet Max Size $112=256
Packet Retransmissions $113=3 Repeat Interval $115=5
Character Timeout $116=10 Average RSSI(dBm) $123=N/A
Attempts b4 re-route $126=9 Network Type F $133=2
Serial Channel Mode $142=0 Sleep mode $143=0
Address Tag $153=0 FEC Mode $158=7
Num of aloha slots $214=60 Num of mesh sync slots $215=1
Protocol Type $217=0 Input Framing $218=0
Routing Request TTL $219=10 Mesh Roaming Mode $222=1
Routing $223=0 Standby trip level $224=20
Ch Access Mode $244=1 Cost of hop in mesh $245=100
OK

```

Connected 5:31:11 Auto detect 9600 8-N-1 SCROLL CAPS NUM Capture Print echo

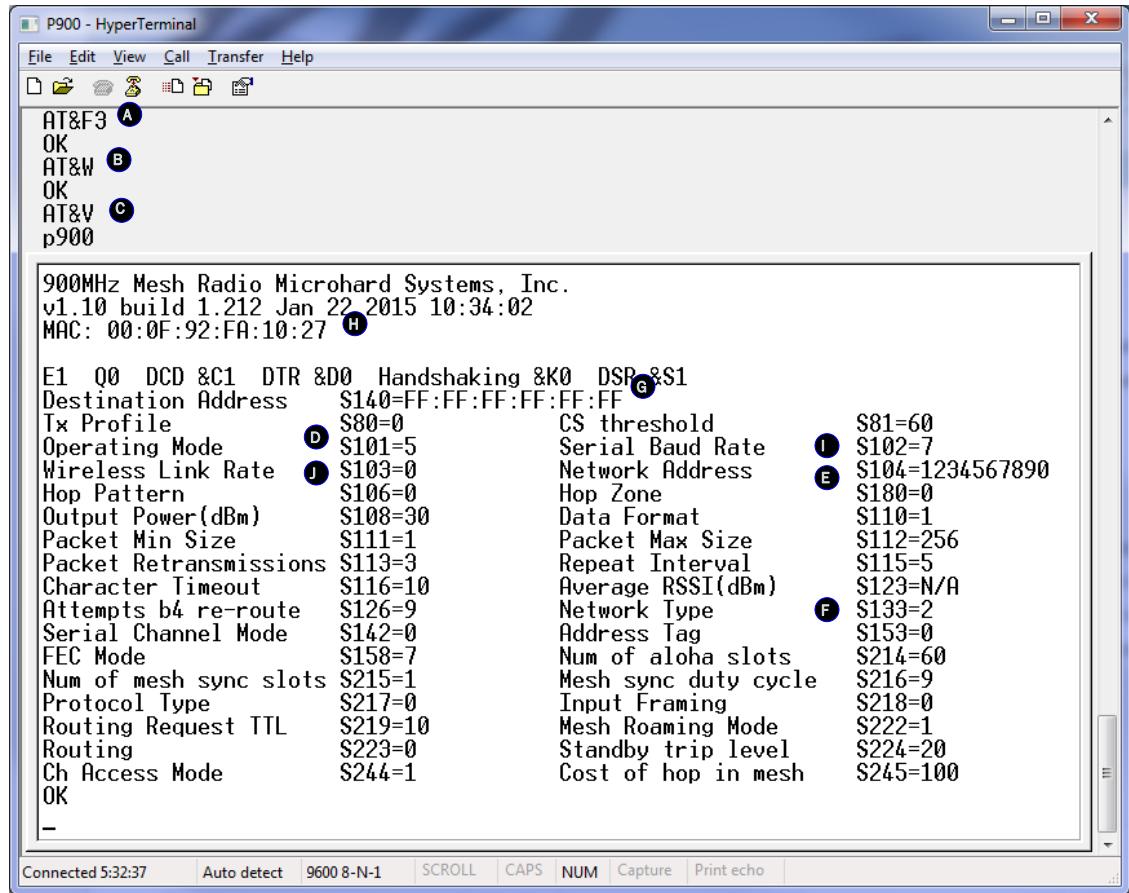
Image 3-5: Factory Defaults AT&F2 - Mesh Remote

- A) AT&F2 - Sets the factory defaults for a Mesh Remote.
- B) AT&W - Writes the changes to NVRAM
- C) AT&V - Displays the configuration as seen above.
- D) S101 - The Operating Mode is automatically set to 2, which is the value required for a Mesh Remote (Slave).
- E) S104 - Each unit in a Network must have the same Network Address. It is strongly recommended to never use the default setting of 1234567890. To change the Network Address, the ATS104=XXXXXXX command can be used.
- F) S133 - The network type must be set to 2 or 3 for Mesh.
- G) S140 - Destination Address. By default, the destination address is set to FF:FF:FF:FF:FF:FF which means that any incoming data is broadcast to all devices. For unicast this can be changed to the specific unit MAC Address.
- H) MAC - Each Pico module has a factory set and defined MAC address which can be viewed here.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S103 - As previously mentioned the link wireless link rate should be set to the same value on each modem in the system.

Remember, anytime registers are changed the values must be written to NVRAM using the AT&W command. To switch from command mode to data mode (online mode), the ATA command can be issued.

### 3.0 Mesh Configuration

#### AT&F3 Secondary Coordinator



```

P900 - HyperTerminal
File Edit View Call Transfer Help
AT&F3 A
OK
AT&W B
OK
AT&V C
p900

900MHz Mesh Radio Microhard Systems, Inc.
v1.10 build 1.212 Jan 22, 2015 10:34:02
MAC: 00:0F:92:FA:10:27 H

E1 Q0 DCD &C1 DTR &D0 Handshaking &K0 DSP &S1
Destination Address $140=FF:FF:FF:FF:FF:FF G
Tx Profile $80=0 CS threshold I $81=60
Operating Mode S101=5 Serial Baud Rate J $102=7
Wireless Link Rate S103=0 Network Address E $104=1234567890
Hop Pattern S106=0 Hop Zone F $180=0
Output Power(dBm) S108=30 Data Format G $110=1
Packet Min Size S111=1 Packet Max Size H $112=256
Packet Retransmissions S113=3 Repeat Interval I $115=5
Character Timeout S116=10 Average RSSI(dBm) J $123=N/A
Attempts b4 re-route S126=9 Network Type K $133=2
Serial Channel Mode S142=0 Address Tag L $153=0
FEC Mode S158=7 Num of aloha slots M $214=60
Num of mesh sync slots S215=1 Mesh sync duty cycle N $216=9
Protocol Type S217=0 Input Framing O $218=0
Routing Request TTL S219=10 Mesh Roaming Mode P $222=1
Routing S223=0 Standby trip level Q $224=20
Ch Access Mode S244=1 Cost of hop in mesh R $245=100
OK
-
```

|          |  |
|----------|--|
| A) AT&F3 | - Sets the factory defaults for a Secondary Coordinator.   |
| B) AT&W  | - Writes the changes to NVRAM  |
| C) AT&V  | - Displays the configuration as seen above.  |
| D) S101  | - The Operating Mode is automatically set to 5, which is the value required for a Secondary Coordinator.   |
| E) S104  | - Each unit in a Network must have the same Network Address. It is strongly recommended to never use the default setting of 1234567890. To change the Network Address, the ATS104=XXXXXXX command can be used.           |
| F) S133  | - The network type must be set to 2 or 3 for Mesh.   |
| G) S140  | - Destination Address. By default, the destination address is set to FF:FF:FF:FF:FF:FF which means that any incoming data is broadcast to all devices. For unicast this can be changed to the specific unit MAC Address. |
| H) MAC   | - Each Pico module has a factory set and defined MAC address which can be viewed here.   |
| I) S102  | - The serial baud rate (and data format S110) must match that of the connected device.   |
| J) S103  | - As previously mentioned the link wireless link rate should be set to the same value on each modem in the system.   |

Image 3-6: Factory Defaults AT&F3 - Secondary Coordinator

- A) AT&F3 - Sets the factory defaults for a Secondary Coordinator.
- B) AT&W - Writes the changes to NVRAM
- C) AT&V - Displays the configuration as seen above.
- D) S101 - The Operating Mode is automatically set to 5, which is the value required for a Secondary Coordinator.
- E) S104 - Each unit in a Network must have the same Network Address. It is strongly recommended to never use the default setting of 1234567890. To change the Network Address, the ATS104=XXXXXXX command can be used.
- F) S133 - The network type must be set to 2 or 3 for Mesh.
- G) S140 - Destination Address. By default, the destination address is set to FF:FF:FF:FF:FF:FF which means that any incoming data is broadcast to all devices. For unicast this can be changed to the specific unit MAC Address.
- H) MAC - Each Pico module has a factory set and defined MAC address which can be viewed here.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S103 - As previously mentioned the link wireless link rate should be set to the same value on each modem in the system.

Remember, anytime registers are changed the values must be written to NVRAM using the AT&W command. To switch from command mode to data mode (online mode), the ATA command can be issued.

## 3.0 Mesh Configuration

### Standby Coordinator

Factory default settings are not available for the Standby Coordinator. The Standby Coordinator provides system redundancy if the Primary Coordinator fails. Generally the configuration of the Standby Coordinator would be identical to that of the Primary Coordinator. For simple configuration, the AT&F1 command can be used to configure as a Primary Coordinator, then the Operating Mode (S101) changed to Standby Coordinator. The Standby Trip Level can be adjusted by changing the value in register (S224).

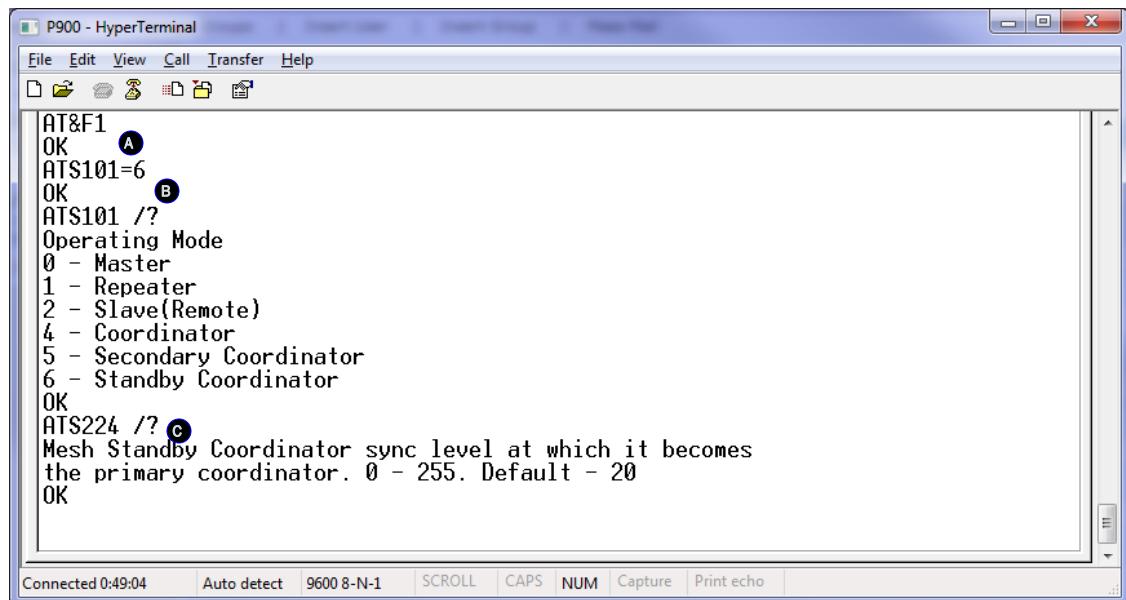


Image 3-7: Standby Coordinator

- A) AT&F1 - Sets the factory defaults for a Primary Coordinator.
- B) S101=6 - Changes Operating Mode to Standby Coordinator.
- C) S224 - Standby Trip Level is used to specify how quickly the P900 will switch from standby mode if sync packets are not received from the Primary.

The smaller the value of S224 the longer the Standby Coordinator will wait before assuming the role of the Primary. The recommended value is 20% of the value of S248 on Primary coordinator. Note that S248 on both Primary and Standby coordinators must be identical.

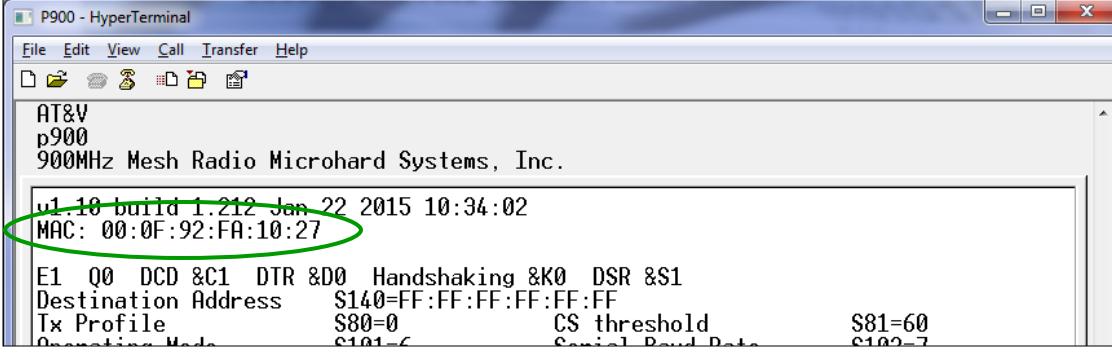
Remember, anytime registers are changed the values must be written to NVRAM using the AT&W command. To switch from command mode to data mode (online mode), the ATA command can be issued.

## 3.0 Mesh Configuration

### 3.2.3 Unit Addressing

Each unit is factory assigned a hardcoded MAC address that can not be changed. Using factory assigned addressing simplifies the configuration process, as addresses do not have to be manually assigned and minimizes errors that are often created when duplicate address are accidentally used. In applications where the data is to be broadcasted to all units in the network, the value FF:FF:FF:FF:FF:FF is used as a destination address in register S140. It is possible to replace the MAC address with a value in S105. See the register S87 for more information.

For unicast operation, the specific unit address must be used. This address can be retrieved by using the AT&V command as highlighted below.



```

P900 - HyperTerminal
File Edit View Call Transfer Help
AT&V
p900
900MHz Mesh Radio Microhard Systems, Inc.

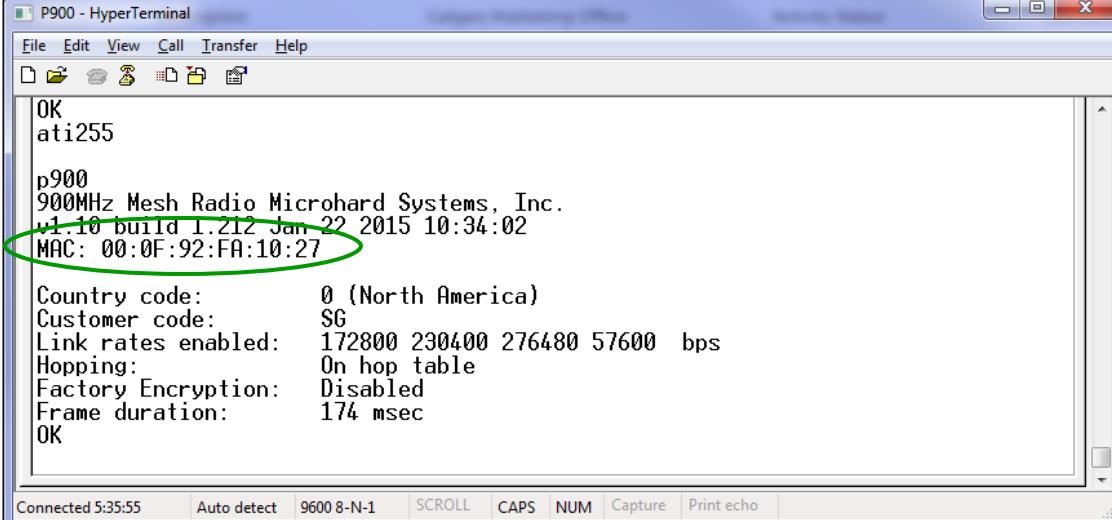
u1.10 build 1.212 Jan 22 2015 10:34:02
MAC: 00:0F:92:FA:10:27

E1 Q0 DCD &C1 DTR &D0 Handshaking &K0 DSR &S1
Destination Address S140=FF:FF:FF:FF:FF:FF
Tx Profile S80=0 CS threshold S81=60
Operating Mode S101=7 Serial Poll Data S102=7

```

Image 3-8: Retrieving unit MAC Address from AT&V output

It can also be viewed using the ATI commands. ATI255 will show the MAC address as well as some additional information seen in the image below. ATI7 will show just the MAC Address.



```

P900 - HyperTerminal
File Edit View Call Transfer Help
OK
ati255

p900
900MHz Mesh Radio Microhard Systems, Inc.
u1.10 build 1.212 Jan 22 2015 10:34:02
MAC: 00:0F:92:FA:10:27

Country code: 0 (North America)
Customer code: SG
Link rates enabled: 172800 230400 276480 57600 bps
Hopping: On hop table
Factory Encryption: Disabled
Frame duration: 174 msec
OK

Connected 5:35:55 Auto detect 9600 8-N-1 SCROLL CAPS NUM Capture Print echo

```

Image 3-9: Retrieving unit MAC Address from ATI255 Output

## 3.0 Mesh Configuration

### 3.2.4 Collision Mitigation

In Mesh topology, as with most wireless systems, one of the primary challenges is the management and mitigation of data collisions. The following section covers several complex interwoven concepts and options that are used to provide robust, low latency communication, while minimizing the effects of data collisions. It is important to plan and design the network layout with these concepts in mind from the start, rather than try to cope with collisions after the system is deployed.

#### 3.2.4.1 Channel Access Mode

To coordinate transmissions from multiple devices and to manage and minimize data collisions, the Pico Series uses three different channel access modes. The recommended mode is purely a function of the type of data being sent. The three modes are **Aloha**, **RTS/CTS** and **TDMA**, which are set using register S244. In systems that send small bursts of data and do not want account for the overhead of CTS/RTS, Aloha mode may be the best solution. For systems sending large packets of data with a low tolerance for data loss or collisions, RTS/CTS may be best.

|          |   |                                |
|----------|---|--------------------------------|
| S244 = 0 | - | Aloha                          |
| S244 = 1 | - | RTS/CTS                        |
| S244 = 2 | - | TDMA (transmit on slot number) |

##### Aloha

In a Mesh based system frames are used to maintain a time reference, and to keep the system synchronized. The frame is composed of a number of different attributes, one of which is a configurable number of Aloha slots (S214). Aloha slots are used for all data communication. When the channel access mode is set to Aloha, the transmitting modem randomly selects a Aloha slot within any frame to begin its data transmission.

The randomness at which modems attempt to access the channel using Aloha is configurable using register S115. The importance of this register becomes apparent when a system is such that many devices attempt to either access the channel at the same time, or transmit data often, increasing the chances of data collisions. Increasing the randomness (S115) will make it less likely that collisions occur, but at the cost of added latency and reduced throughput. It is difficult to suggest a value for S115, as it is impacted by the type, and frequency of data transmissions. A good starting point may be to set the value of S115 to the (number of devices in the system) / 2, so if you have 10 total units in the network, try a value of 5 to start with.

|          |   |                         |
|----------|---|-------------------------|
| S115 = 1 | - | Repeat Interval (0-255) |
|----------|---|-------------------------|

For systems using polling mechanisms (polled protocols, Master/Remote systems) , or if the devices infrequently send data at staggered times, the default value of 1 is recommended, as these types of systems have a low risk of data collisions.

If multiple modems in a system need to transmit at the same time, CSMA (Carrier Sense Multiple Access) is used to detect if the channel is currently in use. If the channel is determined to be busy, the modem will select another random Aloha slot to begin its data transmission. Carrier Detect Threshold is covered in more detail later in this document.

The number of aloha slots have a direct impact on the size of the frame and as a result the hop interval, which is the amount of time spent on any one channel. Increasing the number of aloha slots will increase the number of slots available for data transmission, but at the risk of being affected by interference or noise on a channel. A short hop interval, or reduced number of aloha slots will make the system more immune to outside interference and noise, but at the cost of reduced throughput.

## 3.0 Mesh Configuration

In a clean system or in areas where interference and noise are not an issue, it is ideal to allow as many aloha slots as possible. Although the maximum configurable number of aloha slots is 255, it may not be possible to use this number and the system will generate an error. The maximum number is determined by considering the link rate, the number of sync slots and the number of aloha slots. FCC limits the hop interval at a maximum of 400ms. The ATI255 command shows the current frame duration

S214 = 60 - Number of Aloha Slots (1-255)

S214 must be set to the same value on all units in the system. Failure to do so will prevent the unit from synchronizing and being able to participate in data communication.

### RTS/CTS

When register S244 = 1, the Channel Access Mode is set to RTS/CTS. In this mode, before sending data, the modem will request a channel from the Coordinator. Once the Coordinator fulfills this request, the modem is free to transmit its data. This type of channel access mode is best suited for systems that require large packets of data with a low tolerance for collisions or retransmissions.

As with Aloha mode, RTS/CTS also uses S115 to provide randomness to minimize the number of units attempting to send a RTS (Request to Send) packet to the coordinator at the same time. The larger the value of S115 the more random the channel access becomes, reducing collisions. The cost of making the value of S115 too large, thus increasing the randomness at which devices attempt to access the channel, is increased latency and reduced throughput. Therefore it is important to select a value that minimizes collisions, yet not too large to impact system performance.

### TDMA

When register S244 = 2, the Channel Access Mode is set to TDMA. In this mode each modem in the system starts its transmission on an assigned slot number within the frame. The slot number is defined by S221.

#### 3.2.4.2 Carrier Sense

Carrier Sense Multiple Access (CSMA) is enabled by default and is used to detect if other units are transmitting data by measuring the signal level and determining if the level detected indicates that another unit is transmitting data. The CS Threshold can be modified using S81.

S81 = 60 - Carrier Detect Threshold in -dBm. (0-255)

The default value for S81 is -60dBm, meaning that if a modem has data to send, it will first check if there is RF energy present and then measure the level of that energy to determine if it is noise or a valid signal. If the detected signal is stronger than -60 dBm, it will assume that the channel is busy. If the signal detected is weaker than the threshold, the unit will determine that the channel is free.

The Carrier Detect Threshold can be set individually on each unit in the system, as the noise floor, interference and received signal strength will vary by location. It is not recommended to adjust the value of S80, unless the environment is well understood.



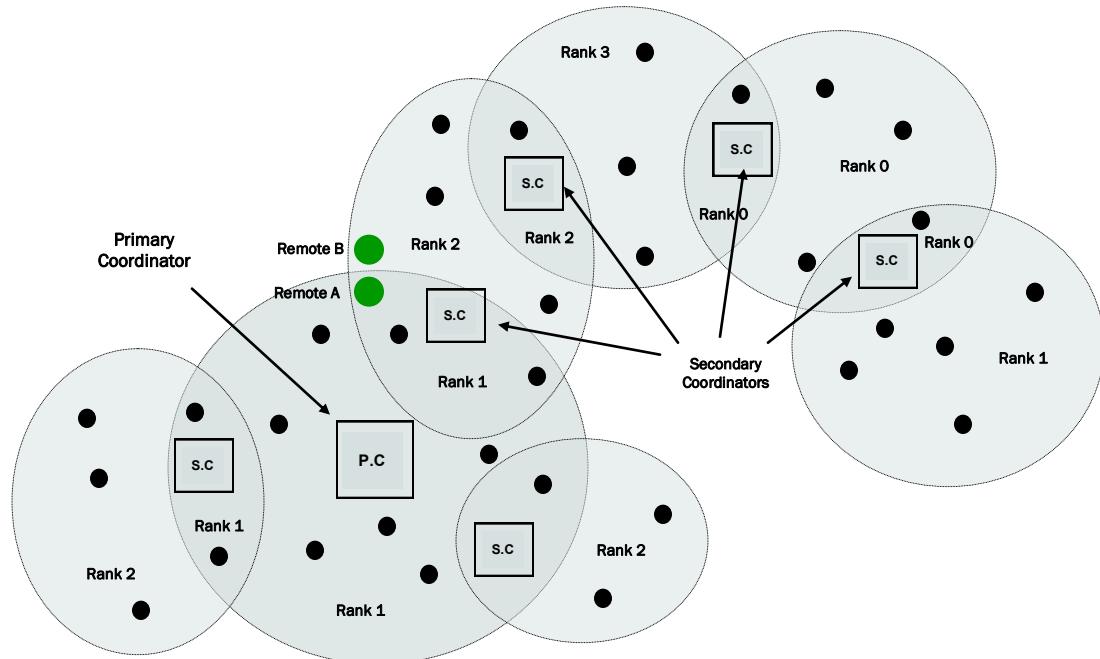
**Caution:** Setting a value of S81 too low will prevent all communication.

## 3.0 Mesh Configuration

### 3.2.4.3 TX Profiling and Ranking

Ranking allows wide area systems with several coordinators a mechanism to segregate and control transmissions to mitigate collisions in overlapping coverage areas. Each Coordinator in a system is automatically assigned a rank, starting with the Primary Coordinator always being assigned Rank 0. Up to 4 levels of ranking are used, and then are repeated for systems that require more layers. Remote units will always associate with the lowest rank coordinator they can hear, regardless of proximity. Ranking information is sent in each sync packet. It is possible to manually assign the coordinator rank by using S220.

The drawing below illustrates how the ranking areas work. Notice that all devices that can hear the Primary Coordinator (Rank 0), are assigned Rank 1. In the overlapping coverage area, the units can hear both the Primary and Secondary Coordinators, but they are also assigned rank 1, as the Primary Coordinator is the lowest ranked coordinator. The remaining units which are in the Secondary Coordinators (Rank 1) coverage area are assigned rank 2. Notice that with the addition of Secondary Coordinators the Rank is incremented by 1. Once reaching Rank 3, the process begins again at Rank 0. Ranking ensures that the Mesh network maintains a stable logical structure and prevents modems from erratic association with multiple coordinators.



Drawing 3-6: Mesh Ranking

The ranking of coordinators is done automatically, and creates some structure and organization to the Mesh Network. Tx Profiling can now use that logical separation to provide collision avoidance in the system by assigning frames to be only used by specific ranked units, as per a TX Profile. This allows guaranteed periods of time in which only certain ranked modems can transmit data. The result is reducing or eliminating collisions on the overlapping coverage boundaries.

### 3.0 Mesh Configuration

In the previous example (Drawing 3-6) we can see that Remote A and Remote B are in close proximity of each other along an overlapping coverage boundary. Remote A can hear both the Primary and Secondary Coordinator. Even though it is closer to the Secondary Coordinator, it will associate with the Primary Coordinator as it has the lowest Rank. Remote B can only hear the Secondary Coordinator, so obviously it can only associate with that coordinator. Without TX Profiling, there will be collision between these units as they try to transmit. A TX profile will assign frames to each rank that they can use to send data, without the worry that there will be collisions.

Currently there are 4 different TX Profiles. Querying the S80 register as seen below shows the TX Profile. A TX Profile is a repeating pattern of 16 frames, each frame can be assigned a rank or combination of ranks, which are allowed to transmit data during that frame. A value of 0xF, or F in hex means that any unit can send data, essentially meaning that TX Profiling is not used for that frame and any rank modem can send data.

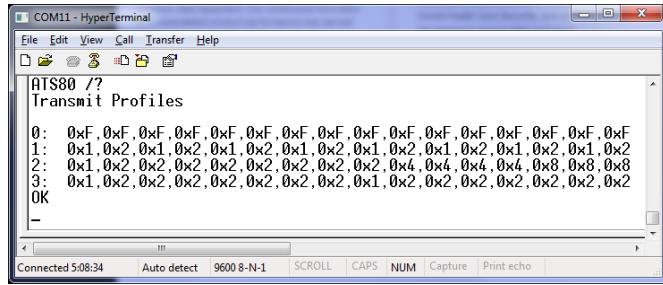


Image 3-10: TX Profiles

| R3 | R2 | R1 | R0 | TX Profile | Description      |
|----|----|----|----|------------|------------------|
| 0  | 0  | 0  | 1  | 0x1        | Rank 0 can TX    |
| 0  | 0  | 1  | 0  | 0x2        | Rank 1 can TX    |
| 0  | 1  | 0  | 0  | 0x4        | Rank 2 can TX    |
| 1  | 0  | 0  | 0  | 0x8        | Rank 3 can TX    |
| 1  | 1  | 1  | 1  | 0xF        | All Ranks can TX |

Table 3-1: TX Profiles

As seen in the table each Hex Value in the pattern corresponds to a specific rank(s) able to transmit during a specified frame. The TX Profile used can be set by using register S80, currently there are 4 different profiles. In future releases additional profiles may be available.

S80 = 0 - TX Profile (0-3)

Profile 0 allows any modem to send data regardless of rank, this essentially disables TX Profiling. This is the default, as TX profiling is generally only useful in partially overlapping coverage areas where collision rates are high.

Profile 1 allows the bandwidth to be split equally between the Primary Coordinator and all rank 1 units. This may be useful in system where there are no secondary coordinators, as there are no frames assigned to any units other than the Primary Coordinator and its' associated units.

Profile 2 allows rank 1 units to have 1/2 of the bandwidth. The reason for this is in many systems, the Primary Coordinator is generally located in a location that provides the greatest coverage, meaning it generally has the most units associated with it. The rest of the bandwidth is split between the rank 2 and rank 3 modems. The Primary Coordinator is given only 1 frame for occasional transmissions.

Profile 3 allocates most of the bandwidth to Rank 1 units with only 2 in 16 frames available for the Rank 0 coordinator. This profile is used in systems with no additional coordinators, where the units send data a majority of the time, with the occasional transmission from the Primary.

## 3.0 Mesh Configuration

### 3.2.5 Retransmissions

Packet Retransmissions can be used to ensure data reaches its intended destination by resending the same packet over and over unless acknowledged by the recipient. While this is an effective tool to add system robustness, it has large impact on the performance of the system in broadcast mode. The more times a modem retransmits data, the more the overall throughput of the system is reduced. To adjust the retransmission rate, use register S113, the default value is 5 (+ the initial transmission).

S113 = 5 - Packet Retransmissions (0-254)

While retransmissions can provide some correction for data collisions, it is not advisable as adding retransmission may actually amplify the number of collisions. Retransmissions are typically used in noisy environments to combat interference and low signal strength, ensuring data is received at the intended destination.

### 3.2.6 Network Synchronization

Network Synchronization is what allows all units to hop from frequency to frequency at the same time. Each Mesh Frame contains a configurable number of sync slots, that the coordinators can use to send synchronization data. Sync data does not need to be sent during each frame, and is therefore configurable using register S216

S216 = 3 - Mesh Duty Cycle (1-100)

Register S216 defines how often the coordinator transmits sync packets (1-100). After each sync packet transmission the coordinator picks a random number from 1 to the value in S216 and transmits the next packet in this slot.

If the network is busy with traffic it is not necessary to send the sync packet very often, as the sync data is also embedded into the data stream. For idle systems, an increased number of sync packets allows for faster synchronization of new units. However, the higher the value of S216, the longer it will take for new units to find and synchronize with a coordinator.

In large systems with many coordinators, it may be necessary to adjust the number of available sync slots per Mesh frame to allow adequate slots for each coordinator to transmit sync data. This can be adjusted using S215.

S215 = 1 - Number of Mesh Sync Slots (1-10)

Adding an unnecessary number of sync slots adds to the length of the Mesh Frame, which in turn creates a longer hop interval (number of sync slots + number of aloha slots = hop interval), increasing overhead and reducing system performance.

For units to synchronize with the network, each unit must have the same:

- Network ID (S104), Network Type (S133), Forward Error Correction (S158) and
- the same number of Aloha Slots (S214), number of Sync Slots (S215).

In Mesh without roaming, Hop Pattern (S106) and Hop Zone (S180) must also match.

## 3.0 Mesh Configuration

### Sync Timeout

Once synchronized to the network the unit does not need to receive sync data often to keep track of where the system is supposed to be (in time and frequency). The sync Timeout defines the number of frames where no sync data is received from a coordinator before losing sync. In other words, how long a unit will remain synchronized with the network without receiving any sync packets before it gives up and loses sync.

S248 = 100      Sync Timeout (4-65534)

Setting a value too low will cause the unit to lose sync easily and time will be wasted trying to re-sync to the network. As seen with the Mesh Duty Cycle several frames can go by without receiving a sync packet, and this is completely normal. If this value is set too high, the unit will assume for a long time that the network is still out there, when especially in mobile applications, it may not be.

### Quick Sync

In a quiet Mesh network it may take some time to synchronize the entire network. To overcome this problem, Quick Sync is used by coordinators when they first come online to quickly send a number of sync packets on random frequencies in the current hop table. This allows the network to synchronize much faster than waiting for the standard sync packets to arrive (which is based on the sync duty cycle and number of sync slots). The number of sync packets sent upon power up is defined by the S151 register.

S151 = 500      Quick Sync Packets (5-65534)

When a Primary Coordinator goes online it will send the configured number of sync packets. Once a Secondary Coordinator is synchronized, it will also transmit quick sync packets based on their configured S151 value.

No data transmission can occur while the coordinators are sending quick sync packets, even if all units are synchronized.

When setting the S151 register, selecting a large value may create an unnecessary delay in data transmission on system startup. A value too low, or not sending enough sync packets to cover all the frequencies in the Hop Pattern will result in slower synchronization of the system as any units that did not hear the quick sync packets will need to wait until they receive a standard sync packet to synchronize.

North America FCC requires that different 50 frequencies(channels) are used to create the hop pattern. The default value of 500 means that 10 packets are sent on each channel to ensure system wide synchronization. Customers located in other regions or government organizations who allow or require more or less entries in the hop pattern may decide that the default value is not appropriate for their systems, and are free to adjust this value.

## 3.0 Mesh Configuration

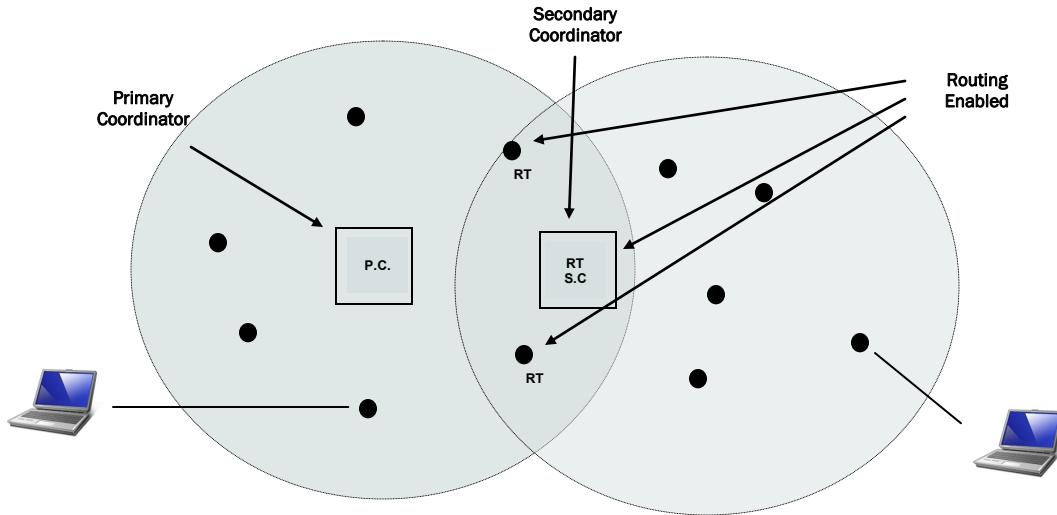
### 3.2.7 Routing

For Mesh Networking to be an effective networking topology, routing functions must be performed to discover paths within the network to each destination, to ensure the best path is chosen. All units in a Mesh Network, including remotes, can be configured to provide routing capabilities by setting register S223.

|          |   |                  |
|----------|---|------------------|
| S223 = 0 | - | Routing Disabled |
| S223 = 1 | - | Routing Enabled  |

All traffic in a Mesh system is either broadcast, where data is sent to everyone; or unicast, where data is sent to a specific destination. Anytime there is no direct line of sight with a primary coordinator, additional coordinators can be added to extend the network. If data is transmitted to a unicast destination, the modems will use a Microhard routing protocol to find a route by initiating route discovery. At this point routing is required to provide route information and load balancing of the network traffic. Routing is a key element in Mesh network design that can have a profound impact on overall system performance.

The diagram below shows a sample Mesh Network comprised of a Primary Coordinator, a Secondary Coordinator and 11 remotes. Routing has been enabled on the Secondary Coordinator and two of the remotes to provide comprehensive routing capabilities. It is always a good idea to assign routing operation to more than one unit to provide redundancy, and to provide alternate paths for routed data to travel, essentially sharing the load of the network. Generally remotes sitting on the edge of the network are not required to perform routing.



Drawing 3-7: Mesh Network w/Routing

As traffic flows through and around a network, routing tables in each unit will be populated using route discovery and routing requests as required routes are discovered. Eventually the entire network is converged, meaning a path to all units are mapped, until something changes - a unit moves, a unit is added, or a unit is removed from the system. When this happens, the routing table(s) must be updated.

## 3.0 Mesh Configuration

### Attempts before Re-Routing

Once a route is entered into the routing table, it is assumed that the route exists and can be used for data transfer. To ensure that the information in the routing table is up to date and accurate, each time a packet is sent to a destination the register S126 tracks the number of consecutive failed attempts to send data before route discovery is triggered. Since all unicast data is acknowledged, the unit will know if the packet was delivered successfully or not.

S126 = 9 - Number of Attempts before starting route discovery (1-255)

Configuration of S126 must consider multiple factors, the first is the number of retransmissions (S113) set in the system. The value of S126 must be set higher than the total number of retransmissions.

The next consideration is the collision rate of the system. If an occasional collision is expected, this may result in a number of unsuccessful attempts to deliver data, but it does not mean that the path is not valid. Setting the value of S126 lower than the initial transmission + retransmissions + collisions or packet loss due to noise or interference, may result not only in unneeded route discovery, which has a large amount of overhead, but it could also result in a system that will never retain a route and become completely unusable.

## 3.0 Mesh Configuration

### Routing Request TTL

When a modem gets a packet to deliver and it does not have a route listed for that packet in the routing table it initiates a routing request. During the routing request, and route discovery, all transmissions from this device are stopped until the request is complete. Since several routes may be available, the modem will wait until the entire Routing Request TTL (S219) has completed, and then pick the best path based on a Microhard path cost calculation discussed in the next section.

$$S219 = 10 \quad - \quad \text{Routing Request Timeout in 10ms ticks (1-10000 ticks)}$$

The default value for S219 is 10 ticks, which means that it will wait 100ms for all possible routes to be returned, or for the request to simply timeout if no routes are found. If the routing request times out, the request is repeated up to 3 times automatically before the packet is discarded.

Finding the right value for S219 can be difficult. Setting a value too low may not result in the best path being reported, or maybe not even time enough at all to receive routing information. A value too long will affect system performance because the devices will wait unnecessary amounts of time for routing discovery to complete when they may have already received the best route.

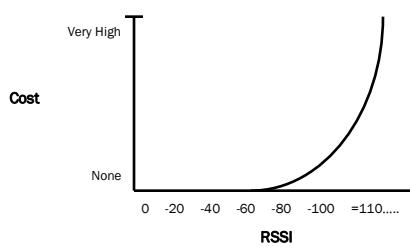
The best option for determining an ideal value for S219, without knowing what the worst case scenario is for the time it takes for packets to traverse a fully loaded network, would be to set the timeout to a small value to where no data is being exchanged. Then slowly increase the value to where data is being exchanged successfully, and then add a few more ticks.

### Cost of Routes

During the routing request / route discovery process, more than one route may be returned as a possible candidate for the best route. Determining which route is the best route can be determined by calculating a cost metric using the number of hops and the signal strength between hops. The following formula allows a user to influence the relationship between the number of hops and the overall health of the path based on RSSI.

$$\text{Cost} = (\text{Number of Hops} \times \text{Cost of a Hop}) + (\text{Cost of RSSI})$$

The number of hops and the RSSI are actual measured values in the system, automatic to the calculation. The cost of RSSI is set by the modem based on the measured value between hops. The stronger a signal, the lower its cost as seen in the relationship below.



Drawing 3-8: Cost of RSSI vs RSSI

### 3.0 Mesh Configuration

Actual cost of RSSI used by Microhard to determine route cost is listed in the table below:

| Cost of RSSI | RSSI (dBm)   | Cost of RSSI | RSSI (dBm) | Cost of RSSI | RSSI (dBm) |
|--------------|--------------|--------------|------------|--------------|------------|
| 0            | Less than 55 | 10           | 79         | 26           | 92         |
| 1            | 55 - 59      | 11           | 80         | 28           | 93         |
| 2            | 60 - 64      | 12           | 81         | 32           | 94         |
| 3            | 65 - 67      | 13           | 82         | 35           | 95         |
| 4            | 68 - 69      | 14           | 83         | 38           | 96         |
| 5            | 70 - 71      | 16           | 84         | 40           | 97         |
| 6            | 72 - 73      | 18           | 85         | 44           | 98         |
| 7            | 74 - 75      | 19           | 86         | 49           | 99         |
| 8            | 76 - 77      | 20           | 87         | 50           | 100        |
| 9            | 78           | 21           | 88 - 91    | 50           | 100+       |

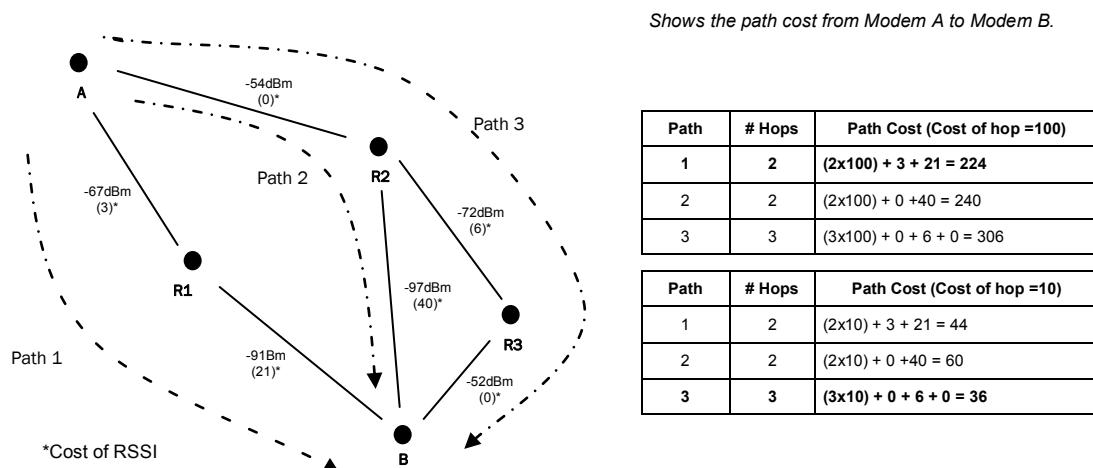
Table 3-2: Cost of RSSI

The cost of a hop can be modified by the user by setting register S245. Setting this register influences the relationship between the number of hops and the signal strength of the path.

$$S245 = 100 \quad - \quad \text{Cost of one hop in Mesh (0-255)}$$

Setting the value of S245 low, in relation to the cost of RSSI would result in a path that is not concerned with the number of hops, so long as the signal between hops was strong. Setting the value of S245 to a high cost value would indicate that using the shortest path possible is the most important, resulting in low latency and increased throughput, even at the risk of the path being weak, resulting in lost packets and retransmissions.

The illustration shows how different paths are calculated, and how the best path is determined before being added to the routing table.



Drawing 3-8: Routing Path Cost

## 3.0 Mesh Configuration

As seen in the first table of the illustration, using a cost of hop of 100, results in Path 1, which is the shortest path, being the lowest cost and the preferred route. It has the least amount of hops and even though the signal strength between hops may not be ideal, it is considered the preferred route and added to the routing table.

The second table of the illustration shows the effect of changing S245 to a small value, S245 = 10, lowering the cost of each hop. The results for this scenario have much different result. Since the cost of each hop is very low, and the strength of the links between hops is very strong, Path 3 results in being the lowest.

As seen, changing the value of S245 can drastically change the results. It should also be noted that the S245 can be modified on each unit, again changing the “best” path as seen by the route discovery process.

### 3.2.8 Hop Pattern

Frequency Hopping modems hop from frequency to frequency to allow for multiple networks to share the same frequency spectrum. The pattern at which the modems hop is known as the hopping pattern. In the Pico Series modems the hop pattern is pseudo-randomly generated using a complex combination of the Network ID (S104), Register S106, and S180, which define which channels are to be included in the calculation. This ensures that no two networks have the same hopping pattern, which would cause interference and collisions.

Register S106: Hop Pattern selects the hop pattern to use for the current system. The value set in this register must be the same for each unit in the system

S106 = 0 - Selects Hopping Pattern

FCC requires that FHSS systems hop on 50 different channels within the 900 MHz ISM Band. The maximum time spent on any one channel must not exceed 400ms.

To calculate the center frequency represented by each channel only the starting frequency and the size of each channel (Channel Bandwidth) need to be known. For the 900 MHz ISM Band, the starting frequency is 902.4 MHz, and the Channel Bandwidth is dependent on the current link rate.

$$\text{Freq channel } n = 902.4 + ((n-1) \times \text{BW}) \text{ MHz.}$$

Example: Channel 75 @ 172 kbps =   
 $902.4 + ((75-1) \times 0.250) \text{ MHz}$   
 $902.4 + (74 \times 0.250) \text{ MHz}$   
 $902.4 + 18.5 \text{ MHz}$   
 $920.9 \text{ MHz}$

| Link Rate (bps) | Channel Bandwidth (kHz) |
|-----------------|-------------------------|
| 57600           | 100                     |
| 115200          | 200                     |
| 172800          | 250                     |
| 230400          | 280                     |
| 276480          | 350                     |

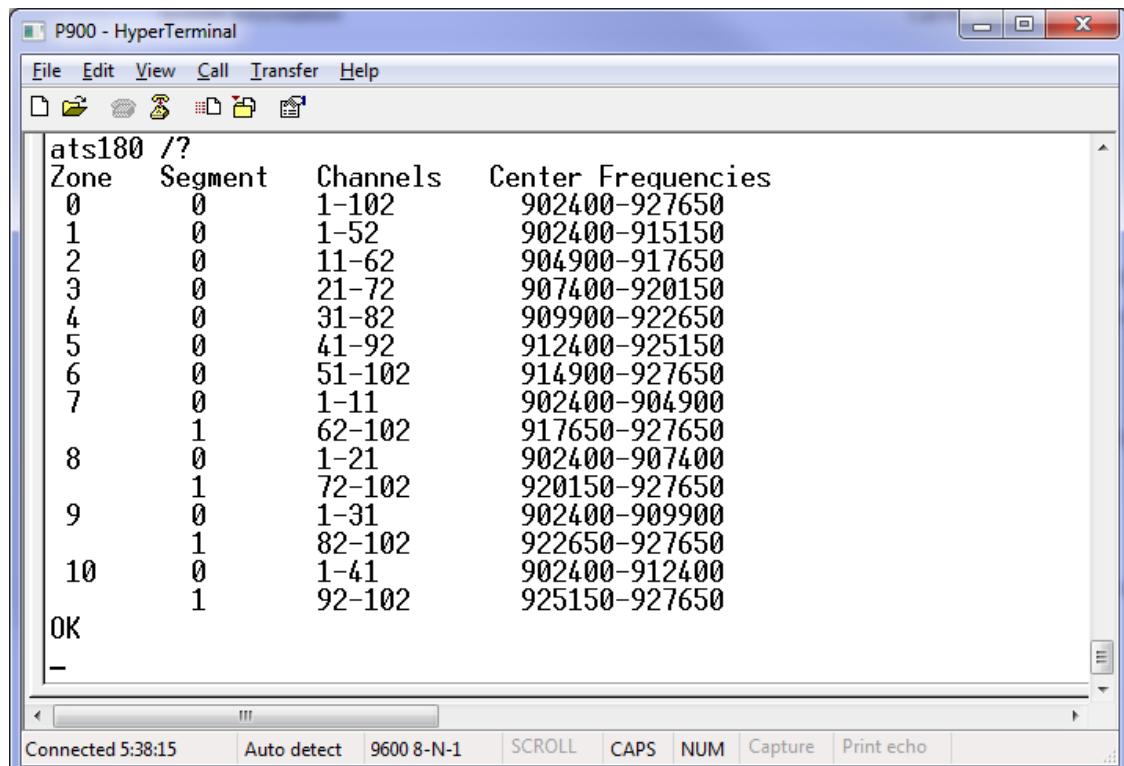
### 3.0 Mesh Configuration

#### Hop Zones

Register **S180: Hop Zone** selects the available frequency zones used by the Pico Series, as there may be times when multiple systems are deployed within close proximity, or there may be outside interference or noise that requires sections of the available spectrum to not be included in the Hop Pattern generation.

S180 = 0 - Use Entire 902-928 MHz ISM Band

Several Hop Zones are predefined by querying the S180 Register as seen below. The ranges listed are the frequency ranges that are available to create the hop table. Using Hop Zones several frequency Bands can be excluded. Also if multiple systems are being deployed within close proximity, Hop Zones can be used to minimize overlap in the frequencies used to populate the Hopping Pattern.



```
ats180 /?
Zone  Segment  Channels  Center Frequencies
 0    0        1-102    902400-927650
 1    0        1-52     902400-915150
 2    0        11-62    904900-917650
 3    0        21-72    907400-920150
 4    0        31-82    909900-922650
 5    0        41-92    912400-925150
 6    0        51-102   914900-927650
 7    0        1-11     902400-904900
        1        62-102   917650-927650
 8    0        1-21     902400-907400
        1        72-102   920150-927650
 9    0        1-31     902400-909900
        1        82-102   922650-927650
10   0        1-41     902400-912400
        1        92-102   925150-927650
OK
-
```

Image 3-11: Hop Zones

## 4.0 Point to Point Configuration

To begin configuration, the P900 must be mounted into a either a Microhard supplied development board (with factory attached interface card), or be mounted into a customer designed platform. The P900 is configured using AT commands through the **Data** port, or using special diagnostic commands through the **Diagnostic** Port. Refer to [Section 2: Hardware Description](#) for information related to interfacing to, or powering the module.

To issue AT commands through the **Data** port, the P900 must first be set into **Command Mode** as described below.

### 4.1 Configuration/Unit Modes

#### 4.1.1 Command Mode

- the P900 module is offline (data is not passing through the unit via it's local data lines or RF communications)
- if installed in a Development Board, the only LED illuminated will be the blue power LED.
- the P900's configuration options (registers) may be viewed and modified using AT commands.

Two methods are typically used to place the Pico Series into Command Mode.

##### 1. Force to Command Mode

- Power down off the Development Board assembly.
- Connect a 9-pin straight-through serial cable from the PC serial port to the rear RS-232 port (DATA) of the modem.
- Launch a terminal communications program (e.g. HyperTerminal) and configure for 9600bps, 8 data bits, No parity, 1 stop bit (8N1), no flow control
- press and hold the CONFIG button
- continue to press the CONFIG button and apply power to the modem
- release the CONFIG button
- On power up the terminal session window should show "NO CARRIER OK" as seen below:



Image 4-1: Command Mode

- the P900 is now in command mode, and AT commands can be used to configure or query the settings. AT&V will display the current configuration, and the registers can be queried using the AT\$XXX=? Command where XXX = the register number. Help is available using the AT\$XXX /? Command.
- Any and all changes must be written to NVRAM using the AT&W command.

## 4.0 Point to Point Configuration

### 2. Escape from Data Mode

- With the P900 powered up and 'online', connect a 9-pin straight-through serial cable from the PC serial port to the RS-232 DATA port on the dev board.
- Launch a terminal program (e.g. HyperTerminal) and configure for the P900's established serial baud rate parameters (PC & modem must match).
- Pause 1 second, type '**+++**' , pause 1 second: the monitor should show the module response of 'NO CARRIER OK'



Image 4-2: Command Mode

- The P900 is now in command mode, and AT commands can be used to configure or query the settings.
- Entering the AT&V command as shown will show the current configuration as seen below: (The data displayed varies based on network and unit type.)

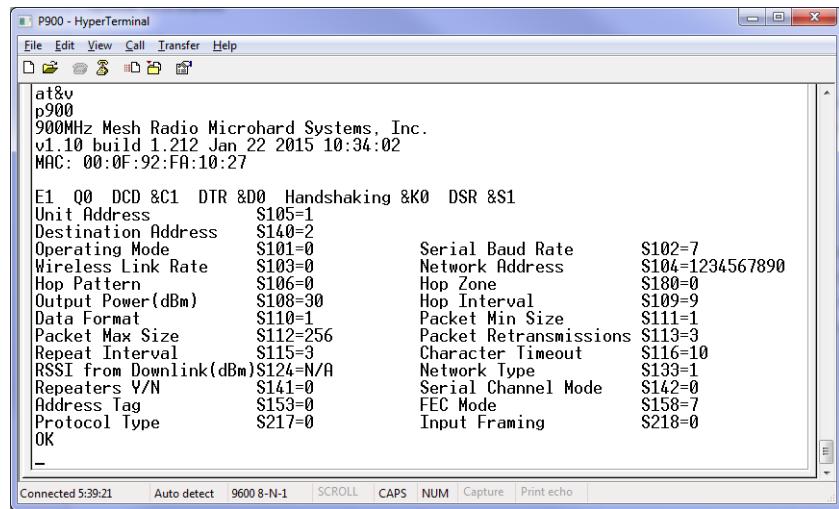


Image 4-3: Command Mode - AT&V Display

### 4.1.2 Data Mode

Data Mode is the normal operational state of all deployed P900 modules. In this mode the module is prepared to exchange data as per its configuration settings. Available LED indications can provide an indication of the data exchange (TX and RX LEDs).

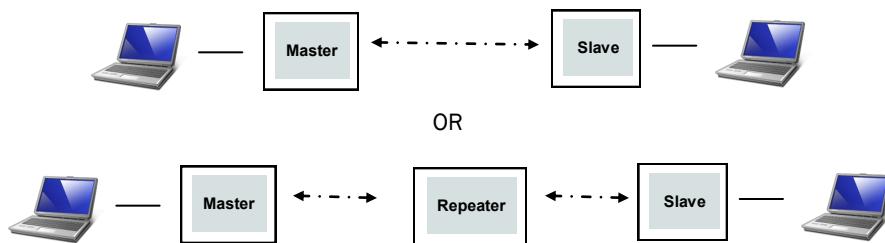
To enter DATA mode from COMMAND mode, enter the command: **ATA [Enter]**

## 4.0 Point to Point Configuration

### 4.2 Point to Point Network

In a point-to-point network, a path is created to transfer data between Point A and Point B, where Point A may be considered the Master modem and Point B a Slave. Such a PTP network may also involve one or more Repeaters (in a store-and-forward capacity) should the radio signal path dictate such a requirement. Point to Point is enabled by setting register S133 to 1 (ATS133=1, *Network Type*).

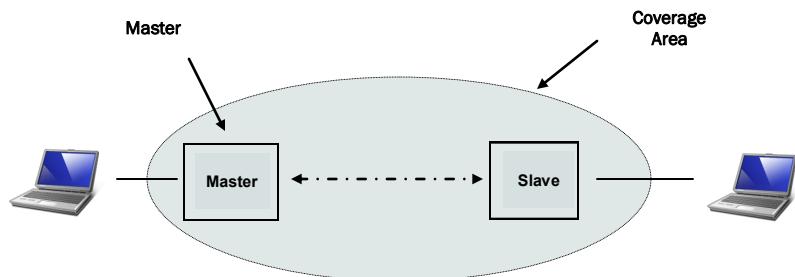
A PTP configuration may also be used in a more dynamic sense: there may be many Slaves (and Repeaters) within such a network, however the Master may have its 'Destination Address' (S140) changed when required to communicate with a specific Slave.



Drawing 4-1: Point to Point Network Topology

#### 4.2.1 Operating Modes / Unit Types

In a Microhard Point to Point Network, three unit types or operating modes are available: the Master, Repeater, and the Remote. The **Masters** role is to provide network synchronization for the system, which ensures all units are active and able to communicate as required. The Master controls the flow of data through the system; all data passes through it. The diagram below shows a unit configured as a Master.

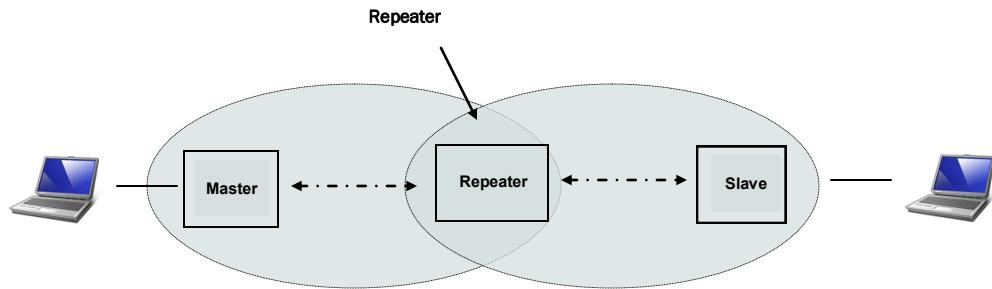


Drawing 4-2: Point to Point Master

## 4.0 Point to Point Configuration

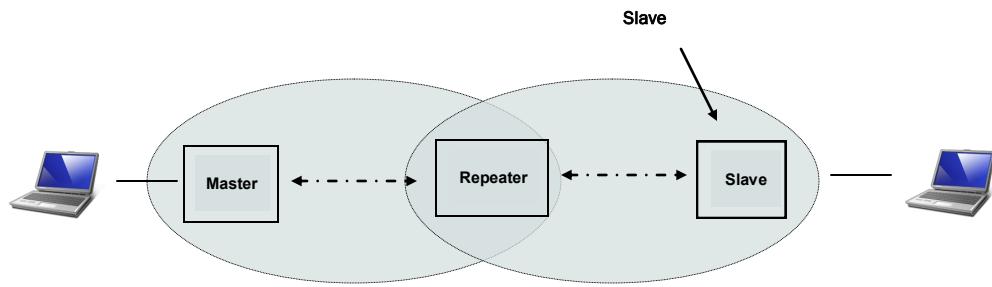
**Repeaters** can be used to extend the coverage of the Master. Required only if it is necessary to establish a radio path between a Master and Slave(s); stores and forwards data sent to it. Synchronizes to Master and provides synchronization to 'downstream' units. If a local device is attached to a Repeater's serial data port, the Repeater will also behave as a Slave (aka Repeater/Slave).

Adding one or more Repeaters within a network will cut the overall throughput of the network in **half**; the throughput is halved only once, i.e. it does not decrease with the addition of more Repeaters. If there is a 'path' requirement to provide Repeater functionality, but throughput is critical, a work around is to place two modems at the Repeater site in a 'back-to-back' configuration. One modem would be configured as a Slave in the 'upstream' network; the other a Master (or Slave) in the 'downstream' network. Local connection between the modems would be a 'null modem' cable. Each modem would require its own antenna; careful consideration should be given with respect to antenna placement and modem configuration.



Drawing 4-3: Point to Point Repeater

A **Slave (Remote)** is an endpoint/node within a network to which a local device is attached. Communicates with Master either directly or through one or more Repeaters.



Drawing 4-4: Point to Point Slave

Units can be configured to perform the various roles discussed by setting register S101 as follows:

- |            |                  |
|------------|------------------|
| ATS101 = 0 | - Master         |
| ATS101 = 1 | - Repeater       |
| ATS101 = 2 | - Slave (Remote) |

## 4.0 Point to Point Configuration

### 4.2.2 Configuration Using Factory Defaults

Factory default setting commands can be used to aid in the configuration and deployment of the Pico series modules, providing a known starting point in the configuration process for each unit type. Using the factory default commands sets all applicable registers to factory recommended settings and allows for initial connectivity between units. Configuring modems using the factory default settings have the following benefits:

- hastens the configuration process - *load default settings and, if necessary, apply only minor settings / adjustments*
- aids in troubleshooting - *if settings have been adjusted and basic communications cannot be established, simply revert to the factory default setting and any improper adjustments will be overwritten and a 'fresh start' can be made with known-to-work settings*

For many networks, the factory default commands may be all that is necessary to configure and deploy a simple Point to Point Network. Other applications may require additional registers to be configured. Regardless of the complexity of the configuration, the factory default settings provide a starting point for all configurations. All unit types have a factory default setting command.

|        |   |                         |
|--------|---|-------------------------|
| AT&F10 | - | Point to Point Master   |
| AT&F11 | - | Point to Point Slave    |
| AT&F12 | - | Point to Point Repeater |

The screen shots for each unit type highlight the key registers that are automatically changed to create a Point to Point configuration. There may also be additional registers such as the Network ID that are recommended to be changed.



Each PTP Network must have a unique network ID. This can be changed using register S104: Network Address.

```
AT&F /?
Factory defaults.
&F1 - Mesh Primary Coordinator
&F2 - Mesh Remote
&F3 - Mesh Secondary Coordinator
&F7 - PMP Master
&F8 - PMP Slave
&F9 - PMP Repeater
&F10 - PP Master
&F11 - PP Slave
&F12 - PP Repeater
&F13 - PMP Master 57K
&F14 - PMP Slave 57K
OK
```

Image 4-4: Factory Defaults

## 4.0 Point to Point Configuration



Compression (S225) was introduced in firmware v1.10. S225 must be set to 0 for compatibility with older versions.

### AT&F10 Point to Point Master

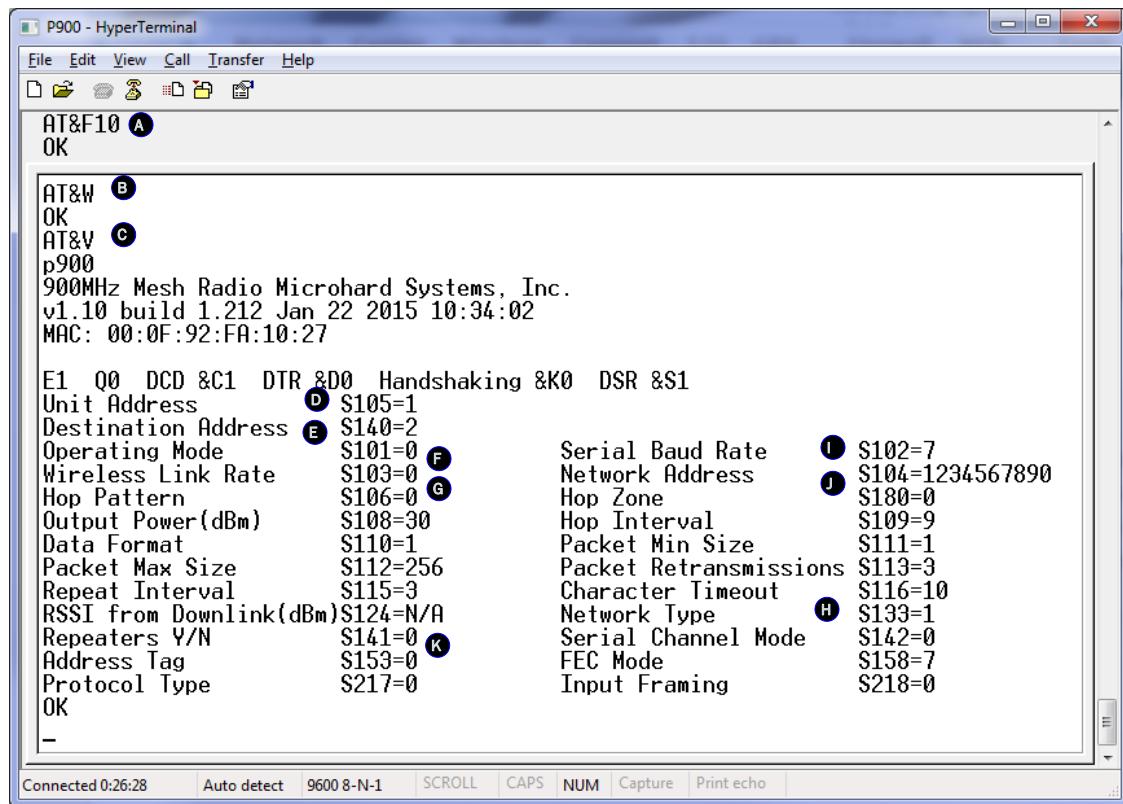


Image 4-5: Factory Defaults AT&F10 - Point to Point Master

- A) AT&F10 - Sets the factory defaults for a Point to Point Master.
- B) AT&W - Writes the changes to NVRAM.
- C) AT&V - Displays the configuration as seen above.
- D) S105 - Every unit in a Point to Point Network must have a unique unit address. The Master is automatically set to 1, and should not be changed.
- E) S140 - The destination address is unit address of the final destination, which all data is to be sent. The address entered would generally be the unit address of the Slave.
- F) S101 - The operating mode defines the unit type and is set to 0, which is a Master.
- G) S103 - Wireless Link Rate must be set to the same value of each unit in the system. Higher link rates may result in higher throughput, but lower link rates usually provide better sensitivity and overall robustness.
- H) S133 - The network type must be set to 1 for Point to Point operation. The content displayed by the AT&V command will vary with the network type.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S104 - Each unit in a Network must have the same Network Address. It is strongly recommended to never use the default setting of 1234567890. To change the Network Address, the AT&S104=XXXXXXX command can be used.
- K) S141 - This register informs the master if 1 or more repeaters are present in the system. This applies only to the master radio.

Remember, anytime registers are changed the values must be written to NVRAM using the AT&W command. To switch from command mode to data mode (online mode), the ATA command can be issued.

## 4.0 Point to Point Configuration

### AT&F11 Point to Point Slave

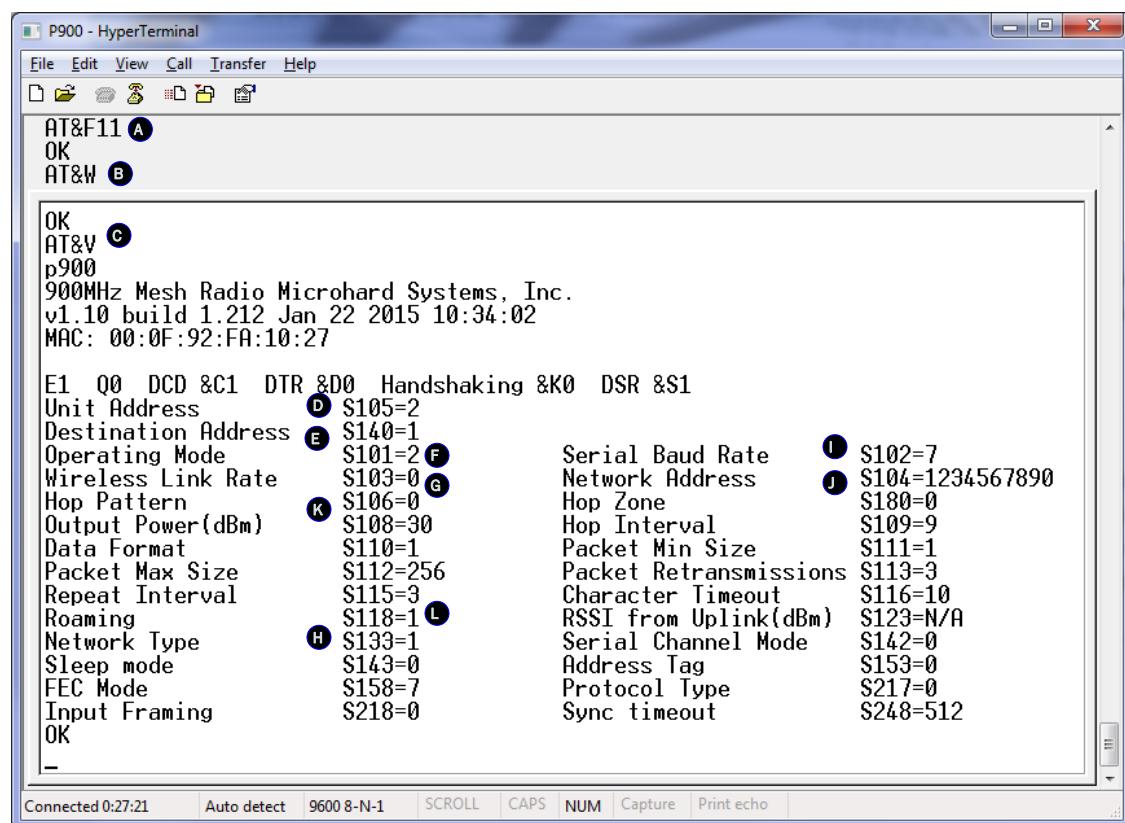


Image 4-6: Factory Defaults AT&F11 - Point to Point Slave

- A) AT&F11 - Sets the factory defaults for a Point to Point Slave.
- B) AT&W - Writes the changes to NVRAM.
- C) AT&V - Displays the configuration as seen above.
- D) S105 - Every unit in a Point to Point Network must have a unique unit address. The address of the slave (remote) is automatically set to 2. *This can be changed, but ensure that the destination address on the master is also changed!*
- E) S140 - The destination address is unit address of the final destination to which all data is to be sent. In a Point to Point Network this address is set to 1, the unit address of the master, and should not be changed.
- F) S101 - The operating mode defines the unit type and is set to 2, which is a Slave (Remote).
- G) S103 - Wireless Link Rate must be set to the same value of each unit in the system.
- H) S133 - The network type must be set to 1 for Point to Point operation. The content displayed by the AT&V command varies with the network type.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S104 - Each unit in a Network must have the same Network Address. To change the Network Address, the ATS104=XXXXXXX command can be used.
- K) S106 - Ensure this register is set to the Hopping Pattern of the Master(S106), or if the unit is to communicate through a repeater, set to match the Secondary Hop Pattern (S206).
- L) S118 - If the slave is to connect through a repeater, enter the unit address of the repeater here, or set to 65535 for roaming.

## 4.0 Point to Point Configuration

### AT&F12 Point to Point Repeater

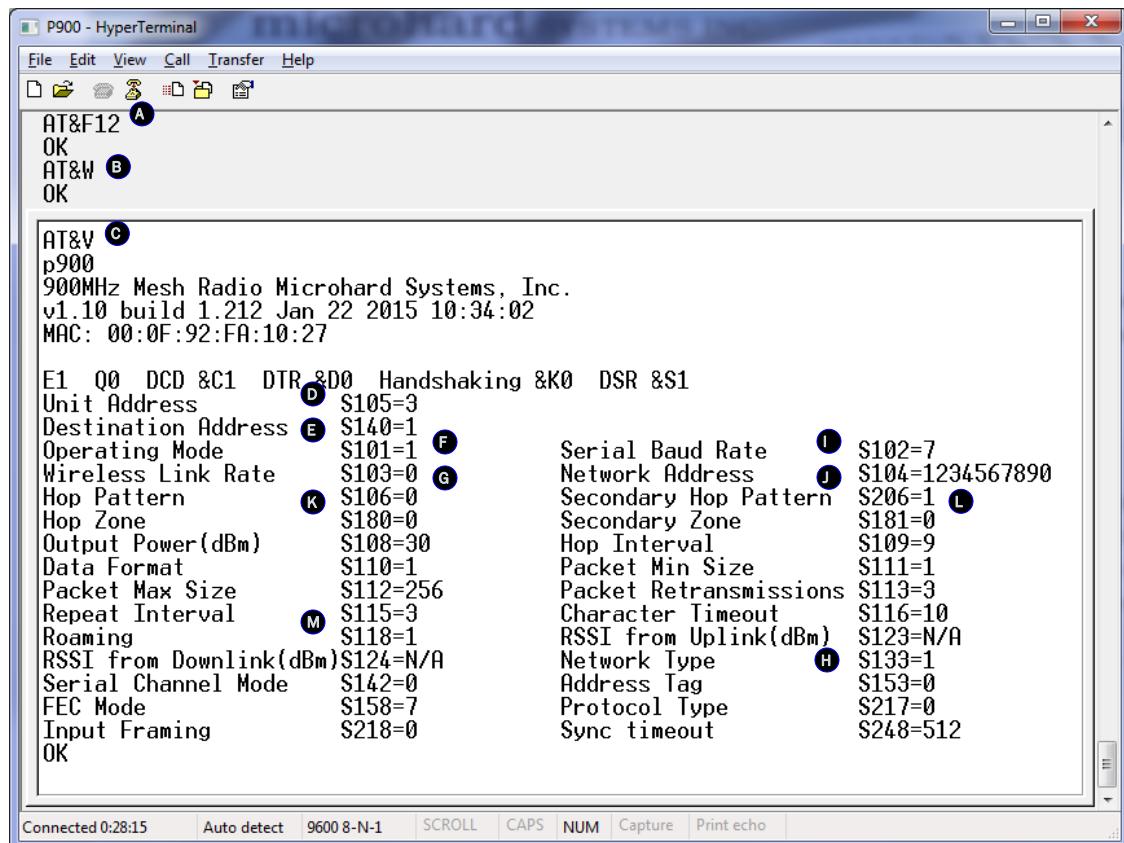


Image 4-7: AT&F12 Point to Point Repeater Configuration

- A) AT&F12 - Sets the factory defaults for a Point to Point Repeater.
- B) AT&W - Writes the changes to NVRAM.
- C) AT&V - Displays the configuration as seen above.
- D) S105 - Every unit in a Point to Point Network must have a unique unit address. The address of the Repeater is automatically set to 3.
- E) S140 - The destination address is unit address of the final destination to which all data is to be sent. In a Point to Point Network this address is set to 1, the unit address of the master, and should not be changed.
- F) S101 - The operating mode defines the unit type and is set to 1, which is a Repeater.
- G) S103 - Wireless Link Rate must be set to the same value of each unit in the system.
- H) S133 - The network type must be set to 1 for Point to Point operation. The content displayed by the AT&V command varies with the network type.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S104 - Each unit in a Network must have the same Network Address. To change the Network Address, the AT&S104=XXXXXX command can be used.
- K) S106 - Ensure this register is set to the Hopping Pattern of the Master(S106), or if the unit is to communicate through a repeater, set to match the Secondary Hop Pattern (S206).
- L) S206 - This is the secondary hop pattern which is used to communicate with downstream units.
- M) S118 - The roaming address must be set to the master or repeaters' address (if more than 1 repeater is used) in which this repeater is to synchronize with.

## 4.0 Point to Point Configuration

### 4.2.3 Retransmissions

Packet Retransmissions can be used to ensure data reaches its intended destination by resending the same packet over and over. In Point to Point system all data is acknowledged by the destination, resulting in retransmissions only being used if no acknowledgement is received. The overall impact on system performance, while not as significant as it is in Mesh and Point to Multipoint networks, should still be considered. The more times a modem retransmits data, the more the overall throughput of the system is reduced. To adjust the retransmission rate, use register S113, the default value is 5 (+ the initial transmission).

S113 = 5 - Packet Retransmissions (0-254)

Retransmissions are typically used in noisy environments to combat interference and low signal strength, ensuring data is received at the intended destination.

### 4.2.4 Network Synchronization

Network Synchronization is what allows all units to hop from frequency to frequency at the same time.

For units to synchronize with the network, each unit must have the same:

- Network ID (S104)
- Forward Error Correction (S158)
- Network Type (S133)

#### Sync Timeout

Once synchronized to the network the unit does not need to receive sync data often to keep track of where the system is supposed to be (in time and frequency). The sync Timeout defines the number of hops where no sync data is received from a Master and/or Repeater before losing sync. In other words, how long a unit will remain synchronized with the network without receiving any sync packets before it gives up and loses sync.

S248 = 512 Sync Timeout (4-65534)

Setting a value too low will cause the unit to lose sync easily and time will be wasted trying to re-sync to the network. Several hops can go by without receiving a sync packet, and this is completely normal. If this value is set too high, the unit will assume for a long time that the network is still out there, when especially in mobile applications, it may not be.

## 4.0 Point to Point Configuration

### 4.2.5 Hop Patterns

Frequency Hopping modems hop from frequency to frequency to allow for multiple networks to share the same frequency spectrum. The pattern at which the modems hop is known as the hopping pattern. In the Pico Series modems the hop pattern is pseudo-randomly generated using a complex combination of the Network ID (S104), Register S106 (or S206), and S180 (or S181), which define which channels are to be included in the calculation. This ensures that no two networks have the same hopping pattern, which would cause interference and collisions.

Register S106: The primary Hop Pattern selects the hop pattern to use between a Master or Repeater to communicate with its associated units. The value set in this register should be the same for each unit that is to communicate with the specific Master or Repeater. A slave will automatically discover the hop patterns of its Master/Repeater based on its S118 setting. Setting S106 to match its Master/Repeater may shorten the discovery process.



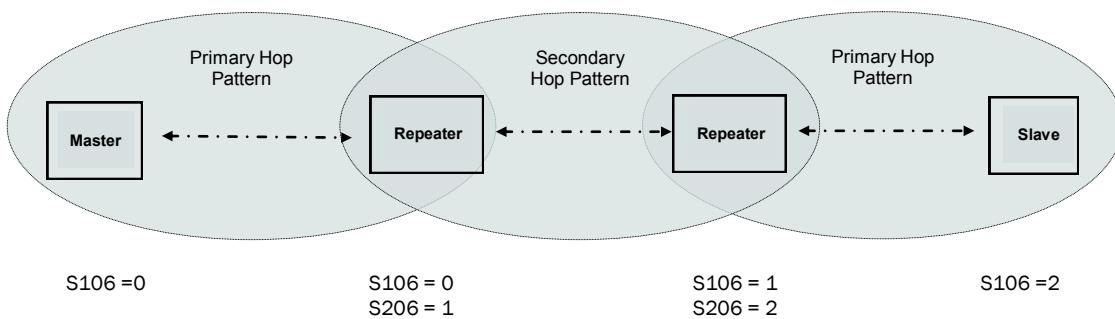
Not every hop pattern is generated orthogonally to others, use AT&H26 command for more information.

S106 = 0 - Primary Hopping Pattern

Register S206: The Secondary Hop Pattern selects a orthogonal, or different, hop pattern with non-overlapping channels used by repeaters to communication with its' associated units.

S206 = 1 - Secondary Hopping Pattern

The following illustration should help to describe how to provision the hop patterns in systems with repeaters.



Drawing 4-5: Hop Pattern (PP)

FCC requires that FHSS systems hop on 50 different channels within the 900 MHz ISM Band. The maximum time spent on any one channel must not exceed 400ms.

To calculate the center frequency represented by each channel only the starting frequency and the size of each channel (Channel Bandwidth) need to be known. For the 900 MHz ISM Band, the starting frequency is 902.4 MHz, and the Channel Bandwidth is dependent on the current link rate.

$$\text{Freq channel } n = 902.4 + ((n-1) \times \text{BW}) \text{ MHz.}$$

Example: Channel 75 @ 172 kbps =  

$$902.4 + ((75-1) \times 0.250) \text{ MHz}$$
  

$$902.4 + (74 \times 0.250) \text{ MHz}$$
  

$$902.4 + 18.5 \text{ MHz}$$
  

$$920.9 \text{ MHz}$$

| Link Rate (bps) | Channel Bandwidth (kHz) |
|-----------------|-------------------------|
| 57600           | 100                     |
| 115200          | 200                     |
| 172800          | 250                     |
| 230400          | 280                     |
| 276480          | 350                     |

## 4.0 Point to Point Configuration

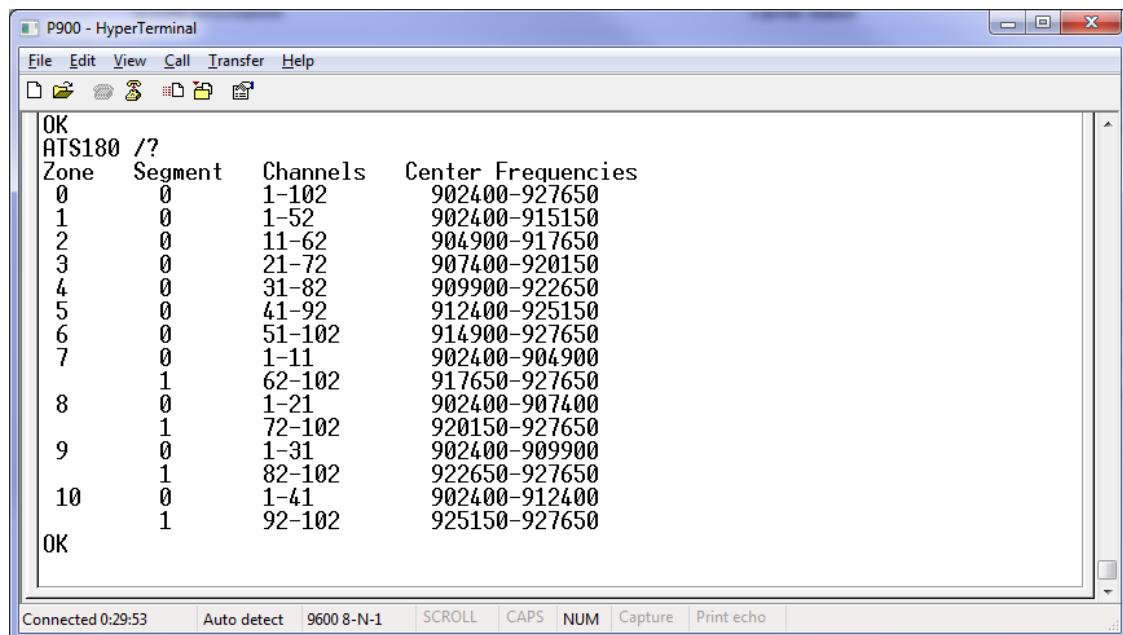
### Hop Zones

Register **S180: Hop Zone** and **S181: Secondary Zone**, select the available frequency zones used by the Pico Series, as there may be times when multiple systems are deployed within close proximity, or there may be outside interference or noise that requires sections of the available spectrum to not be included in the Hop Pattern generation.

S180 = 0 - Primary Zone (0=Use Entire 902-928 MHz ISM Band)  
S181 = 0 - Secondary Zone

The Primary Hop Zone, S180 is applied to the Primary Hop Pattern (S106). The Secondary Hop Zone, is applied to the Secondary Hop Pattern (S206), when determining the hop pattern for each segment of the system.

Several Hop Zones are predefined by querying the S180 Register as seen below. The ranges listed are the frequency ranges that are available to create the hop table. Using Hop Zones several frequency Bands can be excluded. Also if multiple systems are being deployed within close proximity, Hop Zones can be used to minimize overlap in the frequencies used to populate the Hopping Pattern.



| Zone | Segment | Channels | Center Frequencies |
|------|---------|----------|--------------------|
| 0    | 0       | 1-102    | 902400-927650      |
| 1    | 0       | 1-52     | 902400-915150      |
| 2    | 0       | 11-62    | 904900-917650      |
| 3    | 0       | 21-72    | 907400-920150      |
| 4    | 0       | 31-82    | 909900-922650      |
| 5    | 0       | 41-92    | 912400-925150      |
| 6    | 0       | 51-102   | 914900-927650      |
| 7    | 0       | 1-11     | 902400-904900      |
|      | 1       | 62-102   | 917650-927650      |
| 8    | 0       | 1-21     | 902400-907400      |
|      | 1       | 72-102   | 920150-927650      |
| 9    | 0       | 1-31     | 902400-909900      |
|      | 1       | 82-102   | 922650-927650      |
| 10   | 0       | 1-41     | 902400-912400      |
|      | 1       | 92-102   | 925150-927650      |

Image 4-8: Hop Zones

## 5.0 Point to Multipoint Configuration

To begin configuration, the P900 must be mounted into a either a Microhard supplied development board (with factory attached interface card), or be mounted into a customer designed platform. The P900 is configured using AT commands through the **Data** port, or using special diagnostic commands through the **Diagnostic** Port. Refer to [Section 2: Hardware Description](#) for information related to interfacing to, or powering the module.

To issue AT commands through the **Data** port, the P900 must first be set into **Command Mode** as described below.

### 5.1 Configuration/Unit Modes

#### 5.1.1 Command Mode

- the P900 module is offline (data is not passing through the unit via it's local data lines or RF communications)
- if installed in a Development Board, the only LED illuminated will be the blue power LED.
- the P900's configuration options (registers) may be viewed and modified using AT commands.

Two methods are typically used to place the Pico Series into Command Mode.

#### 1. Force to Command Mode

- Power down off the Development Board assembly.
- Connect a 9-pin straight-through serial cable from the PC serial port to the rear RS-232 port (DATA) of the modem.
- Launch a terminal communications program (e.g. HyperTerminal) and configure for 9600bps, 8 data bits, No parity, 1 stop bit (8N1), no flow control
- press and hold the CONFIG button
- continue to press the CONFIG button and apply power to the modem
- release the CONFIG button
- On power up the terminal session window should show "NO CARRIER OK" as seen below:

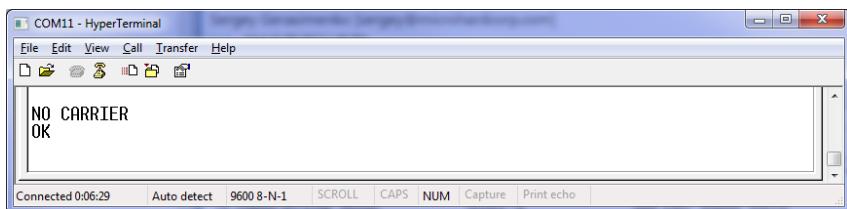


Image 5-1: Command Mode

- the P900 is now in command mode, and AT commands can be used to configure or query the settings. AT&V will display the current configuration, and the registers can be queried using the AT\$XXX=? Command where XXX = the register number. Help is available using the AT\$XXX /? Command.
- Any and all changes must be written to NVRAM using the AT&W command.

## 5.0 Point to Multipoint Configuration

### 2. Escape from Data Mode

- With the P900 powered up and 'online', connect a 9-pin straight-through serial cable from the PC serial port to the RS-232 DATA port on the dev board.
- Launch a terminal program (e.g. HyperTerminal) and configure for the P900's established serial baud rate parameters (PC & modem must match).
- Pause 1 second, type '**+++**' , pause 1 second: the monitor should show the module response of 'NO CARRIER OK'

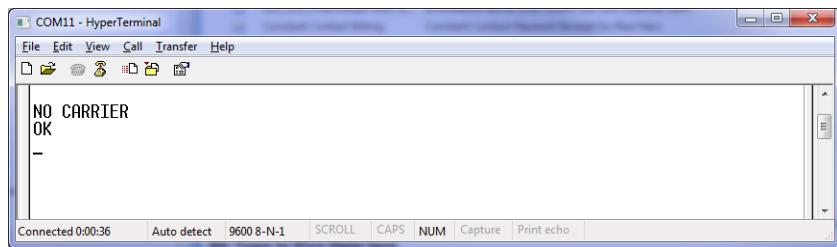


Image 5-2: Command Mode

- The P900 is now in command mode, and AT commands can be used to configure or query the settings.
- Entering the AT&V command as shown will show the current configuration as seen below: (The data displayed varies based on network and unit type.)

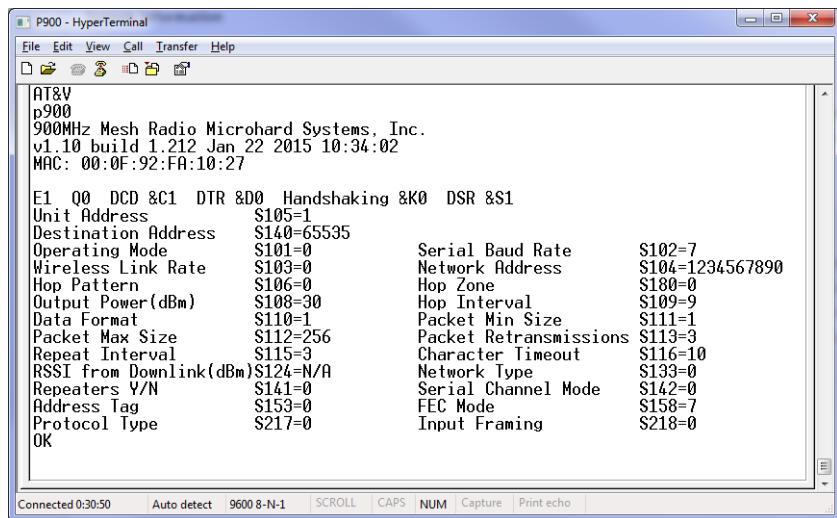


Image 5-3: Command Mode - AT&V Display

#### 4.1.2 Data Mode

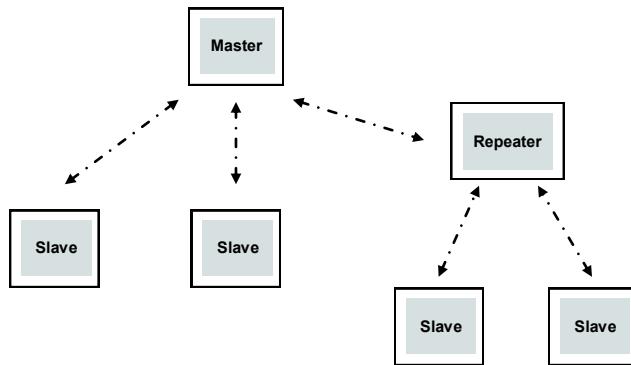
Data Mode is the normal operational state of all deployed P900 modules. In this mode the module is prepared to exchange data as per its configuration settings. Available LED indications can provide an indication of the data exchange (TX and RX LEDs).

To enter DATA mode from COMMAND mode, enter the command: **ATA [Enter]**

## 5.0 Point to Multipoint Configuration

### 5.2 Point to Multipoint Network

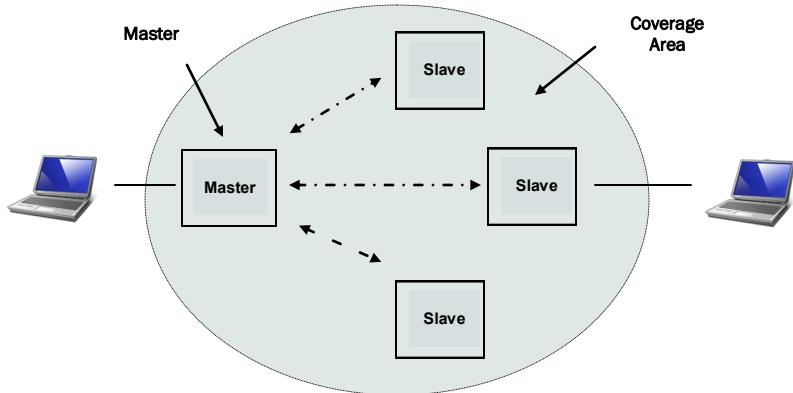
In a Point to Multipoint Network, a path is created to transfer data between the Master modem and numerous remote modems. The remote modems may simply be Slaves with which the Master communicates directly, and/or Slaves which communicate via Repeaters. Some or all of the Repeaters may also act as Slaves in this type of Network, i.e. the Repeaters are not only storing and forwarding data, but are also acting as Slaves. Such Repeaters may be referred to as 'Repeater/Slaves'. Point to Multipoint is enabled by setting register S133 to 0 (ATS133=0, Network Type).



Drawing 5-1: Point to Multipoint Network Topology

#### 5.2.1 Operating Modes / Unit Types

In a Microhard Point to Multipoint Network, three unit types or operating modes are available: the Master, the Repeater, and the Remote. The **Master** modem's role is to provide network synchronization for the system, which ensures all units are active and able to communicate as required. The Master controls the flow of data through the system; all data passes through it. The diagram below shows a unit configured as a Master.

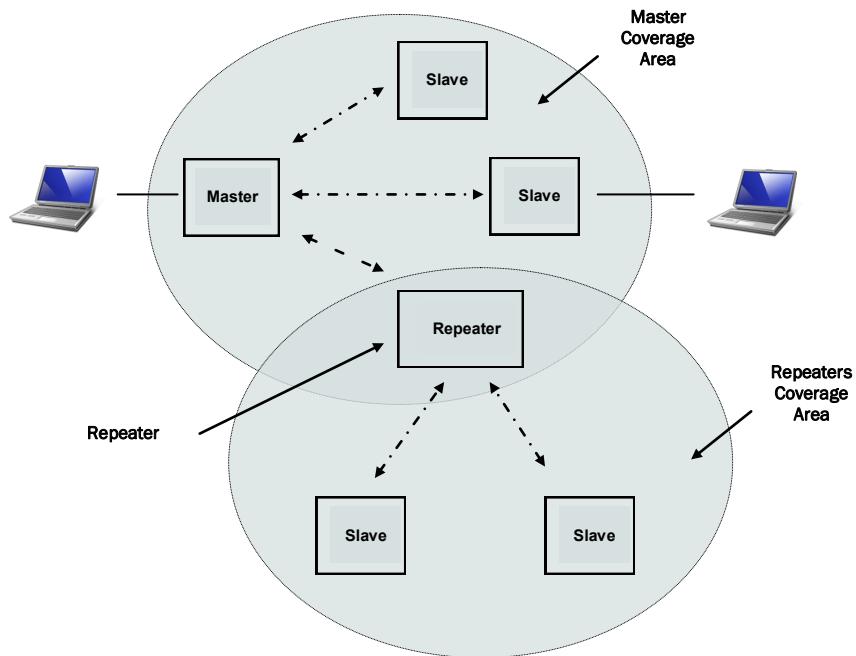


Drawing 5-2: Point to Multipoint Master

## 5.0 Point to Multipoint Configuration

**Repeaters** can be used to extend the coverage of the Master. Required only if necessary to establish a radio path between a Master and Slave(s); stores and forwards data sent to it. Synchronizes to Master and provides synchronization to 'downstream' units. If a local device is attached to a Repeater's serial data port, the Repeater will also behave as a Slave (aka Repeater/Slave).

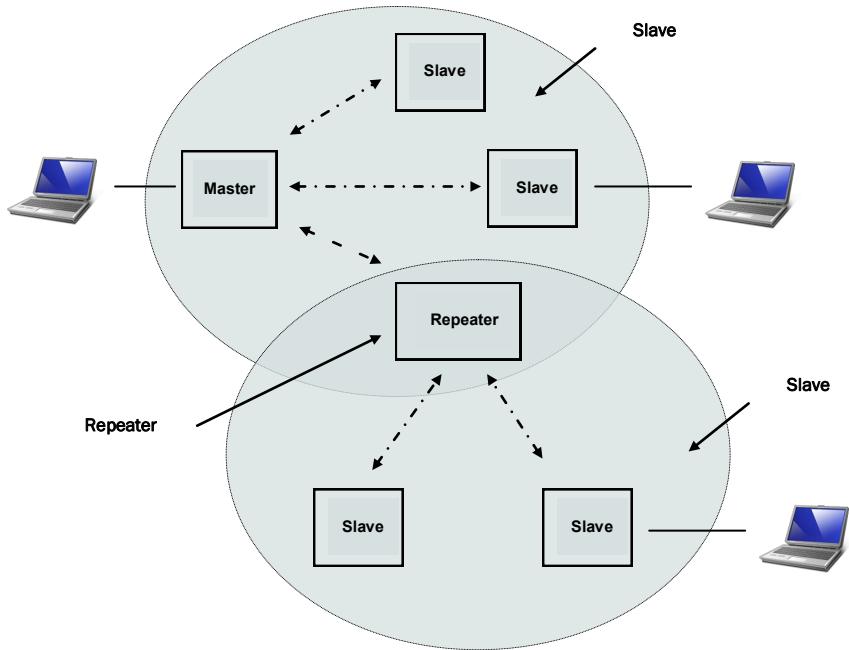
Adding one or more Repeaters within a network will cut the overall throughput of the network in **half**; the throughput is halved only once, i.e. it does not decrease with the addition of more Repeaters. If there is a 'path' requirement to provide Repeater functionality, but throughput is critical, a work around is to place two modems at the Repeater site in a 'back-to-back' configuration. One modem would be configured as a Slave in the 'upstream' network; the other a Master (or Slave) in the 'downstream' network. Local connection between the modems would be a 'null modem' cable. Each modem would require its own antenna; careful consideration should be given with respect to antenna placement and modem configuration.



Drawing 5-3: Point to Multipoint Repeater

## 5.0 Point to Multipoint Configuration

A **Slave (Remote)** is a endpoint or node within a network to which a local serial device is attached. Communicates with Master either directly or through one or more Repeaters.



*Drawing 5-4: Point to Multipoint Slave*

Units can be configured to perform the various roles discussed by setting register S101 as follows:

|            |                  |
|------------|------------------|
| ATS101 = 0 | - Master         |
| ATS101 = 1 | - Repeater       |
| ATS101 = 2 | - Slave (Remote) |

The next section discussed using Factory Default commands to configure the various types of units that are available in a Point to Multipoint network, simplifying the configuration process.

## 5.0 Point to Multipoint Configuration

### 5.2.2 Configuration Using Factory Defaults

Factory default setting commands can be used to aid in the configuration and deployment of the Pico series modules, providing a known starting point in the configuration process for each unit type. Using the factory default commands sets all applicable registers to factory recommended settings and allows initial connectivity between units. Configuring modems using the factory default settings have the following benefits:

- hastens the configuration process - *load default settings and, if necessary, apply only minor settings / adjustments*
- aids in troubleshooting - *if settings have been adjusted and basic communications cannot be established, simply revert to the applicable factory default setting and any improper adjustments will be overwritten and a 'fresh start' can be made with known-to-work settings*

For many networks, the factory default commands may be all that is necessary to configure and deploy a simple Point to Multipoint Network. Other applications may require additional registers to be configured. Regardless of the complexity of the configuration, the factory default settings provide a starting point for all configurations. All unit types have a factory default setting command.

|       |   |                              |
|-------|---|------------------------------|
| AT&F7 | - | Point to Multipoint Master   |
| AT&F8 | - | Point to Multipoint Slave    |
| AT&F9 | - | Point to Multipoint Repeater |

The screen shots for each unit type will highlight the key registers that are automatically changed to create a Point to Point configuration. There may also be additional registers such as the Network ID that are recommended to be changed.



Each PMP Network must have a unique network ID. This can be changed using register S104: Network Address.

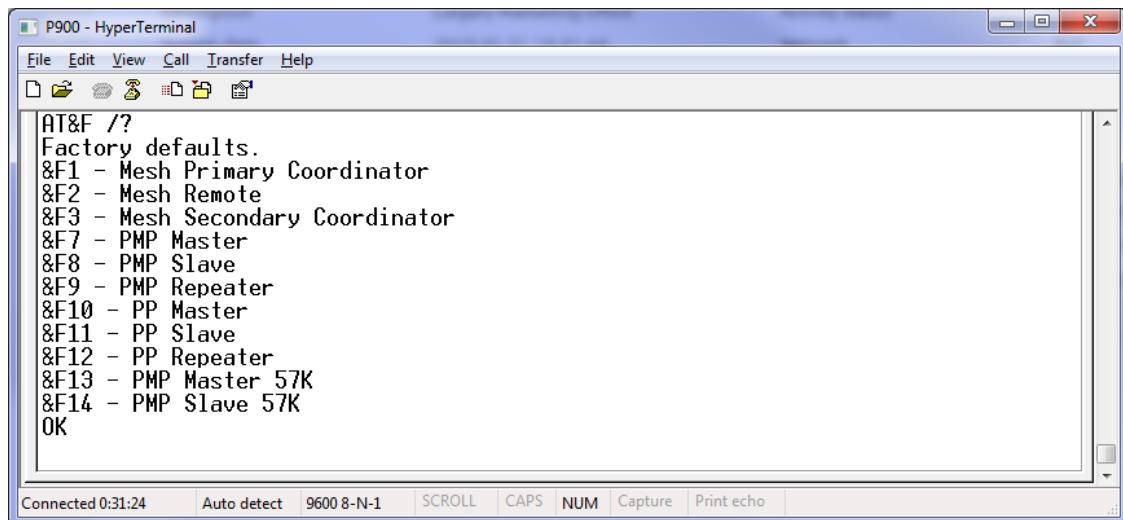


Image 5-4: Factory Defaults

## 5.0 Point to Multipoint Configuration

### AT&F7 Point to Multipoint Master



Compression (S225) was introduced in firmware v1.10. S225 must be set to 0 for compatibility with older versions.

```

P900 - HyperTerminal
File Edit View Call Transfer Help
AT&F7 A
OK
AT&W B
OK
AT&V C
p900
900MHz Mesh Radio Microhard Systems, Inc.
v1.10 build 1.212 Jan 22 2015 10:34:02
MAC: 00:0F:92:FA:10:27

E1 Q0 DCD &C1 DTR &D0 Handshaking &K0 DSR &S1
Unit Address D S105=1
Destination Address E S140=65535
Operating Mode S101=0 F
Wireless Link Rate S103=0 G
Hop Pattern S106=0
Output Power (dBm) S108=30
Data Format S110=1
Packet Max Size S112=256
Repeat Interval S115=3
RSSI from Downlink(dBm) S124=N/A
Repeaters Y/N S141=0 K
Address Tag S153=0
Protocol Type S217=0
OK

Serial Baud Rate I S102=7
Network Address J S104=1234567890
Hop Zone S180=0
Hop Interval S109=9
Packet Min Size S111=1
Packet Retransmissions S113=3
Character Timeout S116=10
Network Type H S133=0
Serial Channel Mode S142=0
FEC Mode S158=7
Input Framing S218=0

Connected 1:10:58 Auto detect 9600 8-N-1 SCROLL CAPS NUM Capture Print echo

```

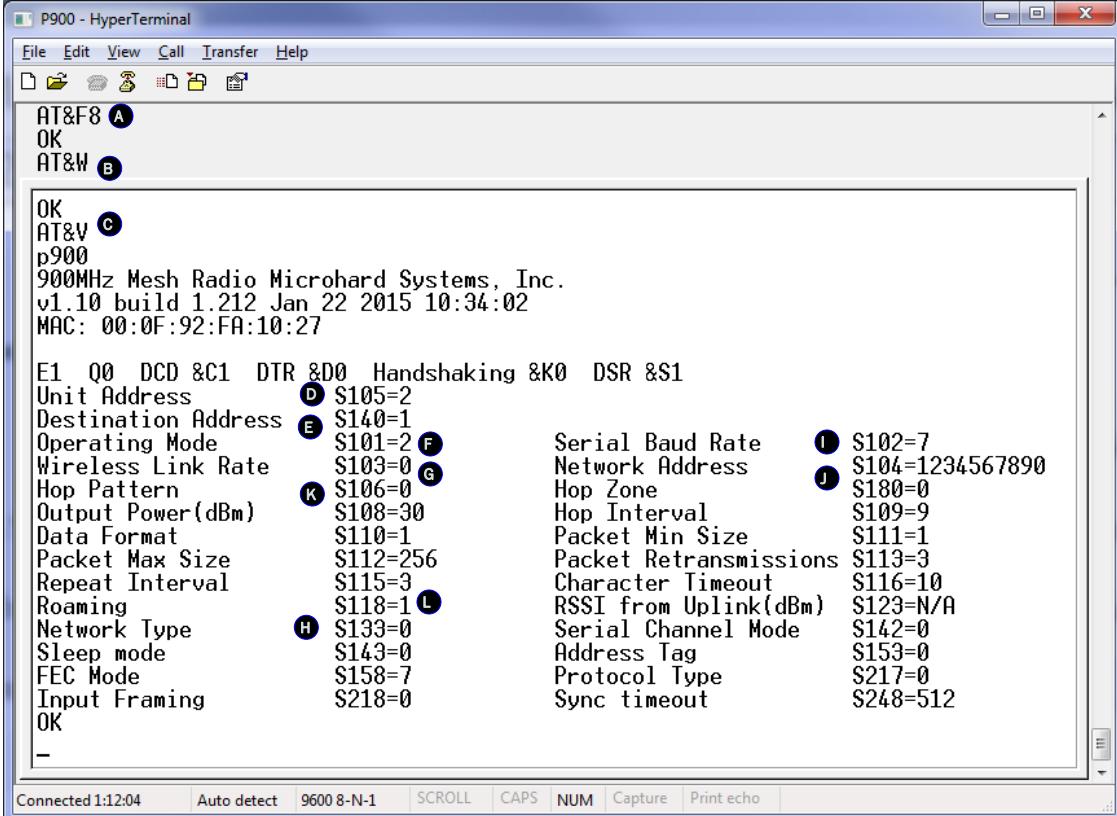
Image 5-5: Factory Defaults AT&F7 - Point to Multipoint Master

- A) AT&F7 - Sets the factory defaults for a Point to Multipoint Master.
- B) AT&W - Writes the changes to NVRAM.
- C) AT&V - Displays the configuration as seen above.
- D) S105 - Every unit in a Point to Multipoint Network must have a unique unit address. The Master is automatically set to 1, and should not be changed.
- E) S140 - The destination address for a PMP Network, by default is 65535, which means data is broadcast from the Master to all other units.
- F) S101 - The operating mode defines the unit type and is set to 0, which is a Master.
- G) S103 - Wireless Link Rate must be set to the same value of each unit in the system. Higher link rates may result in higher throughput, but lower link rates usually provide better sensitivity and overall robustness.
- H) S133 - The network type must be set to 0 for Point to Multipoint operation. The content displayed by the AT&V command will vary with the network type.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S104 - Each unit in a Network must have the same Network Address. It is strongly recommended to never use the default setting of 1234567890. To change the Network Address, the AT&S104=XXXXXXX command can be used.
- K) S141 - This register informs the master if 1 or more repeaters are present in the system. This applies only to the master radio.

Remember, anytime registers are changed the values must be written to NVRAM using the AT&W command. To switch from command mode to data mode (online mode), the ATA command can be issued.

## 5.0 Point to Multipoint Configuration

### AT&F8 Point to Multipoint Slave



| Parameter           | Value    | Notes |
|---------------------|----------|-------|
| Unit Address        | S105=2   | (D)   |
| Destination Address | S140=1   | (E)   |
| Operating Mode      | S101=2   | (F)   |
| Wireless Link Rate  | S103=0   | (G)   |
| Hop Pattern         | S106=0   | (K)   |
| Output Power (dBm)  | S108=30  |       |
| Data Format         | S110=1   |       |
| Packet Max Size     | S112=256 |       |
| Repeat Interval     | S115=3   |       |
| Roaming             | S118=1   | (L)   |
| Network Type        | S133=0   | (H)   |
| Sleep mode          | S143=0   |       |
| FEC Mode            | S158=7   |       |
| Input Framing       | S218=0   |       |
| OK                  |          |       |

Serial Baud Rate: S102=7 (I)

Network Address: S104=1234567890 (J)

Hop Zone: S180=0 (J)

Hop Interval: S109=9 (J)

Packet Min Size: S111=1 (J)

Packet Retransmissions: S113=3 (J)

Character Timeout: S116=10 (J)

RSSI from Uplink (dBm): S123=N/A (J)

Serial Channel Mode: S142=0 (J)

Address Tag: S153=0 (J)

Protocol Type: S217=0 (J)

Sync timeout: S248=512 (J)

Image 5-6: Factory Defaults AT&F8 - Point to Multipoint Slave

- A) AT&F8 - Sets the factory defaults for a Point to Multipoint Slave.
- B) AT&W - Writes the changes to NVRAM.
- C) AT&V - Displays the configuration as seen above.
- D) S105 - Every unit in a Point to Multipoint Network must have a unique unit address. The address of the slave (remote) is automatically set to 2. If adding more than 1 Slave, this will need to be modified for each unit added.
- E) S140 - The destination address is the final destination to which all data is to be sent. In a Point to Multipoint Network this address is set to 1, the unit address of the Master, and should not be changed.
- F) S101 - The operating mode defines the unit type and is set to 2, which is a Slave (Remote).
- G) S103 - Wireless Link Rate must be set to the same value of each unit in the system.
- H) S133 - The network type must be set to 0 for Point to Multipoint operation.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S104 - Each unit in a Network must have the same Network Address. To change the Network Address, the AT&S104=XXXXXX command can be used.
- K) S106 - Normally this register is set to the Hopping Pattern of the Master(S106), or if the unit is to communicate through a repeater, set to match the Secondary Hop Pattern (S206).
- L) S118 - If the slave is to connect through a repeater, enter the unit address of the repeater here. Or set to 65535 for roaming.

## 5.0 Point to Multipoint Configuration

### AT&F9 Point to Multipoint Repeater

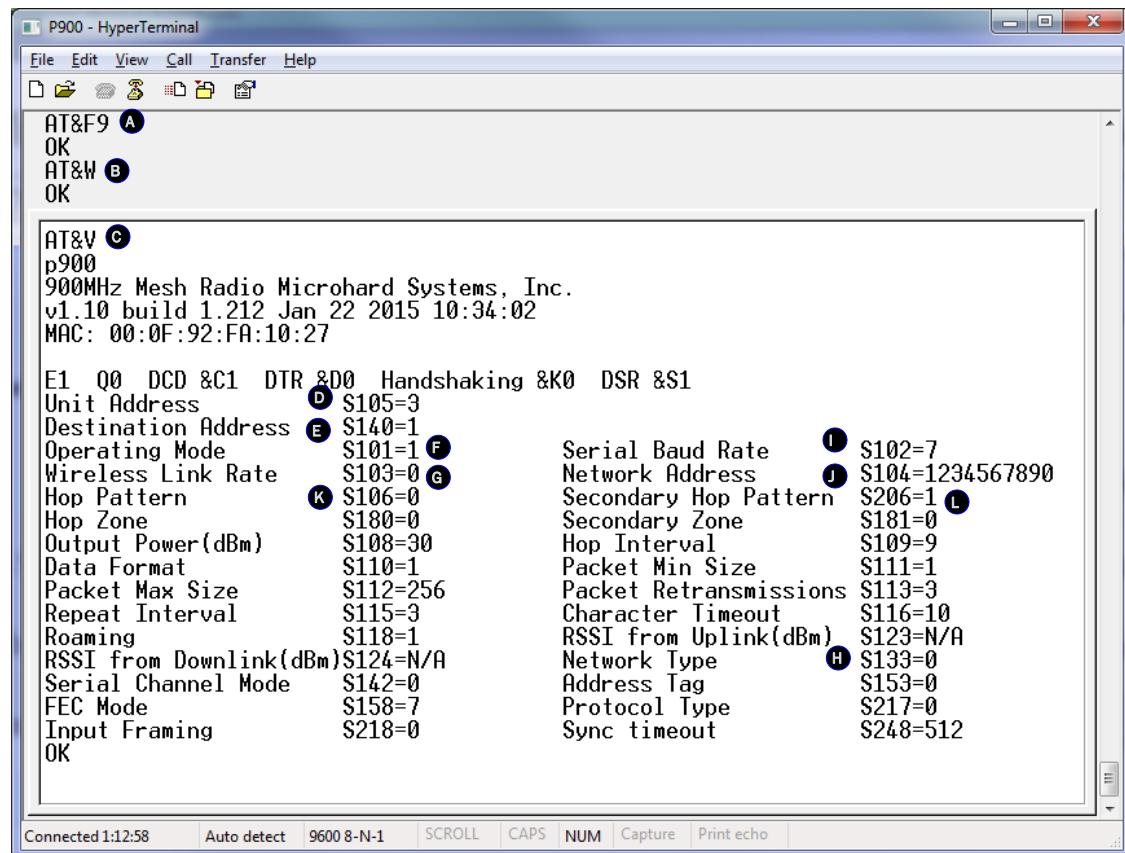


Image 5-7: AT&F9 Point to Multipoint Repeater

- A) AT&F9 - Sets the factory defaults for a Point to Multipoint Repeater.
- B) AT&W - Writes the changes to NVRAM.
- C) AT&V - Displays the configuration as seen above.
- D) S105 - Every unit in a Point to Multipoint Network must have a unique unit address. The address of the Repeater is automatically set to 3.
- E) S140 - The destination address is the final destination to which all data is to be sent. In a Point to Multipoint Network this address is set to 1, the unit address of the Master, and should not be changed.
- F) S101 - The operating mode defines the unit type and is set to 1, which is a Repeater.
- G) S103 - Wireless Link Rate must be set to the same value of each unit in the system.
- H) S133 - The network type must be set to 0 for Point to Multipoint operation.
- I) S102 - The serial baud rate (and data format S110) must match that of the connected device.
- J) S104 - Each unit in a Network must have the same Network Address. To change the Network Address, the AT&S104=XXXXXX command can be used.
- K) S106 - Should normally be set to the Hopping Pattern of the Master(S106), or if the unit is to communicate through a another repeater, set to match the Secondary Hop Pattern (S206) of that device.
- L) S206 - This is the secondary hop pattern which is used to communicate with downstream units.

## 5.0 Point to Multipoint Configuration

### 5.2.3 Unit Addressing

In a Point to Multipoint Network each unit must have a unique unit address, which can be configured using register S105. Duplicate addresses may result in unpredictable problems in the network. In a PMP Network data flow is such that data from the Master is sent to all units by setting the destination address (S140) to 65535, meaning data is broadcast to all units.

### 5.2.4 Retransmissions

Packet Retransmissions can be used to ensure data reaches its intended destination by resending the same packet over and over. In Point to Multipoint system data from the master is not acknowledged by the destination, meaning data will be transmitted an additional number of times specified by S113, resulting in a significant impact on system performance. The more times a modem retransmits data, the more the overall throughput of the system is reduced. To adjust the retransmission rate, use register S113, the default value is 5 (+ the initial transmission). Although, this number should be as low as possible to keep as much bandwidth in the system as possible.

S113 = 5 - Packet Retransmissions (0-254)

Retransmissions are typically used in noisy environments to combat interference and low signal strength, ensuring data is received at the intended destination.

### 5.2.5 Network Synchronization

Network Synchronization is what allows all units to hop from frequency to frequency at the same time.

For units to synchronize with the network, each unit must have the same:

- Network ID (S104)
- Network Type (S133)
- Forward Error Correction (S158)

#### Sync Timeout

Once synchronized to the network the unit does not need to receive sync data often to keep track of where the system is supposed to be (in time and frequency). The sync Timeout defines the number of hops where no sync data is received from a Master and/or Repeater before losing sync. In other words, how long a unit will remain synchronized with the network without receiving any sync packets before it gives up and loses sync.

S248 = 512 Sync Timeout (4-65534)

Setting a value too low will cause the unit to lose sync easily and time will be wasted trying to re-sync to the network. Several hops can go by without receiving a sync packet, and this is completely normal. If this value is set too high, the unit will assume for a long time that the network is still out there, when especially in mobile applications it may not be.

## 5.0 Point to Multipoint Configuration

### 5.2.6 Hop Patterns

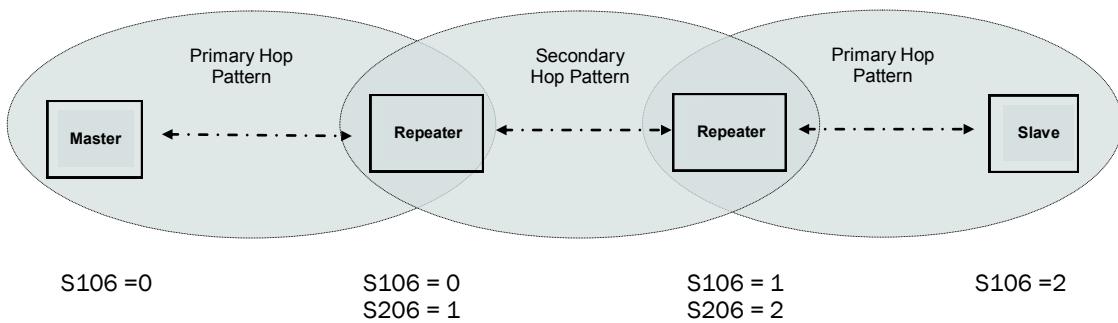
Frequency Hopping modems hop from frequency to frequency to allow for multiple networks to share the same frequency spectrum. The pattern at which the modems hop is known as the hopping pattern. In the Pico Series modems the hop pattern is pseudo-randomly generated using a complex combination of the Network ID (S104), Register S106 (or S206), and S180 (or S181), which define which channels are to be included in the calculation. This ensures that no two networks have the same hopping pattern, which would cause interference and collisions.

Register S106: The primary Hop Pattern selects the hop pattern to use between a Master or Repeater to communicate with its associated units. The value set in this register should be the same for each unit that is to communicate with the specific Master or Repeater. A slave will automatically discover the hop pattern of its Master/Repeater.

|          |   |                           |
|----------|---|---------------------------|
| S106 = 0 | - | Primary Hopping Pattern   |
| S206 = 1 | - | Secondary Hopping Pattern |

Register S206: The Secondary Hop Pattern selects a orthogonal, or different, hop pattern with non-overlapping channels used by repeaters to communication with its' associated units.

The following illustration should help to describe how to provision the hop patterns in systems with repeaters.



*Drawing 5-5: Hop Pattern (PMP)*

FCC requires that FHSS systems hop on 50 different channels within the 900 MHz ISM Band. The maximum time spent on any one channel must not exceed 400ms.

To calculate the center frequency represented by each channel only the starting frequency and the size of each channel (Channel Bandwidth) need to be known. For the 900 MHz ISM Band, the starting frequency is 902.4 MHz, and the Channel Bandwidth is dependent on the current link rate.

$$\text{Freq channel } n = 902.4 + ((n-1) \times \text{BW}) \text{ MHz.}$$

Example: Channel 75 @ 172 kbps =  $902.4 + ((75-1) \times 0.250) \text{ MHz}$   
 $902.4 + (74 \times 0.250) \text{ MHz}$   
 $902.4 + 18.5 \text{ MHz}$   
 $920.9 \text{ MHz}$

| Link Rate (bps) | Channel Bandwidth (kHz) |
|-----------------|-------------------------|
| 57600           | 100                     |
| 115200          | 200                     |
| 172800          | 250                     |
| 230400          | 280                     |
| 276480          | 350                     |

## 5.0 Point to Multipoint Configuration

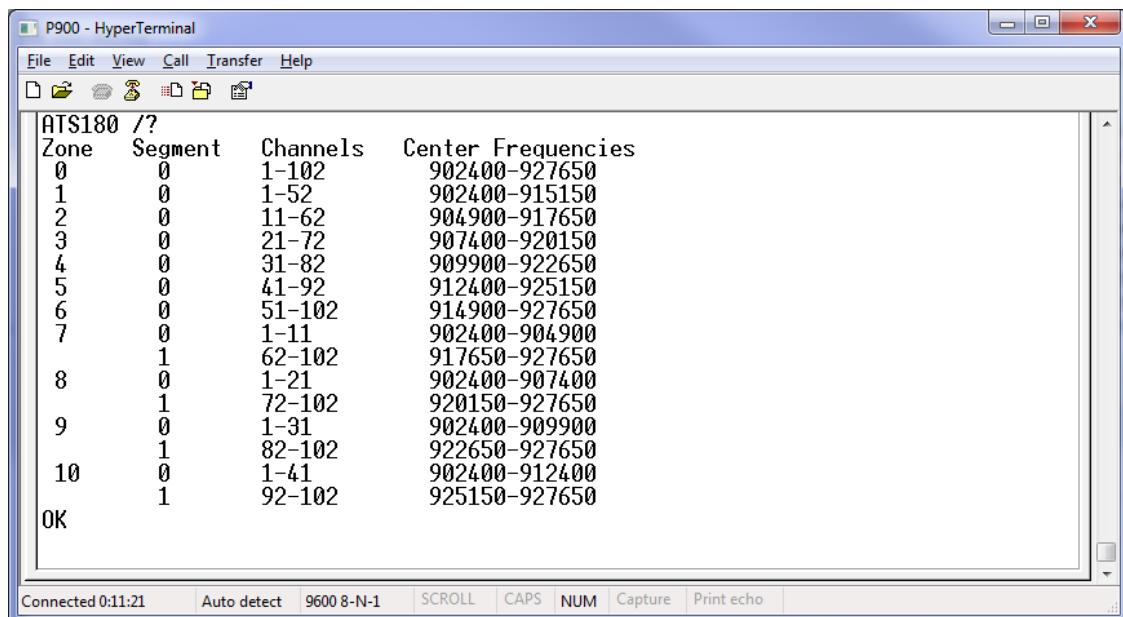
### Hop Zones

Register **S180: Hop Zone** and **S181: Secondary Zone**, select the available frequency zones used by the Pico Series, as there may be times when multiple systems are deployed within close proximity, or there may be outside interference or noise that requires sections of the available spectrum to not be included in the Hop Pattern generation.

S180 = 0 - Primary Zone (0=Use Entire 902-928 ISM Band)  
 S181 = 0 - Secondary Zone

The Primary Hop Zone, S180 is applied to the Primary Hop Pattern (S106). The Secondary Hop Zone, is applied to the Secondary Hop Pattern (S206), when determining the hop pattern for each segment of the system.

Several Hop Zones are predefined by querying the S180 Register as seen below. The ranges listed are the frequency ranges that are available to create the hop table. Using Hop Zones several frequency Bands can be excluded. Also if multiple systems are being deployed within close proximity, Hop Zones can be used to minimize overlap in the frequencies used to populate the Hopping Pattern.



```

P900 - HyperTerminal
File Edit View Call Transfer Help
File Open Save Save as Print Properties Exit
ATS180 /?
Zone Segment Channels Center Frequencies
0 0 1-102 902400-927650
1 0 1-52 902400-915150
2 0 11-62 904900-917650
3 0 21-72 907400-920150
4 0 31-82 909900-922650
5 0 41-92 912400-925150
6 0 51-102 914900-927650
7 0 1-11 902400-904900
1 62-102 917650-927650
8 0 1-21 902400-907400
1 72-102 920150-927650
9 0 1-31 902400-909900
1 82-102 922650-927650
10 0 1-41 902400-912400
1 92-102 925150-927650
OK
  
```

Connected 0:11:21 Auto detect 9600 8-N-1 SCROLL CAPS NUM Capture Print echo

Image 5-8: Hop Zones

## 6.0 Register/Command Reference

### 6.1 AT Commands

Appendix B is a quick reference for the available AT commands; in this sub-section are details regarding the most commonly used. To invoke an AT command, enter Command Mode, then type **AT<command> [Enter]**. Most AT commands have a help string that can be seen by typing **AT<command><space>/?** [Enter].



If changes were made to the modem's configuration and it is intended that those changes be saved to non-volatile memory, do so with the AT command '&W' prior to placing the modem online.

#### A

#### Answer

Upon completion of tasks being done with the modem in Command Mode, invoking this command will place the modem back 'online' (into Data Mode).

#### g, G

#### Spectrum Analyzer

This is a very useful feature of the P900. ATg or ATG will provide a display of signal levels received within the operating environment and frequency range of the modem under test. ATg averages 256 samples, ATG 16,000.

Invoking the ATg command causes the P900 to sweep the operating band and provide a display of both the mean and peak signal levels, in dBm, found on each channel.

The 'graphical' display is limited from -110dBm to -53dBm, and is in 1dB increments. Ignore the leftmost asterisk in calculations (as below).

How to interpret the display (example):

...  
ch 78 -137dBm \* No signal was measured on channel 78.  
ch 80 -105dBm \*\*\*\*\*... Mean signal level: -(110-5 (asterisks)) = -105dBm  
... Peak signal level: -(110-5 (asterisks) -3 (dots)) = -102dBm

| Link Rate (bps) | Channel Bandwidth (kHz) |
|-----------------|-------------------------|
| 57600           | 100                     |
| 115200          | 200                     |
| 172800          | 250                     |
| 230400          | 280                     |
| 276480          | 350                     |

For the P900 Channel 1 is at 902.4MHz (for North America, varies by country & link rate), with subsequent channels in increments dependent on the link rate. Therefore, to calculate the frequency of channel *n*: (BW = Channel Bandwidth in MHz)

$$\text{Freq channel } n = 902.4 + ((n-1) \times \text{BW}) \text{ MHz.}$$

#### In

#### Identification

The I command returns information about the P900. Use ATI /? for a list of current options.

- 0** User string. Use ATI0=<string> to save the string.
- 1** Product Code
- 2** Firmware CRC check
- 3** Product Identification (Firmware Version)
- 4** Firmware Date
- 5** Firmware Copyright
- 6** Firmware Time
- 7** MAC Address
- 11** Statistics
- 18** Error log
- 19, 20** Mesh Timing information.
- 255** Factory-Configured Options listing

## 6.0 Register/Command Reference

## ATlogin

[Login](#)

AT Login can be used to enable a password prior to accessing command mode and changing any configuration parameters. The modem must be restarted before settings will be enabled.

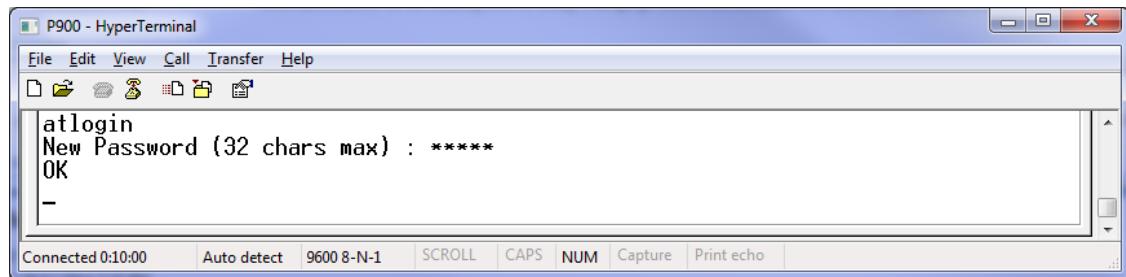


Image 6-1: AT login

## ATM (Mesh)

Main Menu

The Main Menu for Mesh diagnostics provides a user with useful information about Mesh such as the current routing table, routing logs and errors. To access the menu use the **ATM <enter>** command.

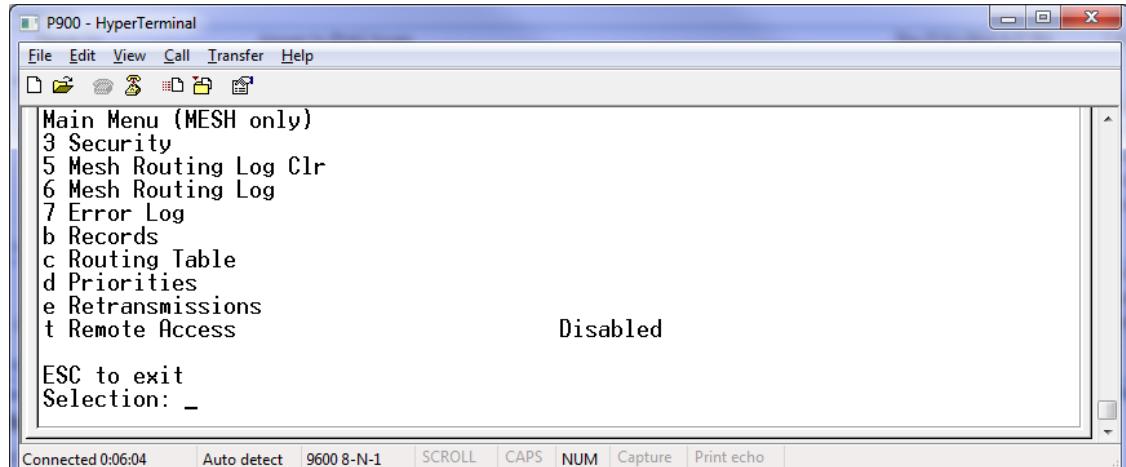


Image 6-2: Mesh Diagnostics Main Menu

For more information about the Mesh Menu contact Microhard Systems for a detailed application note.

## 6.0 Register/Command Reference

### N

### Advanced Spectrum Analyzer

The Advanced Spectrum Analyzer feature provides for a very detailed analysis of a particular area of the radio frequency spectrum within which the P900 operates.

The specific start (of scan) and stop frequencies, along with step (increment) size and dwell (on frequency) time are user-definable.

Following is the format for the ATN command:

In Command Mode

**ATN F<sub>start</sub> F<sub>stop</sub> S D/[Enter]**

where

**F<sub>start</sub>** = start frequency in MHz (including 0-6 decimal places)  
**F<sub>stop</sub>** = stop frequency in MHz (including 0-6 decimal places)  
**S** = step increment in kHz (from 1-1000)  
**D** = dwell time in ms (from 1-1000)

Example:

ATN 905.250 908.500750 25 100

Note: Be sure to enter spaces as shown in the format detailed above. Use ATN /? For help.

### &Fn

### Load Factory Default Configuration

Loading Factory Default settings allow for quick configuration of systems by setting a known starting point with factory recommended settings for each type of unit. The Factory settings change all settings required to initiate default communication with other unit types.

**Mesh Primary Coordinator** - Each Mesh network must have a primary coordinator. The primary coordinator provides the synchronization for the network.

**Mesh Secondary Coordinator** - Secondary coordinators can be deployed to extend the range of the Mesh network. Each device on a Mesh network must have LOS (Line of Sight) with either a Primary or Secondary Coordinator.

**Mesh Remote (Slave)** - Any device on the network that is not a Primary or Secondary Coordinator, generally attached to end devices. Can also be used to perform routing tasks if enabled.

**Master (PMP/PP)** - Only one per network. In PP/PMP network types (see S133) data either originates at, is destined to, or passes through the Master.

**Repeater (PMP/PP)** - May act simply as a 'Repeater' to store and forward data to/from an upstream unit to/from a downstream unit (e.g. when there is a long distance between units), or, may act as a Repeater/Slave in which case the above function is performed AND the unit may also exchange data as a Slave within the network.

**Slave (PMP/PP)** - Interfaces with remote devices and communicates with Master either directly or via Repeater(s).

### Values

- |    |                            |
|----|----------------------------|
| 1  | Mesh Primary Coordinator   |
| 2  | Mesh Remote                |
| 3  | Mesh Secondary Coordinator |
| 7  | PMP Master                 |
| 8  | PMP Slave                  |
| 9  | PMP Repeater               |
| 10 | PP Master                  |
| 11 | PP Slave                   |
| 12 | PP Repeater                |
| 13 | PMP Master 57k             |
| 14 | PMP Slave 57k              |

### &V

### View Configuration

Displays S Register names and current values. AT&V1 displays a complete set of user parameters for advance users.

### &W

### Write Configuration to Memory

Stores active configuration into the modem's non-volatile memory. Any changes made to the Pico Series must be written to NVRAM using the AT&W command (AT&WA will write the changes & set unit in online mode)

## 6.0 Register/Command Reference

### 6.2 Settings (S) Registers

The majority of modem configuration is done via the Settings (S) Registers.

Section 4.0 provides configuration detail related to operating modes and network topologies; this section examines each S register in detail for reference or advanced/custom networks. Appendix C is a quick reference for the S register options.

In the following descriptions, default settings (where applicable) are in **boldface**. In Command Mode,

|                 |   |
|-----------------|---|
| Query format:   | <b>ATS&lt;S register #&gt;? [Enter]</b>               |
| Change format : | <b>ATS&lt;S register #&gt;=&lt;value&gt; [Enter]</b>  |
| Help format:    | <b>ATS&lt;S register #&gt;&lt;space&gt;/? [Enter]</b> |

| S0   |  | Power-up Mode   |
|--|--|---|
| Can be used to select the mode in which the unit powers up. May be useful for users who need to configure that modem at each power up. When used with the login password, can prevent the unauthorized use of the modem.   |  | <b>Values</b><br>0 - In command mode<br><b>1 - In data mode (default)</b> |
| S2   |  | Escape Character  |
| Escape character (0-255) that is used in escape detection to put the modem offline. Entered as a decimal number, the default of which is 43 which is the value for the '+' ASCII character. Setting to zero disables escape detection.<br><br><i>Note: It must be set to the default to use the Microhard AT Command Firmware Upgrade Utility.</i>   |  | <b>Values (0-255)</b><br><b>43 (+)</b><br>0 disables escape detection     |
| S80 (MESH)   |  | Transmit Profiles   |
| In Mesh, coordinators use automatic ranking (if enabled by S220) to logically separate networks, ensuring that the shortest path to the Primary Coordinator is achieved. Also to ensure that modems do not erratically associate to multiple coordinators. Once ranked, TX Profiling can be used to split the bandwidth to allow differently ranked units opportunity to send data during assigned frames. Refer to TX Profiling & Ranking in Section 3. |  | <b>Values (0-3)</b><br><b>0</b>   |
| S81 (MESH)   |  | CS Threshold  |
| The P900 uses CSMA (Carrier Sense Multiple Access) to determine if the channel is available. The Carrier Detect Threshold is used to set the measured level in which the signal is deemed as a valid carrier signal or outside noise or interference (noise floor). The value represented by S81 is in -dBm. A value of Zero (0) disabled CSMA. See Section 3 for more information.  |  | <b>Values (0 to -255 dBm)</b><br><b>60</b>                                |

## 6.0 Register/Command Reference

### S83

The P900 keeps record of all other modems it has heard from. This information may be useful to advanced users in system testing and troubleshooting. The RSSI in the records is averaged over the last 8 measurements. Every time a modem is heard from its record is renewed. The 'Time To Live' parameter defines how quickly entries get aged and deleted if not renewed. The range is 10 to 65535 seconds. The default is 30 seconds. The content of the records can be viewed through the menu, see the ATM command for more information.

### Records TTL

#### Values (10 to 65535)

30

### S85 (PP/PMP)

### Distance to Master

#### Values (0 to 255km)

3

### S86 (PP/PMP)

### Distance From Master

#### Values (0 to 255km)

3

The distance from a master (repeater) to its farthest slave (repeater). It is used by the Master and repeaters in PMP and PP modes. 0 to 255km, the default is 3km. A setting of 255 means no slaves will be transmitting any packets - one way transmission from the master.

Since the timing on slaves (relative to master) is already offset by the propagation delay, transmitting data back from slaves to the master causes doubling of the delay when viewed on the master. When distances are long and not accounted for by setting S86 accordingly, a packet from far away slaves may arrive too late for the master to receive it before the hop interval expires. When there are no slaves that may transmit data back to the master (one way transmission), the master may use its bandwidth more effectively by not reserving time in the hop interval for slave's data. S86=255 is a special value to indicate to the master that slaves will not transmit back.

**IMPORTANT:** Slaves in PP mode acknowledge the master's data, therefore in PP mode S86 must be configured properly even if there is no user data coming from the slaves.

### S87 (MESH)

### Enable S105 as MAC

#### Values (selection)

##### 0 - Disable (default)

1 - Enable

Enables using S105 as modem's units address in Mesh. Can be useful in installations where many modems send data to a central location. If the Destination address of those modems is set to match a unique MAC address of the receiver, and the receiver fails and needed to be replaced, it may be difficult to reprogram the destination address S140 on all radios to the new MAC address of the replaced radio.

This feature can also be useful in fleet management applications, or roaming mesh networks. With roaming, a sink of data in each network will have the same address, for example UA = 1. In this case a roaming remote will have its DA = 1 and will always send data to a sink regardless of which network the remote is connected to in any given time. The range is 1 - FFFE (of S105), the value must be entered as a hex number.

## 6.0 Register/Command Reference

| S101 (MESH)  |  | Operating Mode   |              |                  |               |                         |                       |          |         |         |        |
|--|--|--|--------------|------------------|---------------|-------------------------|-----------------------|----------|---------|---------|--------|
| <p>The Operating mode defines the role in the network a unit plays. A P900 modem may be configured for any role required within a radio network. This is convenient for reasons of familiarity with any/all units, as well as for hardware sparing purposes.</p>   |  | <table border="1"> <thead> <tr> <th>Values</th></tr> </thead> <tbody> <tr> <td>2 Slave (Remote)</td></tr> <tr> <td>4 Coordinator</td></tr> <tr> <td>5 Secondary Coordinator</td></tr> <tr> <td>6 Standby Coordinator</td></tr> </tbody> </table> | Values       | 2 Slave (Remote) | 4 Coordinator | 5 Secondary Coordinator | 6 Standby Coordinator |          |         |         |        |
| Values   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 2 Slave (Remote)   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 4 Coordinator  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 5 Secondary Coordinator  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 6 Standby Coordinator  |  |  |              |                  |               |                         |                       |          |         |         |        |
| <p><b>Remote:</b> Any unit that is not a coordinator.</p>  |  |  |              |                  |               |                         |                       |          |         |         |        |
| <p><b>Coordinator:</b> Every Mesh network requires a primary coordinator. Coordinators are used to synchronize the network. If additional coverage is required additional secondary coordinators can be deployed.</p>  |  |  |              |                  |               |                         |                       |          |         |         |        |
| <p><b>Secondary Coordinator:</b> Secondary Coordinators can be deployed to extend the network and to provide LOS for geographically challenged remotes.</p>  |  |  |              |                  |               |                         |                       |          |         |         |        |
| <p><b>Standby Coordinator:</b> Can be used to take over the duties of the Primary Coordinator to provide redundancy.</p>   |  |  |              |                  |               |                         |                       |          |         |         |        |
| S101 (PP/PMP)  |  | Operating Mode   |              |                  |               |                         |                       |          |         |         |        |
| <p>The Operating mode defines the role in the network a unit plays. A P900 modem may be configured for any role required within a radio network.</p>   |  | <table border="1"> <thead> <tr> <th>Values</th></tr> </thead> <tbody> <tr> <td>0 - Master</td></tr> <tr> <td>1 - Repeater</td></tr> <tr> <td>2 - Slave (Remote)</td></tr> </tbody> </table>  | Values       | 0 - Master       | 1 - Repeater  | 2 - Slave (Remote)      |                       |          |         |         |        |
| Values   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 0 - Master   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 1 - Repeater   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 2 - Slave (Remote)   |  |  |              |                  |               |                         |                       |          |         |         |        |
| <p><b>Master:</b> Only one per network. In PP/PMP network types (see S133) data either originates at, is destined to, or passes through the Master.</p>  |  |  |              |                  |               |                         |                       |          |         |         |        |
| <p><b>Repeater:</b> May act simply as a 'Repeater' to store and forward data to/from an upstream unit to/from a downstream unit (e.g. when there is a long distance between units), or, may act as a Repeater/Slave in which case the above function is performed AND the unit may also exchange data as a Slave within the network.</p>                 |  |  |              |                  |               |                         |                       |          |         |         |        |
| <p><b>Slave:</b> Interfaces with remote devices and communicates with Master either directly or via Repeater(s).</p>   |  |  |              |                  |               |                         |                       |          |         |         |        |
| S102   |  | Serial Baud Rate   |              |                  |               |                         |                       |          |         |         |        |
|   | <p>The serial baud rate is the rate at which the modem is to communicate with the attached local asynchronous device. This value must match the PC or serial device that is connected to data port on the P900.</p>  |  |              |                  |               |                         |                       |          |         |         |        |
|  | <p>When forcing a module to Command Mode the data port will temporarily communicate at the default value. When the P900 is returned to Data Mode, the serial port settings are returned to those specified in S102 and S110.</p>   |  |              |                  |               |                         |                       |          |         |         |        |
| <p>Note: Most PC's do not readily support serial communications greater than 115200bps.</p>  | <table border="1"> <thead> <tr> <th>Values (bps)</th></tr> </thead> <tbody> <tr> <td>0 230400</td></tr> <tr> <td>1 115200</td></tr> <tr> <td>2 57600</td></tr> <tr> <td>3 38400</td></tr> <tr> <td>4 28800</td></tr> <tr> <td>5 19200</td></tr> <tr> <td>6 14400</td></tr> <tr> <td>7 9600</td></tr> </tbody> </table> |  | Values (bps) | 0 230400         | 1 115200      | 2 57600                 | 3 38400               | 4 28800  | 5 19200 | 6 14400 | 7 9600 |
| Values (bps)   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 0 230400   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 1 115200   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 2 57600  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 3 38400  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 4 28800  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 5 19200  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 6 14400  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 7 9600   |  |  |              |                  |               |                         |                       |          |         |         |        |
|  |  |  |              |                  |               |                         |                       |          |         |         |        |
| S103   |  | Wireless Link Rate   |              |                  |               |                         |                       |          |         |         |        |
| <p>This register determines the rate at which RF communications will occur over a given network. All modems within a particular network must be configured with the same wireless link rate. Faster link rates result in greater throughput, however, for each 'step' increase in link rate, there is an approximately 1dB reduction in sensitivity.</p> |  | <table border="1"> <thead> <tr> <th>Values (bps)</th></tr> </thead> <tbody> <tr> <td>0 172800</td></tr> <tr> <td>1 230400</td></tr> <tr> <td>2 276480</td></tr> <tr> <td>3 57600</td></tr> <tr> <td>4 115200</td></tr> </tbody> </table>         | Values (bps) | 0 172800         | 1 230400      | 2 276480                | 3 57600               | 4 115200 |         |         |        |
| Values (bps)   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 0 172800   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 1 230400   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 2 276480   |  |  |              |                  |               |                         |                       |          |         |         |        |
| 3 57600  |  |  |              |                  |               |                         |                       |          |         |         |        |
| 4 115200   |  |  |              |                  |               |                         |                       |          |         |         |        |

## 6.0 Register/Command Reference



Change the default value for the Network ID to something unique for your network. Do this for an added measure of security and to differentiate your network from others which may be operating nearby.



FCC regulations allow for up to 36dBi effective isotropic radiated power (EIRP). The sum (in dBm) of the transmitted power, the cabling loss, and the antenna gain cannot exceed 36dBi.

### S104

All modems in a given network must have the same Network Address. This unique network address is not only a security feature for a particular network, but also allows other networks - with their own unique network address - to operate in the same area without the possibility of undesired data exchange between networks.

### Network Address (ID)

**Values (0 - 4,294,967,295)**

1234567890

### S105

Unit address in PP and PMP modes, or in MESH if S87=1. The unit address is, and must be, a unique identifier of each modem in a network. The address value is 16-bits in length.

The Master has by default, and must retain, a unit address of 1; 65535 is the broadcast address.

### Unit Address

**Values (1 - 65534)**

1 in PP/PMP  
1-FFFF in MESH

### S106

This register, together with the Network ID and the Hop Zone, determines the Hopping Pattern or table on which the P900 will frequency hop. This register must be set to the hop pattern of the immediate Master/Repeater, unless roaming is used.

### Hop Pattern

**Values (0 - 49)**

0

### S108

This setting establishes the transmit power level which will be presented to the antenna connector at the rear of the modem.

Unless required S108 should be set not for maximum, but rather for the minimum value required to maintain an adequate system fade margin.

### Output Power

**Values (dBm (mw))**

|    |       |    |        |
|----|-------|----|--------|
| 20 | (100) | 26 | (400)  |
| 21 | (125) | 27 | (500)  |
| 22 | (160) | 28 | (630)  |
| 23 | (200) | 29 | (800)  |
| 24 | (250) | 30 | (1000) |
| 25 | (320) |    |        |

## 6.0 Register/Command Reference

| S109 (PP/PMP) | Hop Interval |
|---------------|--------------|
|---------------|--------------|

This register is effective only on the Master and is responsible for establishing the rate at which all modems within a particular network change frequency (hop - from frequency to frequency).

Long hop intervals typically result in the greatest data throughput, however shorter hop intervals may decrease latency and make the system more immune to interference.

The default setting of 20ms is satisfactory for most applications

| S109 | time (ms) |
|------|-----------|------|-----------|------|-----------|------|-----------|
| 0    | 1.498     | 16   | 89.997    | 32   | 11.997    | 48   | 21.998    |
| 1    | 2.001     | 17   | 99.998    | 33   | 12.500    | 49   | 22.999    |
| 2    | 2.498     | 18   | 125.000   | 34   | 12.998    | 50   | 24.000    |
| 3    | 3.002     | 19   | 150.001   | 35   | 13.501    | 51   | 25.001    |
| 4    | 3.997     | 20   | 4.500     | 36   | 13.998    | 52   | 26.001    |
| 5    | 4.997     | 21   | 5.501     | 37   | 14.502    | 53   | 27.002    |
| 6    | 6.999     | 22   | 5.998     | 38   | 15.502    | 54   | 27.997    |
| 7    | 10.001    | 23   | 6.501     | 39   | 16.000    | 55   | 28.998    |
| 8    | 14.999    | 24   | 7.502     | 40   | 16.497    | 56   | 8.335     |
| 9    | 19.997    | 25   | 8.000     | 41   | 17.001    | 57   | 199.997   |
| 10   | 29.999    | 26   | 8.497     | 42   | 17.498    | 58   | 250.000   |
| 11   | 40.000    | 27   | 9.000     | 43   | 18.001    | 59   | 300.002   |
| 12   | 50.002    | 28   | 9.498     | 44   | 18.499    | 60   | 349.998   |
| 13   | 59.998    | 29   | 10.499    | 45   | 19.002    | 61   | 378.997   |
| 14   | 69.999    | 30   | 11.002    | 46   | 19.499    |      |           |
| 15   | 80.001    | 31   | 11.499    | 47   | 20.998    |      |           |



Hop Interval S109 should only be changed if recommended by Microhard Support and/or for specific applications!

Table 6-1: Hop Interval (S109)

| S110  | Data Format |
|---|-------------|
| <p>This register determines the format of the data on the serial port. The default is 8 data bits, No parity, and 1 Stop bit. The value must match the PC or Serial Based device that is connected to the data port.</p> <p>When forcing a module to Command Mode the data port will temporarily communicate at the default value. When the P900 is returned to Data Mode, the serial port settings are returned to those specified in S102 and S110.</p> |             |
| Values  |             |
| 1 8N1   | 6 7N2       |
| 2 8N2   | 7 7E1       |
| 3 8E1   | 8 7O1       |
| 4 8O1   | 9 7E2       |
| 5 7N1   | 10 7O2      |

## 6.0 Register/Command Reference

| S111  | Packet Min Size  |
|---|--|
| <p>This is the minimum number of collected bytes in one buffer before the buffer can be closed by the character timeout timer controlled by S116. It is STRONGLY advised not to modify this parameter. Changing S111 may prevent the modem from detecting the escape sequence.</p>  | <b>Values (1 - 255)</b><br><b>1</b>  |
| S112  | Packet Max Size  |
| <p>Determines that maximum number of bytes from the connected device that will be encapsulated into a packet unless the character timeout timer S116 expires. Large packet sizes may produce the best data throughput; however, a smaller packet is less likely to become corrupted and, if it does, is retransmitted with a lesser impact on network traffic. The default setting of 256 bytes is suited to most applications.</p> | <b>Values (1 - 256)</b><br><b>256</b>  |
| S113  | Packet Retransmissions   |
|  <p>In a PMP system, set S113 to the minimum value required as, effectively, the data throughput from Master to Remote is divided by 1 plus the number stored in S113.</p>  | <p>This register determines the maximum number of times that a packet will be retransmitted (in addition to the initial transmission). Retransmissions can be used to provide system robustness and to ensure data delivery due to noisy environments or weak signal levels. Retransmissions should not be used as the only means to correct for data collisions. Retransmissions create additional traffic and can have a significant impact on overall throughput of a system.</p> |
| S115  | Repeat Interval  |
| <p>In <b>Mesh</b> S115 defines the randomness of accessing the channel (0 - 255). The bigger the number, the less often attempts are made to access the channel, resulting in lower collisions, but at the cost of added latency.</p>   | <b>Values (0 - 255)</b><br><b>5 (Mesh), 3 (PP/PMP)</b>   |
| S116  | Character Timeout  |
| <p>Character Timeout in 1/4 of character time (10-255). Default = 10 (2.5 character time). This 'timer' looks for gaps in the data being received from the local attached device. The timer is activated after the Minimum Packet Size (S111, default 1 Byte) has been accumulated in the modem. If the timer detects a gap in the data exceeding the Character Timeout value, the modem will transmit the data.</p>                | <b>Values (10 - 254)</b><br><b>10</b>  |

The Pico will accumulate data in its buffers until either (a) Maximum Packet size (S112) has been accumulated, or (b) Minimum Packet Size (S111) has been accumulated AND the Character timeout has expired—whichever occurs first.

## 6.0 Register/Command Reference

### S118 (PP/PMP)

This feature allows a Remote unit to synchronize with a specified 'upstream' unit (either Master or Repeater). The options are as follows:

S118=65535: A Remote will synchronize with an upstream unit which has the same network address (S104). Should that upstream unit fail, this Remote will attempt to synchronize with another 'upstream' unit within the same network. This ability is particularly well-suited to mobile applications.

S118=1-65534 In most static (fixed) networks, where there are no Repeaters, the default value of 1 is maintained: All Slaves synchronize to the Master (whose unit address is 1).

In networks where Repeaters are present, the value of a Remote's S118 corresponds to the particular upstream modem with which a particular Remote is intended to communicate, e.g. Slave UA (S105)=3 may have an S118=2, where the modem with UA 2 is a Repeater between the Slave and the Master; the Repeater will have an S118=1.



A Master modem's RSSI LEDs will not illuminate to any degree until such time as it has received valid packets from a 'downstream' unit.

### S123 (MESH)

This register displays (it is not a 'setting') the average signal strength received over the previous 8 hop intervals. The value in this register is also reflected in status lines RSSI1, 2, and 3, which connect to the modem's RSSI LEDs.

### S123 (PP/PMP)

In repeaters and slaves this register displays the average signal strength received over the previous 8 hop intervals from a Master/Repeater. The value in this register is also reflected in status lines RSSI1, 2, and 3, which connect to the modem's RSSI LEDs.

### S124 (PP/PMP)

On the master this register displays the average signal strength received over the previous 8 hop intervals from a Slave/Repeater. The value in this register is also reflected in status lines RSSI1, 2, and 3, which connect to the modem's RSSI LEDs.

### S126 (MESH)

Number of consecutive unacknowledged transmissions before starting route discovery in Mesh. 1-255, default = 9. When a route is added to a routing table it is important that the data in the table remain current and correct. The S126 register sets a maximum number of attempts to reach a route before the route is removed from the routing table and route discovery is started. See section 3 for more information.

### S130

When enabled allows a modem to receive and keep data from the local com port while the modem is searching for synchronization. Does not apply to master and primary coordinator. Should normally be disabled to prevent accumulation of stale data inside a modem.

### Roaming

#### Values

65535 full roaming

1-65534 specific (fixed) unit address with which to associate

1

### Average RSSI

#### Values (dBm)

-110 to -55dBm (max reading)

### RSSI from Master (dBm)

#### Values (dBm)

-110 to -55dBm (max reading)

### RSSI from Slave (dBm)

#### Values (dBm)

-110 to -55dBm (max reading)

### Attempt Before Re-route

#### Values (1-255)

9

### No Sync Data Intake

#### Values (selection)

0 - Disabled (default)

1 - Enabled

## 6.0 Register/Command Reference

| S133   | Network Type   |
|--|--|
| <p>This register defines the type of network being deployed. This register must be set to the same value on every unit in the system.</p> <p><b>Point to Multipoint</b> - The Master broadcasts data to all units, and all remote units send data back to the Master. (See <a href="#">Section 5</a>)</p> <p><b>Point to Point</b> - Point to point traffic between a Master and a Slave (with 0 or more Repeaters in between). (See <a href="#">Section 4</a>)</p> <p><b>Mesh</b> - A Mesh network is a network where radios can communicate with each other directly or, if required through another mesh node, without all data being routed through a master. (See <a href="#">Section 3</a>)</p> <p><b>Mesh with Roaming</b> - This is identical to Mesh S133=2 except a remote may join networks with different S106 and S180. Used in roaming applications.</p> | <p><b>Values (selection)</b></p> <p>0 - Point to Multipoint (PMP)<br/>1 - Point to Point (PP)<br/>2 - Mesh<br/>3 - Mesh with Roaming</p> |
| S140   | Destination Address  |
| <p>As the name implies, this register specifies the ultimate destination for a modem's data.</p> <p>In a <b>Mesh</b> system, the destination address is entered in MAC address format, where FF:FF:FF:FF:FF is broadcast. For unicast operation, the factory assigned MAC address of the destination device must be used. Or S105 if S87 = 1.</p> <p>In <b>PMP</b> and <b>PP</b> modes - the range is 1 to 65535, where 65535 is broadcast:</p> <p style="text-align: center;">PMP - Master S140=65535, Remote S140=1<br/>PP - Master S140=UA of Remote, Remote S140=1 (Master)</p>  | <p><b>Values</b></p> <p>Varies by network and unit type</p>  |
| S141 (PP/PMP)  | Repeaters Y/N  |
| <p>This register informs, and only applies to the Master, as to the presence of any Repeater(s) in the network. With one or more Repeaters in the system, a network's throughput is divided in half.</p>   | <p><b>Values (selection)</b></p> <p>0 - no repeater<br/>1 - 1 or more repeaters</p>  |
| S142   | Serial Channel Mode  |
| <p>This register selects the serial channel mode for the data port. The default is RS232. In RS485 either DSR or CTS (set high) can be used to enable the transmitter of the RS485 driver chip. If &amp;K1 is used, CTS will control the transmitter. Otherwise DSR does it. In this case the value of &amp;S is ignored. The RING line is set high and is normally used to enable the receiver of the RS485 driver chip.</p>  | <p><b>Values (selection)</b></p> <p>0 - RS232<br/>1 - RS485 half duplex<br/>2 - RS485 full duplex</p>                                    |
| S143   | Sleep Mode   |
| <p>When set to 0 the modem is active at all times. When S143=1 enables sleep mode on remotes only. Sleeps for S144 seconds or until the rising edge of the Wakeup_usr line. Stays on for at least S145 seconds. After that goes to sleep if all data including over the air is sent. Upon wake up the modems will be out of sync with the network and need time to re-synchronize. The DSR line can be configured to indicate when the modem is asleep (DSR = 1) and awake (DSR = 0).</p>  | <p><b>Values (selection)</b></p> <p>0 - Active all the time<br/>1 - Enabled</p>  |

## 6.0 Register/Command Reference

|  |   |
|--|---|
| <b>S144</b>  | <b>Sleep Time</b>   |
| Sleep time in seconds. If Sleep mode is enabled (S143), modem will go to sleep for S144 seconds or a rising edge of the Wakeup-user line.  | <b>Values (2 - 65535)</b><br>60   |
| <b>S145</b>  | <b>Wake Time</b>  |
| Wake time in seconds. If Sleep mode is enabled (S143), modem will stay awake for S145 seconds if all conditions of S143 are met.   | <b>Values (1 - 65535)</b><br>10   |
| <b>S146</b>  | <b>Tx Done timeout, 1/4</b>   |
| Normally used with Modbus RTU protocol which requires a 3.5 character delay between packets output on the com port. Range is 0 to 255, default is 14 (3.5 chars). This register along with Modbus RTU setting of S217 can be used to insert a gap between individual packets coming out of the serial port even in non-Modbus applications.  | <b>Values (0 - 255)</b><br>14   |
| <b>S151 (MESH)</b>   | <b>Quick Sync Packets</b>   |
| At system startup when coordinators first come online, they send out a number of quick sync packets, defined by register S151, used to quickly attain network synchronization. Each quick sync packet is sent on a random channel listed in the hop pattern. The more sync packets sent, the quicker network synchronization occurs, but at a cost of delayed data transmission. The lower the number of packets sent, the less likely the entire network will synchronize during the quick sync process, resulting in slower overall synchronization. | <b>Values (5 - 65534)</b><br>500  |
| <b>S153</b>  | <b>Address Tag</b>  |
| Prepends each packet received from the radio with 10 bytes of the following data:<br><br>Type 1: First 2 bytes - size (high byte first), one byte - RSSI, one reserved byte (0x00), last six bytes - source unit address (high byte first).  | <b>Values (selection)</b><br><b>0 - Disable (default)</b><br>1 - Type 1 |

## 6.0 Register/Command Reference



If throughput is not of primary concern and there is an emphasis on providing the most robust data communications, FEC should be considered.

### S158

#### FEC (Forward Error Correction) Mode

##### Values

- |   |                             |
|---|-----------------------------|
| 0 | No FEC                      |
| 1 | Hamming (7,4)               |
| 2 | Hamming (15,11)             |
| 3 | Hamming (31,24)             |
| 5 | Binary BCH (47,36)          |
| 6 | Golay (23,12,7)             |
| 7 | <b>Reed-Solomon (15,11)</b> |

A number of FEC schemes are available with different coding rates.

FEC consumes significant bandwidth: depending on which coding rate is chosen, a number of coding bits are transmitted along with the 'data' bits. In 'noisy' or long-range communications environments, FEC may effectively increase throughput by decreasing the amount of packet retransmissions which would otherwise be required.

Communications range may also be extended with the use of FEC: at a certain distance where data would otherwise be unacceptably corrupted, employing FEC may be all that is required to maintain the integrity of that data at that distance.

Types of FEC available within the P900:

|                      |   |   |
|----------------------|---|---|
| Hamming (7,4)        | : | Information rate 0.5,<br>corrects 1 out of 7 bits   |
| Hamming (15,11)      | : | Information rate 0.66,<br>corrects 1 out of 15 bits |
| Hamming (31,24)      | : | Information rate 0.75,<br>corrects 1 out of 31 bits |
| Binary BCH (47,36)   | : | Information rate 0.75,<br>corrects 2 bits           |
| Golay (23, 12, 7)    | : | Information rate 0.5,<br>corrects 3 bits            |
| Reed-Solomon (15,11) | : | Information rate 0.687,<br>corrects 2 nibbles       |

### S159

#### Encryption Mode (AES)

##### Values

- |   |               |
|---|---------------|
| 0 | No encryption |
| 1 | AES 128 bit   |
| 2 | AES 192 bit   |
| 3 | AES 256 bit   |

**AES encryption is only available in models delivered as -AES. This is a factory configured option that can only be loaded and enabled at the factory at time of assembly. The use of AES encryption, and export laws governing AES, vary from country to country, contact Microhard Systems Inc. for more information.**

AES (Advanced Encryption Standard) provides an extremely strong level of encryption for data for security of wireless data communication.

Up to three levels of AES are available, 128 bit, 192 bit and 256 bit. Only the specific options enabled by the factory will be available. Once a level of AES is chosen using register S159, the encryption key must be entered. The same AES setting and encryption key must be entered on every modem in the network.

The size of the key is dependant of the level of AES:

|             |                        |
|-------------|------------------------|
| 128bit AES: | 16 Byte Encryption Key |
| 192bit AES: | 24 Byte Encryption Key |
| 256bit AES: | 32 Byte Encryption Key |

The encryption key can be entered in registers S107 or S177 as they share the same key array for encryption. S107 (Static Mask) is used to enter in up to 32 printable characters (ASCII). If using 128 or 192 bit AES, any character entered after 16 or 24 bytes respectively will be ignored. If less than the required number of characters is entered, 0's will be appended to fill the encryption key array.

To improve the strength of the key, S177 can be used to enter 16-32 bytes (dependant of the AES type) of binary non-printable characters. This register requires the appropriate number bytes to be entered. In other words, if you are using AES256, S177 requires 32 bytes of data to be entered. A binary file can be transferred to the modem using a terminal program after a ATS177= command has been invoked.

## 6.0 Register/Command Reference

|  |   |
|--|---|
| <b>S163</b>  | <b>CRC check on diag port</b>   |
| Enables CRC16 checking of received data on local diagnostic port. Note that even if disabled, the incoming data must have two dummy bytes transmitted in place of crc bytes. Disabling CRC check is only advisable during troubleshooting of the user's diagnostic requests.   | <b>Values (selection)</b><br>0 - Disable<br><b>1 - Enable (default)</b> |
| <b>S177</b>  | <b>Binary Encryption Key</b>  |
| When using AES encryption, S177 can be used to define the encryption key in binary. The type of AES used defines the minimum number of binary bytes that need to be entered. See S159 for more information.  | <b>Values (Binary Bytes)</b><br>16 - 32 Bytes (AES type dependant)      |
| <b>S180</b>  | <b>Hop Zone</b>   |
| S180 will allow the use of hopping zones to restrict the hopping table to specific segments of the 900 MHz ISM band. The default is to populate the hopping pattern/table using channels or frequencies from the entire 900MHz ISM band. Additional zones can be seen by displaying help for the S180 register.  | <b>Values (0-10)</b><br>0 - Use entire ISM band                         |
| <b>S181 (PP/PMP)</b>   | <b>Secondary Hop Zone</b>   |
| Used on PP and PMP Repeaters, S181 will allow the use of hopping zones to restrict the secondary hopping pattern to specific segments of the 900 MHz ISM band. Any downstream units connected to this will need to have their S180 (Primary Hop Zone) set to same value as the Secondary Hop Zone of the Repeater they are connected to.<br><br>The default is to populate the hopping pattern/table using channels or frequencies from the entire 900MHz ISM band. Additional zones can be seen by displaying help for the S181 register. | <b>Values (0-10)</b><br>0 - Use entire ISM band                         |
| <b>S183 (PP/PMP)</b>   | <b>DCD Pulse Period</b>   |
| The period of DCD pulses on synchronized slaves in &C3 mode. Minimum value = 1, Max value = number of channels in a hop pattern minus one. The default is 5.<br><br>S183 = 1 - DCD will pulse every hop interval, if S183 = 3 - every third, etc. The counter starts at hop index 0. It is used in some applications to generate common synchronization on many slaves. With the default setting of 5 and the hop interval of 20ms, each slave will synchronously generate a pulse of approximately 3ms every 100ms.                       | <b>Values</b><br><b>5</b>   |

## 6.0 Register/Command Reference

|   |                                    |
|---|------------------------------------|
| <b>S184 (MESH)</b>  | <b>Data Time to Live</b>           |
| Data time to live in 10ms ticks. Used to age data in mesh networks. The default is 65535 (never age).   | <b>Values (1 - 65535)</b><br>65535 |
| <b>S206 (PP/PMP)</b>  | <b>Secondary Hop Pattern</b>       |
| This register, together with the Network ID and the Secondary Hop Zone, determines the Secondary Hopping Pattern which a P900 Repeater will use to synchronize and communicate with downstream units. The S106 (Primary Hop Pattern) register must be set to the same value on each repeater/slave that is downstream of this unit.   | <b>Values (0 - 49)</b><br>1        |
| <b>S214 (MESH)</b>  | <b>Number of Aloha Slots</b>       |
| This register defines the number of aloha slots available in a Mesh Frame. A slot is a set period of time required to transmit the shortest packet (RTS, CTS, ACK).   | <b>Values (1-255)</b><br>60        |
| Increasing the number of aloha slots allows more time for a modem to transmit data during a Mesh Frame. The number of aloha slots directly impacts the hop interval, the more aloha slots, the more time to transmit data, but also the longer the system sits on a single frequency. Reducing the number of aloha slots creates a shorter hop interval which results in a system more immune to interference, but too short an interval may disable communication if devices do not have time to transmit. |                                    |
| <b>S215 (MESH)</b>  | <b>Number of Mesh Sync Slots</b>   |
| This register defines the number of sync slots available in a Mesh Frame. The valid range is 1 - 10, with a default of 1. In systems with many coordinators, additional slots may be required to avoid collisions. Register S216 can also be used to provide randomness in sending sync packets to avoid collisions.  | <b>Values (1-10)</b><br>1          |
| S215 must be set to the same value for each modem on the network or the unit will not synchronize.  |                                    |
| <b>S216 (MESH)</b>  | <b>Mesh Sync Duty Cycle</b>        |
| Defines how often the coordinator transmits sync packets (1-100). After each sync packet transmission the coordinator picks a random number from 1 to the value in S216 and transmits the next packet in this slot. 1 - every sync slot, 2 - on average once every 1.5 slots, 3 - on average once every 2 slots etc.  | <b>Values (1-100)</b><br>3         |

## 6.0 Register/Command Reference

| S217   | Protocol Type   |
|--|---|
| Defines how data is output on the local serial port. When Modbus RTU is enabled, there is a delay between the packets coming out of the serial port. The register S146 defines the delay between individual packets.   | <b>Values (selection)</b><br>0 - Transparent Serial (default)<br>1 - Modbus RTU |
| S218 (MESH)  | Input Framing   |
| Input Framing Type. Controls how the modem treats data coming to its serial port. Allows the destination address to be embedded into the data stream, which is automatically stripped by the P900 before transmitting the packet.  | <b>Values</b><br>0  |
| S219 (MESH)  | Routing Request TTL   |
| Routing Request Timeout in 10ms ticks. (1-10000). The default is 10, which is 100 msec. This defines how long a unit will wait for a Routing Request to provide possible routes. During this time no other data may be sent from the unit. Setting this value too low may not give the system enough time to report the best path, alternately, a value too high may create latency in the system as it waits for the TTL to expire before allowing data transmission, although it has already received the best path. | <b>Values (1-10000)</b><br>10 (100ms)   |
| S220 (MESH)  | Mesh Coordinator Rank   |
| Used with Tx Profiles. Can be set to 0-3 or 255. Value of 255 (default) is for automatic ranking.  | <b>Values (selection)</b><br>0-3 or,<br>255                                     |
| S221 (MESH)  | Mesh TDMA Slot to Tx  |
| Aloha slot number in mesh TDMA in which the modem will start its transmission in Tx On Slot channel access mode S244 = 2. 1-255 (default is 1). See the app note for Mesh TDMA.  | <b>Values (1 - 255)</b><br>1  |
| S222 (MESH)  | Roaming Mode  |
| When roaming is disabled a mesh radio will synchronize only to a coordinator with the matching set of S106 and S180. When roaming is enabled the modem will synchronize with any valid coordinator.  | <b>Values (selection)</b><br>0 - Disabled<br>1 - Roaming on Zone/Pattern        |

## 6.0 Register/Command Reference

### S223 (MESH)

### Routing

This register is used to enable or disable Mesh Routing function of the modem. Whenever coordinators are added to a system, routers are typically required in a network. Any unit in a Mesh network can be used to perform routing tasks. Although it is a good idea to have more than a single router, too many routers may create unnecessary traffic in the system. See Section 3 for additional information.



Each unit in a Mesh network has a unique MAC Address. Unicast Data with a destination address of the primary Coordinator will NOT be automatically routed to the Standby Coordinator.

0 - Disabled - Disabled by default

1 - Enabled - Routing can be enable on any unit, but the more units performing routing tasks, the more routing traffic generated.

### Values

- 0 - Disabled  
1 - Enabled

### S224 (MESH)

### Standby Trip Level

Mesh Standby Coordinator sync level at which it becomes the primary coordinator. 0 - 255, Default = 20.

This register works with the Sync Timeout (S248) on the Primary coordinator to monitor the sync level to determine when the Primary Coordinator has failed. The Sync Timeout sets a counter (set by S248 on the Primary coordinator and propagated in sync packets) that counts down each time a frame is received that does not contain sync data from a coordinator. If the unit receives sync data the counter is reset, if the counter reaches zero - the unit loses sync.



Compression was introduced in firmware v1.10. Older versions of firmware will not be compatible with v1.10 unless S225 is disabled or older units are upgraded.

### S225

### Compression Mode

Using compression may improve overall performance of the modem. Default is enabled.

### Values

- 0 - Disabled  
1 - Type 1 Enabled

### S232

### Max Buffer in Storage

Maximum number of buffers from the local com port. 1 to 255, default 200. Used to limit the amount of storage the modem will allocate to incoming user's data. Each buffer is S112 number of bytes. With S112=256 (default) and S232=200 (default) the modem can store up to 51200 bytes.

### Values (1-255)

- 200

## 6.0 Register/Command Reference

| S234 (PMP)  | Master Ch. Req. Timeout                               |
|---|---|
| <p>After the master releases the channel, it will wait for the S234 number of hop intervals to allow the slaves to send channel requests before the master arbitrates the channel.</p> <p>When there are many slaves that may want to request the channel at the same time, setting this register to a bigger number will help ensure that the channel arbiter in the master will allocate the channel fairly - new modems will be given higher priority over modems that were recently allocated the channel.</p>  | <b>Values (1-254)</b><br>1                            |
| S235 (PP)   | PP Routing TTL, sec                                   |
| <p>Routing Time to Live in seconds. (1-65535). Defines the aging interval for routing information in PP Mode.. 65535—never age. Default is 30 seconds.</p>  | <b>Values (1-65535)</b><br>30                         |
| S236  | Max Buffer Out Storage                                |
| <p>Maximum buffer out storage. Limits the number of buffers waiting to be output to the user on COM1 (1-65535), default is 255. Normally should not be changed.</p>   | <b>Values (1-65535)</b><br>255                        |
| S244 (MESH)   | Channel Access Mode                                   |
| <p>Channel Access Mode. This register defines how devices access the channel when they have data to transmit.</p> <p>0 - Aloha - Units use Carrier Sense (CSMA) to access the channel, if available, and send data. Register S115 can be set to configure the randomness at which devices access the channel to avoid collisions. Default for coordinator.</p> <p>1 - RTS/CTS - When units wish to transmit, they request a channel (RTS) from the associated coordinator. The Coordinator will respond immediately (CTS) if the channel is successfully allocated. Default for secondary coordinators and remotes.</p> <p>2 - TDMA - Transmission on slot. See S221.</p> | <b>Values</b><br>0 - Aloha<br>1 - RTS/CTS<br>2 - TDMA |
| S245 (MESH)   | Cost of Hop   |
| <p>Cost of one hop in mesh routing. When choosing the best route, the cost of each route must be considered. Cost of Hop allows a user to influence the relationship between the cost of RSSI and the Cost of Each hop. See <u><a href="#">Section 3.2.7 Routing</a></u> for a detailed explanation.</p>  | <b>Values (0-255)</b><br>100                          |
| S247  | Country Code (Read Only)                              |
| <p>This register shows the currently factory set country code. This is a read only register and can only be modified at the factory.</p>  | <b>Values (N/A)</b><br>Read Only, Varies              |

## 6.0 Register/Command Reference

| S248  | Sync Timeout  |
|---|---|
| To remain synchronized to the network a unit must receive sync data occasionally from a coordinator or master. The Sync Timeout defines the number of frames (Mesh) or hops (PMP/PTP), before losing sync completely.<br><br>The sync timeout works like a counter that decrements with each frame or hop interval where sync data is not received. When valid sync data is received the counter is reset to the value set in S248, if the counter reaches zero, the unit will lose sync.<br><br>In MESH is only set on Primary Coordinator and propagated in sync packets. | <b>Values (4-65534)</b><br>100 (Mesh)<br>512 (PP/PMP) |
| S249 (PMP/PP)   | Pkts per hop tx limit                                 |
| Limits the number of packets a modem can send in one hop interval (1-255). Default - 255 (unlimited). Normally should be left unchanged.  | <b>Values (1-255)</b><br>255                          |
| S250 (PMP)  | Master Bandwidth, %                                   |
| Sets a limit on bandwidth available to the master in PMP mode when the channel is allocated to a slave.   | <b>Values (0-100%)</b><br>50                          |
| S251 (PMP)  | Master Hop Allocation Timeout                         |
| In PMP mode S251 defines the channel release timeout in hop intervals. (1-255). Normally a slave must release the channel by sending a channel release packet. If slave stopped communicating with master and didn't release the channel, the master will wait for S251 hop intervals before de-allocating the channel. Normally should be left unchanged.  | <b>Values (1-255)</b><br>10                           |
| S252 (PMP)  | Slave Ch Allocation Timeout                           |
| Channel Allocation Limit for slave, packets (1-255). Defines a number of packets a slave can transmit before releasing the channel. 255 - no restrictions. Default - 10.  | <b>Values (1-255)</b><br>10                           |

## 6.0 Register/Command Reference

### 6.3 Serial Interface Commands

A number of register settings are specifically related to the serial data interface. Some, which have been discussed previously, include:

- |                              |   |
|------------------------------|---|
| <b>S102 Serial Baud Rate</b> | determines the rate of communication between the modem and the local device |
| <b>S110 Data Format</b>      | defines the data, stop, and parity bit count                                |

Also, there are AT commands which effect the configuration of the module, specifically with respect to the handling of data at the RS-232 interface:

- &C Data Carrier Detect (DCD)**
- &D Data Terminal Ready (DTR)**
- &K Handshaking**
- &S Data Set Ready (DSR)**

#### &Cn

Controls the module's DCD output signal to the attached device. Determines when the DCD line is active.

&C0 - DCD always on  
 &C1 - DCD on when synchronized  
 &C3 - In PP/PMP systems, slaves/repeaters provides an external global synchronization pulse. See S183  
 &C4 - In Mesh - DCD as carrier detect. Active (0V CMOS) when carrier is detected. Uses CS threshold S81  
 &C5 - In Mesh - DCD as carrier detect. Opposite to &C4 - active when there is no carrier

#### Data Carrier Detect (DCD)

##### Values

- |   |                                  |
|---|----------------------------------|
| 0 | DCD always on                    |
| 1 | <b>DCD on when synchronized*</b> |
| 3 | PP/PMP Sync Pulse                |
| 4 | Mesh DCD active when carrier     |
| 5 | Mesh DCD not active w/carrier    |

#### &Dn

Controls the action that the module will perform when the DTR input line's state is modified.

#### Data Terminal Ready (DTR)

##### Values

- |   |  |
|---|--|
| 0 | <b>DTR ignored</b>                           |
| 2 | DTR disconnects and switches to command mode |

#### &Kn

Enables or disables hardware handshaking.

#### Handshaking

##### Values

- |   |   |
|---|---|
| 0 | <b>Handshaking disabled</b>                   |
| 1 | CTS Control Transmitter of RS485 driver chip. |
| 3 | RTS/CTS handshaking enabled                   |



Software flow control (XON/XOFF) is not supported.

#### &Sn

Controls the module's DSR line and determines when it is active.

In RS485 modes DSR controls the transmitter of the RS485 driver chip unless &K1 is used. High level enables the transmitter.

#### Data Set Ready (DSR)

##### Values

- |   |                                      |
|---|--------------------------------------|
| 0 | <b>DSR always on</b>                 |
| 1 | DSR = 0 in data mode, 1 command mode |
| 2 | DSR = 0 when awake, 1 asleep         |

## 7.0 Installation

The are a number of factors to consider when preparing to deploy a radio network, several of which have been touched-upon or detailed elsewhere within this manual. Following is a listing of a number of factors, in no particular order:



**The installation, removal, or maintenance of any antenna system components must be undertaken only by qualified and experienced personnel.**

### Network Topology

The P900 currently supports Mesh, Roaming Mesh, Point to Point, and Point to Multipoint topologies.

### Throughput

The P900 is capable of up to 230.4kbps asynchronous baud rate. The network topology has an effect on how this available throughput is 'shared' between all nodes on the network.

### Distance

The physical distance between the modems dictates such things as required antenna performance and heights. When contemplating antenna types, keep in mind the directivity (omnidirectional or directional) of the antennas being used.

### Terrain

Along with distance, the terrain is a very important consideration with respect to antenna height requirements. The term 'line-of-sight' (LOS) refers to being able to 'see' one location from another - a minimum requirement for a radio signal path. In addition to LOS, adequate clearance must also be provided to satisfy 'Fresnel Zone' requirements - an obstruction-free area much greater than the physical LOS, i.e. LOS is not enough to completely satisfy RF path requirements for a robust communications link.

### Transmit Power

Having read thus far through the factors to be considered, it should be clear that they are all interrelated. Transmit power should be set for the minimum required to establish a reliable communications path with adequate fade margin. Required transmit power is dictated primarily by distance, antenna type (specifically the 'gain' of the antennas being used), and the receive sensitivity of the distant modem. Cable and connector losses (the physical path from the modem's 'antenna connector' to the antenna's connector) must also be taken into account.

### Receive Sensitivity

The Pico Series has exceptional receive sensitivity, which can produce a number of benefits, such as: added fade margin for a given link, being able to use less expensive coaxial cable or antenna types, being able to operate at greater distances for a given distant transmitter power (perhaps negating the requirement for a Repeater site!). Distance, antenna gain, transmit power, and receive sensitivity are critical 'numbers' for radio path calculations. Fortunately, the Pico Series features the maximum available transmit power combined with exceptional receive sensitivity - two 'numbers' which will produce the most favorable path calculation results.

## 7.0 Installation

### **Fade Margin**

When all radio path numbers are being considered and hardware assumptions are being made, another factor to consider is the 'fade margin' of the overall system. The fade margin is the difference between the anticipated receive signal level and the minimum acceptable receive level (receive sensitivity). Being that the Pico Series performs to exacting specifications, the overall deployment should be such that the modems may be utilized to their full potential to provide a reliable and robust communications link. A typical desired fade margin is in the order of 20dB, however oftentimes a 10dB fade margin is acceptable.

### **Frequency**

The 900MHz frequency range is not effected by rain to any significant degree, and is also able to penetrate through foliage and 'around obstacles' to a certain degree. This being the case, some may choose to scrimp on the physical deployment, particularly when it comes to antenna (tower) heights. Path calculations provide results which specify 'required' antenna heights. For cost savings and in taking advantage of the characteristics of the frequency range, sometimes the height requirements are not adhered to: this may result in unreliable communications.

### **Power Requirements**

The Pico Series may be integrated into a system (Development Board, or custom) which accepts a range of DC input voltages (supply current requirements must also be met). In some deployments, power consumption is critical. A number of features related to minimizing power consumption are available with the P900 such the ability to operate at lower transmit power given the receive sensitivity of the distant modem.

### **Interference**

The frequency hopping spread spectrum (FHSS) operation of the Pico Series most often allows it to work well in an environment within which there may be sources of in-band interference. Frequency Restriction (Hopping Zones) is a built-in feature which may be utilized to avoid specific frequencies or ranges of frequencies; the Spectrum Analyzer function may be used to identify areas of potential interference. Cavity filters are also available if required: contact Microhard Systems Inc. for further information.

## 7.0 Installation

### 7.1 Path Calculation



FCC regulations allow for up to 36dB<sub>i</sub> effective isotropic radiated power (EIRP). The sum (in dBm) of the transmitted power, the cabling loss, and the antenna gain cannot exceed 36dB<sub>i</sub>.

Assuming adequate antenna heights, a basic formula to determine if an adequate radio signal path exists (i.e. there is a reasonable fade margin to ensure reliability) is:

$$\text{Fade Margin} = \text{System Gain} - \text{Path Loss}$$

*where all values are expressed in dB.*

As discussed on the previous page, a desired fade margin is 20dB.

System gain is calculated as follows:

$$\text{System Gain} = \text{Transmitter Power} + (\text{Transmitter Antenna Gain} - \text{Transmitter Cable and Connector Losses}) + (\text{Receiver Antenna Gain} - \text{Receiver Cable and Connector Losses}) + |\text{Receiver Sensitivity}|.$$

*where all values are expressed in dB, dB<sub>i</sub>, or dBm, as applicable.*

Assuming a path loss of 113dB for this example, the fade margin = 143-113 = 30dB.

30dB exceeds the desired fade margin of 20dB, therefore this radio communications link would be very reliable and robust.

On the following page are examples of actual path loss measurements taken in an open rural environment; the path loss numbers do not apply to urban or non-LOS environments.

#### Example:

Tx power = 30dBm  
Tx antenna gain = 6dB<sub>i</sub>  
Tx cable/connector loss = 2dB  
Rx antenna gain = 3dB<sub>i</sub>  
Rx cable/connector loss = 2dB  
Rx sensitivity = -108dBm

$$\begin{aligned}\text{System Gain} &= [30 + (6 - 2) + (3 - 2) + 108] \text{dB} \\ &= [30 + 4 + 1 + 108] \text{dB} \\ &= 143 \text{dB}.\end{aligned}$$

## 7.0 Installation



To satisfy FCC radio frequency (RF) exposure requirements for mobile transmitting devices, a separation distance of 23cm or more should be maintained between the antenna of this device and persons during device operation. To ensure compliance, operation at less than this distance is not recommended. The antenna used for this transmitter must not be co-located in conjunction with any other antenna or transmitter.



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

| Distance (km) | Master Height (m) | Remote 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          |

Table 5-1: Path Loss

Once the equipment is deployed, average receive signal strength may be determined by accessing S Register 123.

### 7.2 Installation of Antenna System Components

The installation, removal, or maintenance of any antenna system components must be undertaken only by qualified and experienced personnel.

#### 7.2.1 Antennas

The two most common types of antenna are the omnidirectional ('omni') and directional (Yagi).

An **omni** typically has 3-6dBi gain and spreads its energy in all directions (hence the name 'omnidirectional'). The 'pattern' of the energy field is in the shape of a donut, with the antenna mounted vertically at the centre. This vertical-mounted antenna produces a signal which is vertically 'polarized'.

A **Yagi** has a more focused antenna pattern, which results in greater gain: commonly, 6-12dBi. The pattern of a Yagi is in the shape of a large raindrop in the direction in which the antenna is pointed. If the elements of the Yagi are perpendicular to the ground (most common orientation) the radiated signal will be vertically polarized; if parallel to the ground, the polarization is horizontal.

The network topology, application, and path calculation are all taken into consideration when selecting the various antenna types to be used in a radio network deployment.

## 7.0 Installation



Direct human contact with the antenna is potentially unhealthy when a P900 is generating RF energy. Always ensure that the P900 equipment is powered down (off) during installation.

### 7.2.2 Coaxial Cable

The following types of coaxial cable are recommended and suitable for most applications (followed by loss at 900MHz, in dB, per 100 feet):

- LMR 195 (10.7)
- LMR 400 (3.9)
- LMR 600 (2.5)

For a typical application, LMR 400 may be suitable. Where a long cable run is required - and in particular within networks where there is not a lot of margin available - a cable with lower loss should be considered.

When installing cable, care must be taken to not physically damage it (be particularly careful with respect to not kinking it at any time) and to secure it properly. Care must also be taken to affix the connectors properly - using the proper crimping tools - and to weatherproof them.



To comply with FCC regulations, the maximum EIRP must not exceed 36dBm.

### 7.2.3 Surge Arrestors

The most effective protection against lightning-induced damage is to install two lightning surge arrestors: one at the antenna, 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-type female.



All installation, maintenance, and removal work must be done in accordance with applicable codes.

### 7.2.4 External Filter

Although the Pico Series 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 P900's antenna can desensitize the receiver. Microhard Systems Inc.'s external cavity filter eliminates this problem. The filter has two N-female connectors and should be connected inline at the interface to the RF equipment.

## Appendix A: AT Command Quick Reference

The following commands may be used when the modem is in COMMAND MODE; all are to be preceded with "AT" and followed with [Enter]. An asterisk (\*) indicates a default setting, where applicable.

### A

#### **Answer**

This command puts the modem into online/data mode

#### **g, G**

#### **Spectrum Analyzer**

Used to help determine if interfering RF signals are present.

#### **In**

#### **Identification**

Follow ATI with either of the following 'n':

0-User String

1-product code

2-firmware CRC check

3-firmware version

4-firmware date

5-firmware copyright

6-firmware time

7-Mac Address

11-statistics

255-factory-configured options listing

#### **Login**

Enables/allows the addition/changes to a password to login to the modem.

### M

#### **Mesh Diagnostic Main Menu**

Displays a menu used for Mesh diagnostics

### N

#### **Advanced Spectrum Analyzer**

Advanced spectrum analyzer provides for a more detailed scrutiny of the RF environment.

#### **&Fn**

#### **Load Factory Default Configuration**

-follow AT&F with either of the following 'n':

1-Mesh Primary Coordinator

2-Mesh Remote

3-Mesh Secondary Coordinator

7-PMP Master

8-PMP Slave

9-PMP Repeater

10-PP Master

11-PP Slave

12-PP Repeater

13-PMP Master 57k

14-PMP Slave 57k

#### **&Cn**

#### **DCD (Data Carrier Detect)**

-controls modem's DCD output signal

0-DCD always on

1-DCD on when modem's sync'ed, always on if Master\*

3-In PP/PMP provides global sync pulse

4-In Mesh Active when Carrier detected

5- In Mesh Active when Carrier absent

#### **&Dn**

#### **DTR (Data Terminal Ready)**

-controls the action the modem performs when the DTR input line is toggled

-follow ATD with either of the following 'n':

0-\*DTR line ignored

2-deassert DTR to force modem from data mode into command mode at S102 serial baud rate; DTR must be asserted before putting modem back into data mode (normally done using 'ATA' command)

#### **&Kn**

#### **Handshaking**

-controls modems CTS line and determines handshaking between modem and host device.

0-disable handshaking

1-CTS controls transmitter of RS485 driver chip

3-enable hardware (RTS/CTS) handshaking\*

#### **&Sn**

#### **DSR (Data Set Ready)**

-controls modem's DSR line and determines when it is active

0-DSR always on

1-\*DSR ON in data mode, OFF in command mode

2-DSR=0 when awake, 1 when asleep

#### **AT&V**

#### **View Configuration**

-displays all visible S registers and their current values

#### **&W**

#### **Write Configuration to Memory**

-stores active configuration into modem's non-volatile memory

#### **Sxxx?**

#### **Read S Register Value**

-where xxx is the S register's number, this command will result in displaying the current setting of that register

#### **Sxxx=yyy**

#### **Set S Register Value**

-where xxx is the S register's number, this command will place value yyy in that register

#### **Sxxx /?**

#### **Display S Register Help Text**

-where xxx is the S register's number, this command will result in displaying the available settings of that register. Not all registers have help text.

## Appendix B: Settings (S) Register Quick Reference

The registers described in this Appendix are ones which are normally 'visible' to the user. The values stored in these registers effect the operation of the modem. An asterisk \* represents default value (if applicable).

Query format : **AT\$xxx? [Enter]** where xxx is S register *number* detailed below  
 Change format : **AT\$xxx=y [Enter]** where xxx is S register number and y is desired value  
 Help Format : **AT\$xxx /? [Enter]** where xxx is S register number (space between xxx and /?)

### **S80 - TX Profiles (MESH)**

0-3  
0\*

### **S81 - CS Threshold**

0-255 (-dBm)  
60

### **S101 - Operating Mode**

0-Master (PMP/PTP)  
 1-Repeater (PMP/PTP)  
 2-Remote (Slave) (MESH/PMP/PTP)  
 4-Coordinator (MESH)  
 5-Secondary Coordinator (MESH)  
 6-Standby Coordinator (MESH)

### **S102 - Serial Port Baud Rate (bps)**

|            |           |
|------------|-----------|
| ● 0-230400 | ● 8-7200  |
| ● 1-115200 | ● 9-4800  |
| ● 2-57600  | ● 10-3600 |
| ● 3-38400  | ● 11-2400 |
| ● 4-28800  | ● 12-1200 |
| ● 5-19200  | ● 13-600  |
| ● 6-14400  | ● 14-300  |
| ● 7-*9600  |           |

### **S103 - Wireless Link Rate (bps)**

0-172800\*  
1-230400  
2-276480

### **S104 - Network Address**

0-4294967295  
1234567890\*

### **S105 - Unit Address (PP/PMP)**

1-65534

### **S106/S206 - Primary/Secondary Hop Pattern**

0-49  
0/1\*

### **S108 - Output Power Level**

20-30dBm  
30\* (1W)

### **S110—Data Format (of Asynchronous serial input to modem)**

|          |          |
|----------|----------|
| ● 1-8N1* | ● 6-7N2  |
| ● 2-8N2  | ● 7-7E1  |
| ● 3-8E1  | ● 8-7O1  |
| ● 4-8O1  | ● 9-7E2  |
| ● 5-7N1  | ● 10-7O2 |

### **S113 - Packet Retransmissions**

0-255  
5\*

### **S115 - Repeat Interval**

0-255  
1\*

### **S123 - RSSI Value (dBm, read only)**

### **S133 - Network Type**

0-Point to Multipoint  
 1-Point to Point  
 2-Mesh  
 3-Mesh with Roaming

### **S140 - Destination Address**

Mesh - MAC Address (FF:FF:FF:FF:FF:FF=Broadcast)  
 PP/PMP - 1-65535, where 65535 = Broadcast

### **S158 - FEC Mode**

|   |                       |
|---|-----------------------|
| 0 | No FEC                |
| 1 | Hamming (7,4)         |
| 2 | Hamming (15,11)       |
| 3 | Hamming (31,24)       |
| 5 | Binary BCH (47,36)    |
| 6 | Golay (23,12,7)       |
| 7 | Reed-Solomon (15,11)* |

### **S180/S181 - Primary/Secondary Hop Zone**

0-Use entire ISM Band\*

### **S223 - Routing (Mesh)**

0-Disabled\*  
 1-Enabled

### **S225 - Compression**

0 - Disabled  
 1 - Type 1 Enabled\*

### **S244 - Channel Access Mode**

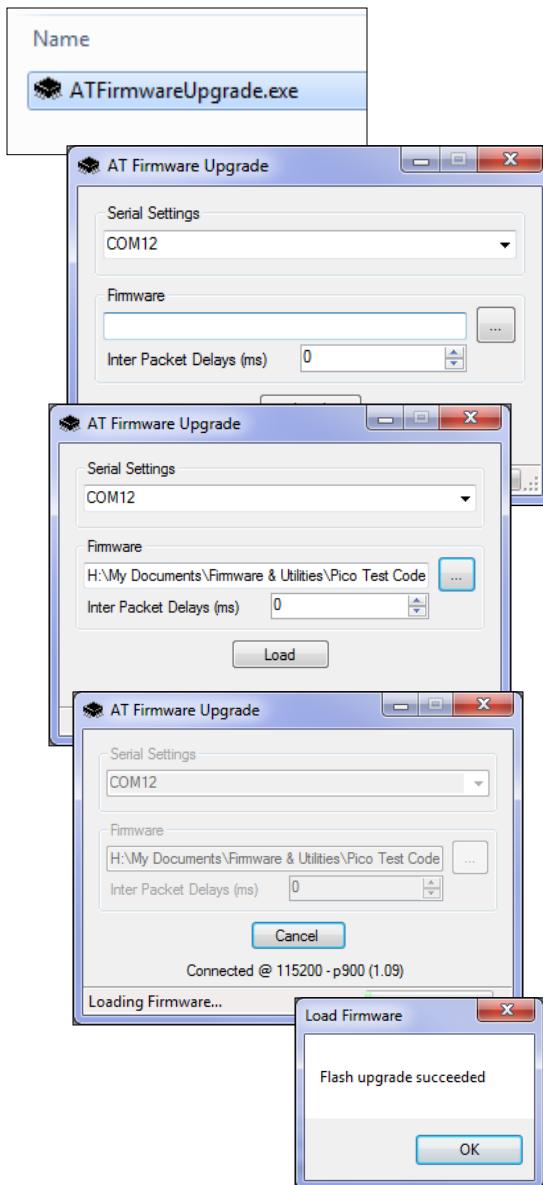
0-Aloha  
 1-RTS/CTS\*  
 2-TDMA

## Appendix C: AT Utility Firmware Upgrade Procedure

To update the firmware on the Pico Series Radio, it is recommended to use the Microhard Utility called **AT Firmware Upgrade**. This utility is available for download from the Microhard Support Site below:

<http://www.microhardcorp.com/support>

To access the downloads section of the support site, you must first register, if you have not already done so.



1. Power up the Pico Modem and Connect a straight through serial cable to the DATA Port of the module. (If installed in development board).

2. Run the firmware utility downloaded from the Microhard Support site.

### **“ATFirmwareUpgrade.exe”**

3. Select the COM port on your PC that is connected to the Pico Module.

4. Browse to the firmware file supplied by Microhard Systems. (.img) to be uploaded to the module. It is recommended to set the delay to 0.

5. Click the “Load” button.

6. The utility will establish a connection to the module and load the firmware. Once complete, a message will be displayed at the bottom of the utility window indicating that the process succeeded.

Image C-1: Firmware Upgrade

## Appendix D: AT Command Firmware Upgrade Procedure

To update the firmware on the Pico Series Radio, it is recommended to use the Microhard Utility called **AT Firmware Upgrade**, discussed on the previous page. If it is not possible to use the utility, the following procedure can be used to load firmware using AT commands. The file type used for this procedure is not the same as when using the utility. A file must be supplied by Microhard Systems with the .svg extension.

*More detailed information can be obtained by contacting Microhard Systems. This procedure is recommended for advanced users only.*

### AT Command Upgrade Procedure

1. Enter Command Mode.
2. Select the baud rate 115200 bps (ATS102=1) for the modem to minimize the firmware upgrade time. Connect Microhard modem through a COM port as the setting with serial port terminal software:

|               |        |
|---------------|--------|
| Baud Rate:    | 115200 |
| Parity bit:   | None   |
| Data bits:    | 8      |
| Stop bits:    | 1      |
| Flow Control: | None   |
3. Run Microhard AT commands to do the flash upgrade in the following sequence:

#### 3.1 Run “at&u0<CR>” at command terminal

Initialize the modem into flash image upgrade mode

#### 3.2 Run “at&u1<CR>” at command terminal

Load the flash image into the modem. After this command is entered, don't do anything except send the firmware file provided by Microhard (.svg). It sends an “ERROR” response if the file was not received.

#### 3.3 Run “at&u2<CR>” at command terminal

Pre-arm the image flashing. You have 20s to trigger the writing procedure of the firmware image from RAM to Flash memory. If you missed that window of opportunity, you need to pre-arm the modem again.

#### 3.4 Run “at&u3<CR>” at command terminal

Flash the loaded image. After this command has been issued, any action and power changes could damage the modem. Modem returns the “ERROR” response when the 20s time-out is expired. The approximate duration on this step is 30s.

After the flash upgrade finishes, the modem reboots and it is ready to work.

## Appendix E: Development Board Serial Interface

Arrows denote the direction that signals are asserted (e.g., DCD originates at the DCE and tells the DTE that a carrier is present).

The P900 Serial Interface on the Development Board uses 8 pins on the header connector for asynchronous serial I/O. The interface conforms to standard RS-232 signals without level shifting, so direct connection to a host microprocessor is possible.

The signals in the asynchronous serial interface are described below:

| Module<br>(DCE) |   | Signal | Host<br>Microprocessor<br>(DTE) |     |
|-----------------|---|--------|---------------------------------|-----|
| 1               |   | DCD    | →                               | IN  |
| 2               |   | RX     | →                               | IN  |
| 3               | ← | TX     |                                 | OUT |
| 4               | ← | DTR    |                                 | OUT |
| 5               |   | SG     |                                 |     |
| 6               |   | DSR    | →                               | IN  |
| 7               | ← | RTS    |                                 | OUT |
| 8               |   | CTS    | →                               | IN  |

Table F1

**DCD** *Data Carrier Detect* - Output from Module - When asserted (TTL low), DCD informs the DTE that a communications link has been established with another n920.

**RX** *Receive Data* - Output from Module - Signals transferred from the n920 are received by the DTE via RX.

**TX** *Transmit Data* - Input to Module - Signals are transmitted from the DTE via TX to the n920.

**DTR** *Data Terminal Ready* - Input to Module - Asserted (TTL low) by the DTE to inform the module that it is alive and ready for communications.

**SG** *Signal Ground* - Provides a ground reference for all signals transmitted by both DTE and DCE.

**DSR** *Data Set Ready* - Output from Module - Asserted (TTL low) by the DCE to inform the DTE that it is alive and ready for communications. DSR is the module's equivalent of the DTR signal.

**RTS** *Request to Send* - Input to Module - A "handshaking" signal which is asserted by the DTE (TTL low) when it is ready. When hardware handshaking is used, the RTS signal indicates to the DCE that the host can receive data.

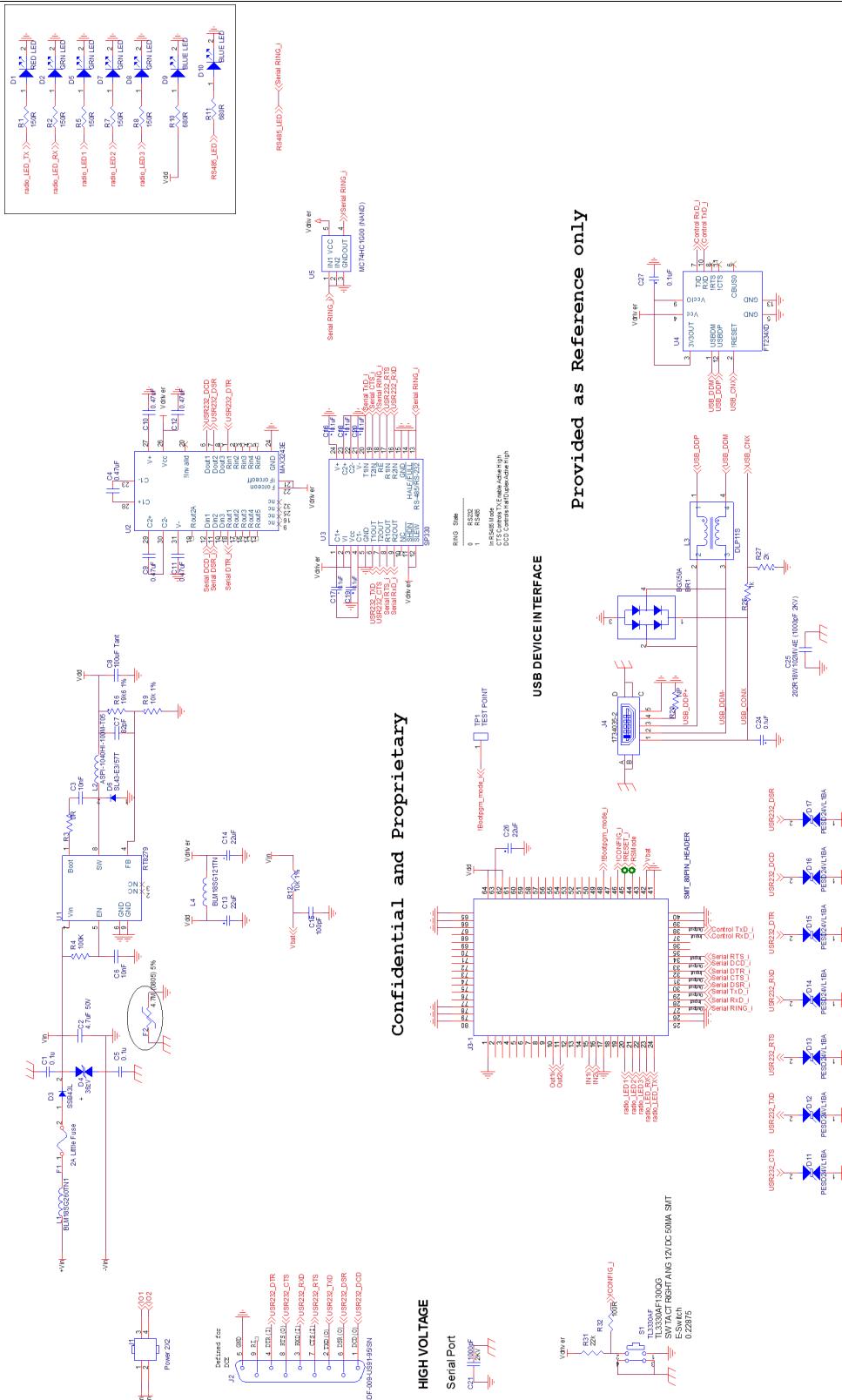
**CTS** *Clear to Send* - Output from Module - A "handshaking" signal which is asserted by the DCE (TTL low) when it has enabled communications and transmission from the DTE can commence. When hardware handshaking is used, the CTS signal indicates to the host that the DCE can receive data.

**Notes:** It is typical to refer to RX and TX from the perspective of the DTE. This should be kept in mind when looking at signals relative to the module(DCE); the module transmits data on the RX line, and receives on TX.

"DCE" and "module" are often synonymous since a module is typically a DCE device.

"DTE" is, in most applications, a device such as a host microprocessor.

## Appendix F: Pico Reference Schematic



Provided as Reference only

Confidential and Proprietary

## Appendix G: Pico-MHX Adapter Board (Page 1 of 2)

### Pico-MHX Adapter Card

The Pico-MHX Adapter card is available to users of the MHX platform who wish to transition to and/or evaluate the Pico platform without a complete redesign.



Pico-MHX Adapter Board

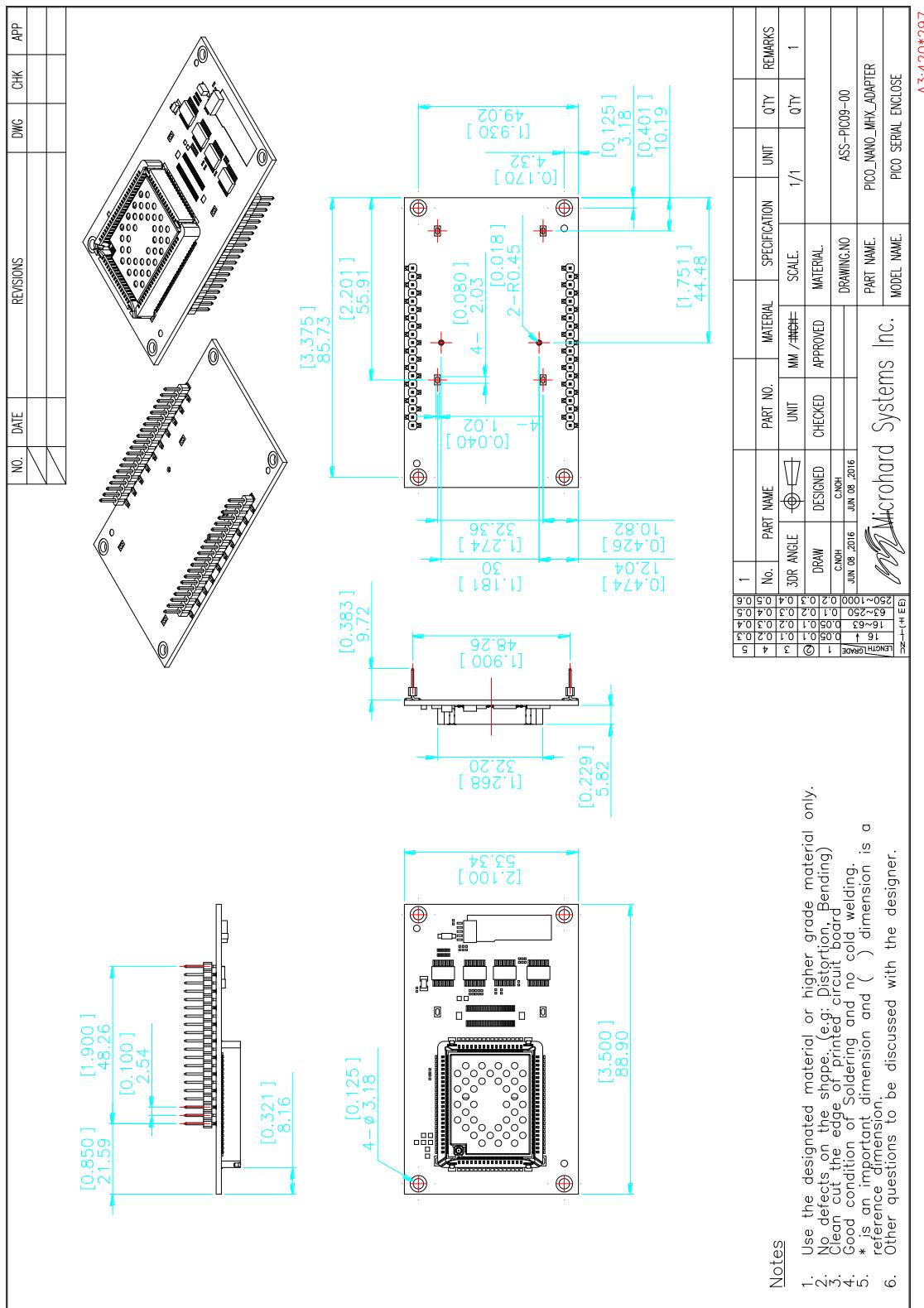
### Pico-MHX Adapter Pin-outs

The following shows the pins available on the Pico-MHX Adapter. For more information, refer to the detailed pin description in this manual, or in the respective MHX manual. This is provided as a quick reference. The drawing depicts a top view of the Adapter. The corner pins (1,20,21,40) are printed directly on the PCB for reference.

|                   | MHX<br>Pin-Out<br>(Top View) |    |
|-------------------|------------------------------|----|
| Vcc               | 1                            | 40 |
| Vcc               | 2                            | 39 |
| 3.3V or 5V Select | 3                            | 38 |
| VClock            | 4                            | 37 |
| !Shutdown         | 5                            | 36 |
| !Bootpgm_Mode     | 6                            | 35 |
| USR_AN0           | 7                            | 34 |
| !WAKEUP_usr       | 8                            | 33 |
| !Config           | 9                            | 32 |
| !Reset            | 10                           | 31 |
| VBat              | 11                           | 30 |
| Sleep_Mode        | 12                           | 29 |
| GND               | 13                           | 28 |
| GND               | 14                           | 27 |
| GND               | 15                           | 26 |
| GND               | 16                           | 25 |
| GND               | 17                           | 24 |
| USR_1             | 18                           | 23 |
| USR_2             | 19                           | 22 |
| USR_3             | 20                           | 21 |

MHX Series Pin-Out (Top View)

## Appendix G: Pico-MHX Adapter Board (Page 2 of 2)



## Appendix H: P900 Approved Antennas

| Group   | Part Number | Description   |
|---|-------------|---|
| <b>Rubber Ducky</b>                                     |             |   |
|   | MHS031000   | 2dBi, 900MHz Rubber Ducky Antenna RPTNC Swivel                  |
|   | MHS031070   | 2dBi, 900MHz Rubber Ducky Antenna Reverse SMA Swivel            |
|   | MHS031080   | 2dBi, 900MHz Rubber Ducky Antenna Reverse SMA Straight          |
| <b>Transit Antennas</b>                                 |             |   |
|   | MHS031210   | 3dBd, 900 MHz Transit Antenna with Ground Plane                 |
|   | MHS031220   | 3dBd, 900MHz Transit Antenna No Ground Plane                    |
|   | MHS031230   | 3dBd, 900MHz Transit Antenna Permanent Mount GP                 |
|   | MHS031240   | 3dBd, 900MHz Transit Antenna Permanent Mount NGP                |
| <i>Mounts for Transit Antennas have a RPTNC Pigtail</i> |             |   |
| <b>Yagi Antennas</b>                                    |             |   |
|   | MHS031311   | 6dBd, 900MHz Yagi Directional Antenna Antenex, RPTNC Pigtail    |
|   | MHS031431   | 6.5dBd, 900MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail |
|   | MHS031501   | 9dBd, 900MHz Yagi Directional Antenna Antenex, RPTNC Pigtail    |
|   | MHS031441   | 10dBd, 900 MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail |
|   | MHS031451   | 11dBd, 900 MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail |
| <b>Patch Antennas</b>                                   |             |   |
|   | MHS031440   | 8dBi, 900 MHz, Patch Antenna, RPTNC Pigtail                     |
| <b>Omni Directional</b>                                 |             |   |
|   | MHS031251   | 3dBd, 900MHz Omni Directional Antenna Antenex, RPTNC Pigtail    |
|   | MHS031461   | 3dBd, 900 MHz Omni Directional Antenna Bluewave, RPTNC Pigtail  |
|   | MHS031321   | 6dBd, 900MHz Omni Directional Antenna Antenex, RPTNC Pigtail    |
|   | MHS031471   | 6dBd, 900 MHz Omni Directional Antenna Bluewave, RPTNC Pigtail  |



**WARNING:** Changes or modifications not expressly approved by Microhard Systems Inc. could void the user's authority to operate the equipment. This device has been tested with UFL connectors with the antennas listed in Appendix H. When integrated in OEM products, fixed antennas require installation preventing end-users from replacing them with non-approved antennas. Antennas not listed in the tables must be tested to comply with FCC Section 15.203 (unique antenna connectors) and Section 15.247 (emissions). Please Contact Microhard Systems Inc. if you need more information.

**Industry Canada:** This device has been designed to operate with the antennas listed above, and having a maximum gain of 13.2 dBi. Antennas not included in this list or having a gain greater than 13.2 dBi are strictly prohibited for use with this device. The required antenna impedance is 50 ohms. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (EIRP) is not more than that required for successful communication. This Class B digital apparatus complies with Canadian ICES-003.

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