INSTRUCTION MANUAL

CSI Maxon
Radiotelemetry Network

Revision: 4/03

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CSI Maxon Radiotelemetry Network
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Section 1. General Radiotelemetry Network

1.1 Introduction

Data retrieval from a remote site can be difficult. To accomplish data collection from isolated sites Campbell Scientific, Inc. utilizes a radiotelemetry (RF telemetry) network. Dataloggers can be accessed by RF telemetry which requires no physical connection from the computer to the datalogger. The RF telemetry link reduces the number of visits to a remote site for data collection.

The RF telemetry network is designed for complete computer control. One computer can establish communication with up to 254 remote sites. PC208W Datalogger Support Software allows data collection from the datalogger, transmitting datalogger programs, and displaying current readings from the datalogger.

The requirements specific to a RF telemetry network include:

- The distance between radio stations should not be greater than approximately 25 miles.

- The stations should not have major obstacles between them; therefore, they should be within line-of-sight of each other.

The stations communicate over a radio frequency which is specified in Megahertz (MHz, 148 to 174 MHz and 440 to 470 MHz are supported). A data communication network must have its own specific frequency to prevent interference from other sources. Typical radio frequencies are either VHF (Very High Frequency) ranging from 148 to 174 MHz or UHF (Ultra High Frequency) ranging from 440 to 470 MHz. A typical RF system is shown in Figure 1-1.

Telemetry network's three basic components are:

- Field Station

- Base Station

- Repeater Station

This manual covers the use of the RF310 and RF312 radios, the RF310M radio modem and the RF310B base station. Some PC208W software topics are also addressed.
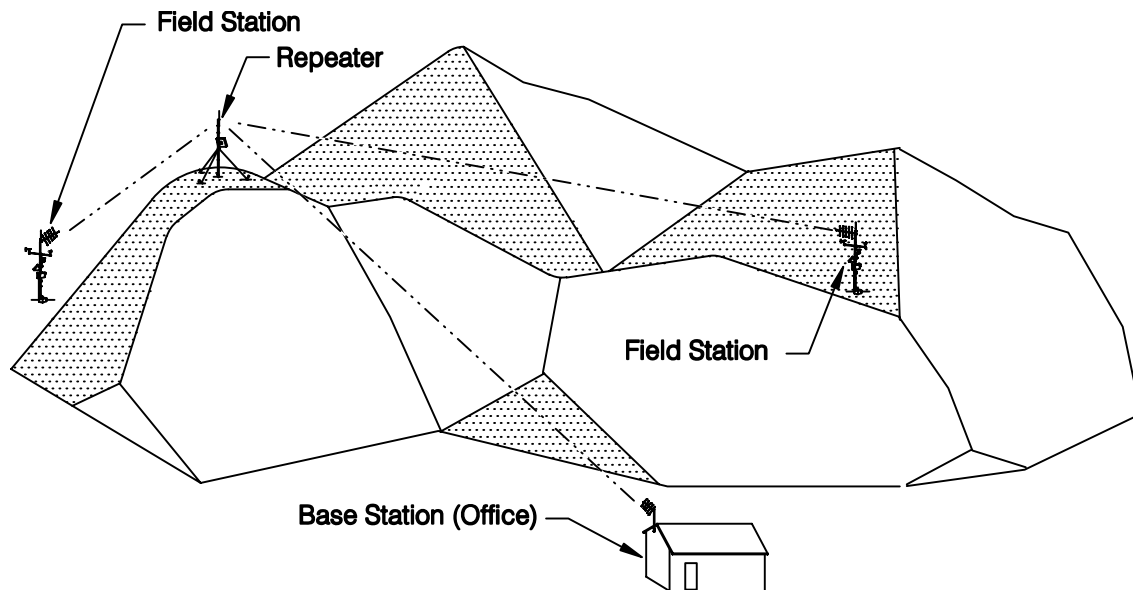
FIGURE 1-1. A Basic RF Telemetry Network

1.2 Field Station

Purpose: The field station is where the measurements are made. The Campbell Scientific datalogger resides at this station taking the desired measurements. Any field station can also operate as a repeater. The only requirement is that the station's antenna must be able to communicate in all desired directions. This may require an omnidirectional antenna.

Equipment Required:

- Radio

- RF Modem

- Antenna and antenna cable

- Datalogger

- Power supply, enclosure, sensors, and mounting needs
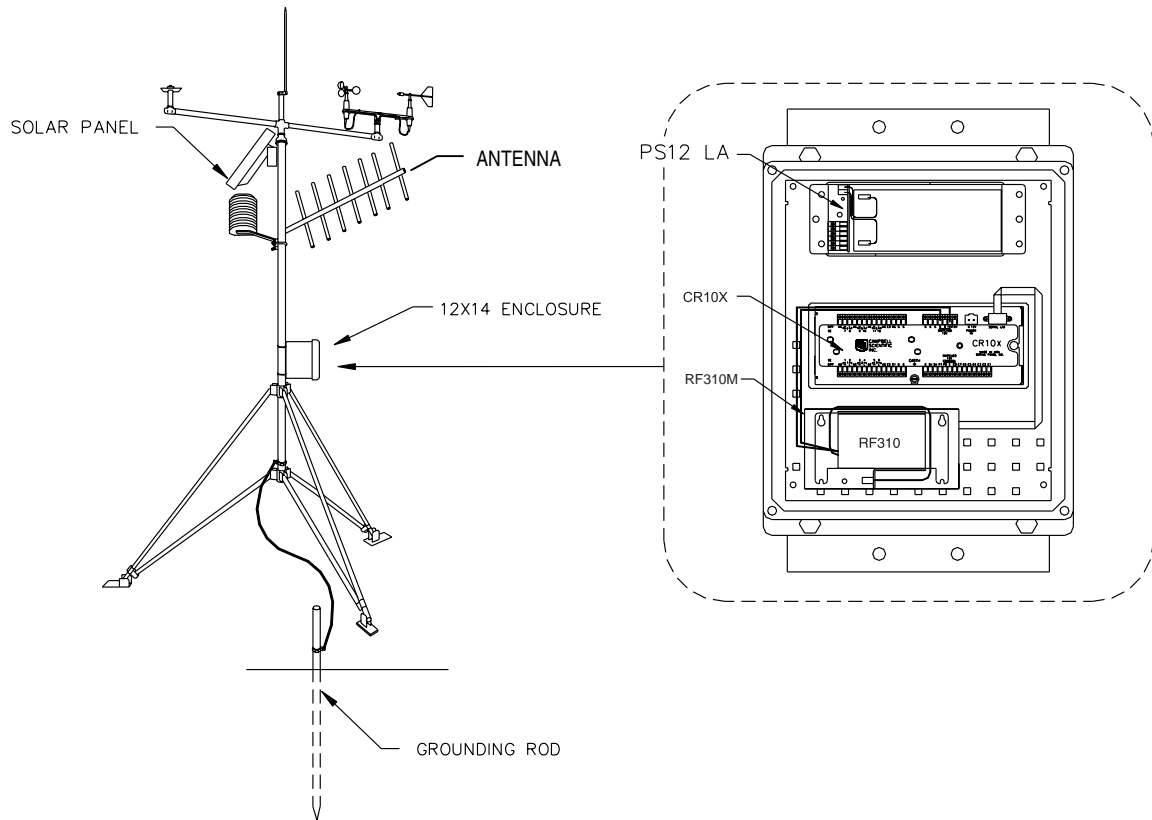
FIGURE 1-2. A CR10(X) Field Station

1.3 Base Station

Purpose: A base station utilizes a computer to collect data from the field station(s). Normally, all communication to the field stations originate at the base station. Data retrieval, remote programming, and system analysis can all be done from the base station.

Equipment Required:

- Radio

- RF Base Station

- Computer with PC208W software

- Antenna and antenna cable

- AC power

RS232 Cable

To Antenna

PC208W DATALOGGER
SUPPORT SOFTWARE
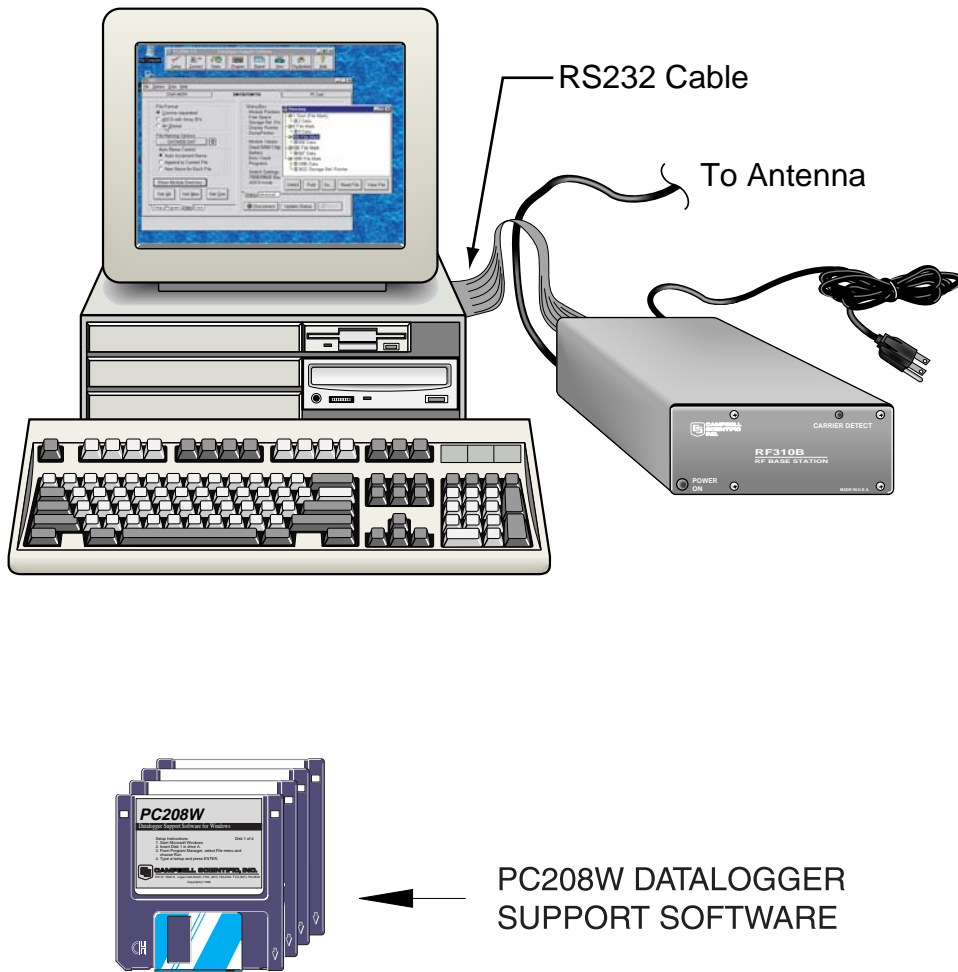
FIGURE 1-3. An RF Telemetry Base Station

1.4 **Repeater**

Purpose: To act as relay between two communicating stations separated by too long of a distance or an obstacle which impedes direct communication. A repeater is not always required in an RF telemetry network. A field station can also function as a repeater.

Equipment Required:

- Radio

- RF Modem

- Antenna and antenna cable

- 12 V and 5 V power supply (PS512M or CH512R and BP12)

- Enclosure and other mounting needs
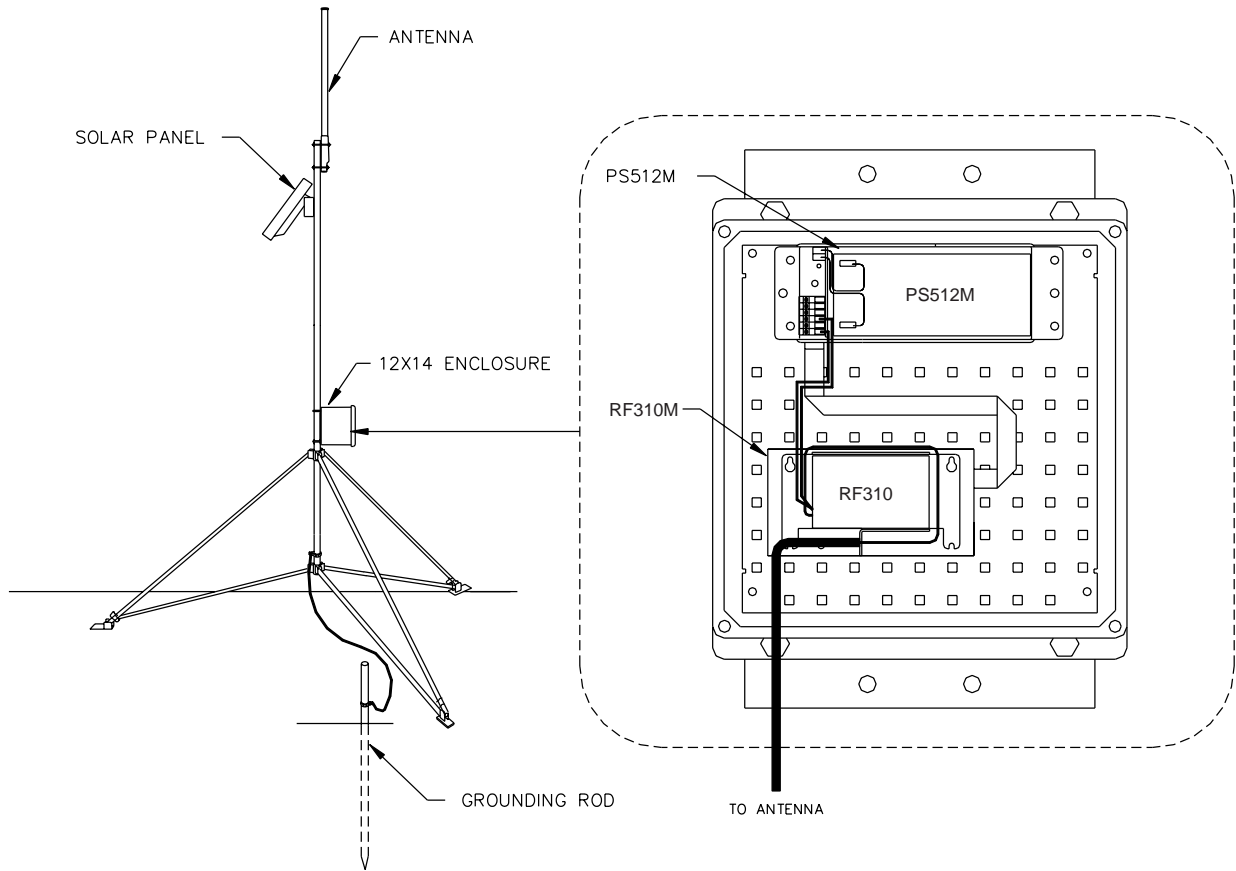
FIGURE 1-4. A Typical RF Telemetry Repeater Station

Section 2. Assembling the Radiotelemetry Network

This section provides a logical order for RF network assembly and deployment. Details of specific components in the system are described in Section 3 "Radiotelemetry Network Components." Section 3 is cross-referenced throughout this assembly section.

2.1 Final Layout

The initial locations of the base, field, and repeater stations have likely been determined already. Locate RF stations on an area map, preferably a topographic map. Draw a line along every communication path. Each field station must have a path connecting it back to the base station. No path can be going through a mountain or large obstacle; this would negate the line-of-sight requirement. A station may need to be moved or a repeater station may need to be added if this requirement is not met.

At each station there is an RF modem. Each modem requires a unique ID number (Station ID). The number may range from 0 to 255. On the map, label the base station as 254. Label the remaining stations with different ID numbers. Later, each modem will be set with the corresponding ID number. The Station ID, similar to a phone number, allows the base station to call many different field stations.

2.2 Install Base Station

2.2.1 Base Station Hardware

The major component of the base station is the RF310B Base Station. Refer to Section 3.5 for location drawings and a description of the RF310B Base Station.

1. Remove the top of the RF310B by unscrewing the four screws on the sides.

2. Remove the radio and its cable from its mounting bracket. Mount the radio directly onto the bottom of the RF310B. Secure the BNC connector from the radio's cable to its hole on the back of the RF310B. See Figure 3-7 for assistance.

3. Connect the radio to 12 V, ground, and the RF Modem (RF310M). The RF modem is located behind the front panel above the "POWER ON" light. See Figure 3-8 for assistance.

CAUTION	Radio transmission without an antenna connected can damage radio.

4. Mount the base station antenna in a location that is higher than any surrounding buildings or obstacles. Refer to Section 3.3 for more information on mounting the antenna.

5.   After the antenna is mounted, connect the coax cable between the antenna and the BNC connector mounted in Step 2.

6.   Replace the cover of the RF310B.

7.   Connect a large gauge (approximately 8 AWG) copper wire from the antenna to a good earth ground. This is for lightning protection. This is required for any antenna, especially if the coax cable from the antenna goes inside a building.

8.   Connect a 25-pin RS-232 cable from the computer serial port to the RF310B.

9.   After verifying that the RF310B power switch is off, plug in the RF310B's wall transformer.

2.2.2 PC208W Datalogger Support Software

Once the base station hardware is installed, the PC208W software must be setup. If PC208W is not installed on the computer, you will need to install it. Refer to the PC208W Manual if you have questions about the installation procedure or PC208W. PC208W will refer to the RF310M as either "RF Modem" or "RF95".

There are eight main windows in PC208W:

- SETUP - Used to define communication paths, set data collection parameters, and schedule automatic data collection.

- CONNECT - Used for manual communications with field site. Supports real time data display, graphs, data retrieval and program transfer.

- STATUS - Shows status of schedules and communication information.

- PROGRAM - Editor to aid writing datalogger programs.

- REPORT - Generates reports and reduces data stored on computer.

- VIEW - Used to view text files.

- STG MODULE - Used to service storage modules.

- HELP - On line help. Also accessed anywhere by typing F1.

PC208W uses a main tool bar to access each of the eight windows. The shape of the main tool bar can be changed using standard Windows methods. Closing the main tool bar closes all other PC208W windows.
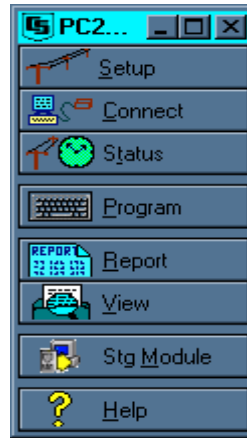
The SETUP window is used to create a device map which contains the RF Link information. This information includes the station ID, communication path and conditions for calling a particular field station. Procedures for creating an RF communications link are explained in Section 1 of the PC208W manual.

Basic steps required to setup an RF link include: 1) select appropriate communications port (COM Port), 2) attach RF modem to COM port, and 3) attach datalogger to RF modem. The default COM port settings should not be changed. The RF modem default settings do not need to be changed. The default datalogger settings do not need changing except for the "Dialed using RF 95 path:".

The RF Path (Dialed Using RF 95 Path:), found on the datalogger hardware tab of the setup screen, designates which field station to call. In the example shown, the base station will call the field station with an RF path of 10. If a repeater is needed to contact Field Station 10, the repeater ID must also be specified. For example, "RF Path: 5 10F," would call Field Station 10 through a repeater with a Station ID of 5. The "F" at the end of the RF Path is optional and is explained later. Click on Save Edits.
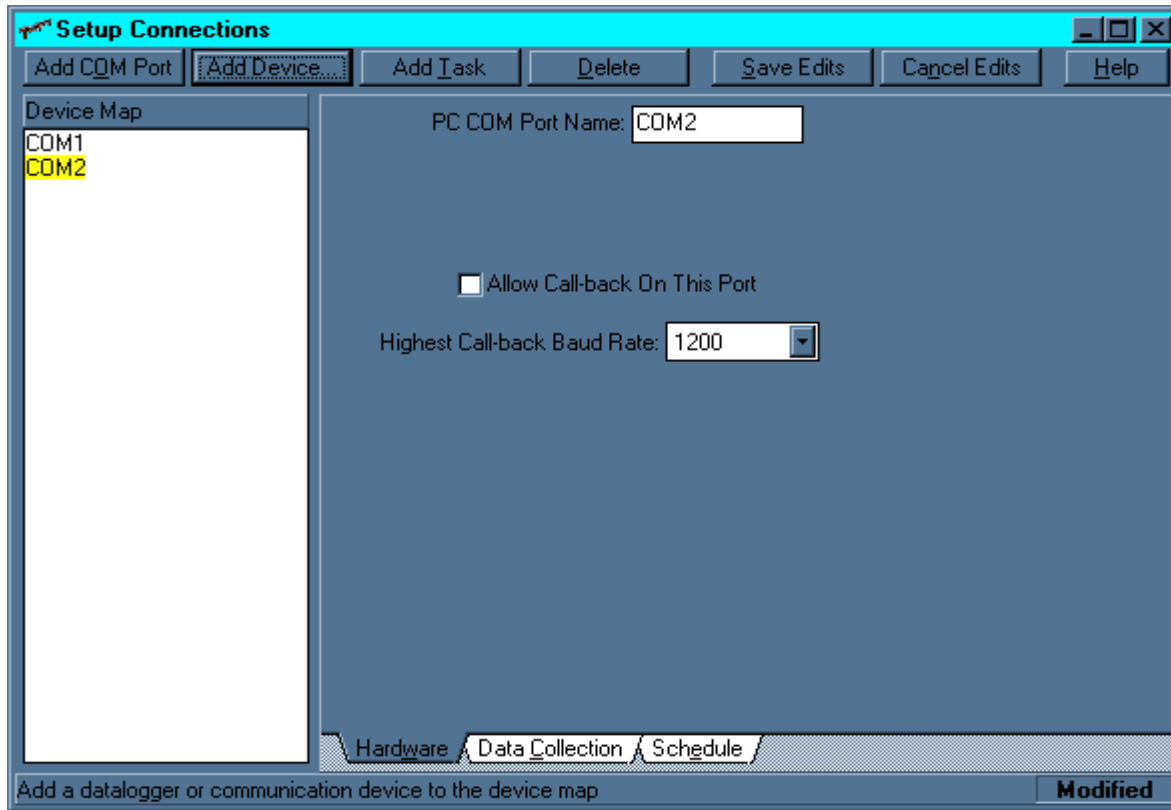
Select the Appropriate Communications port. If your computer uses COM2, click the "Add COM port" button to add an RS-232 communications port. Next click the "Add Device" button.
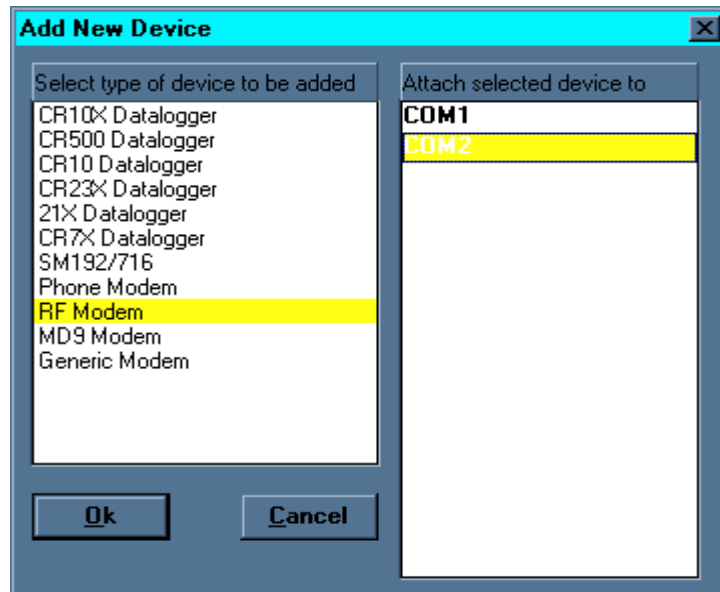
When the "Add Device" button is clicked the "Add New Device" dialog box opens. Select the RF Modem and attach to the appropriate RS-232 communications port. Click OK.
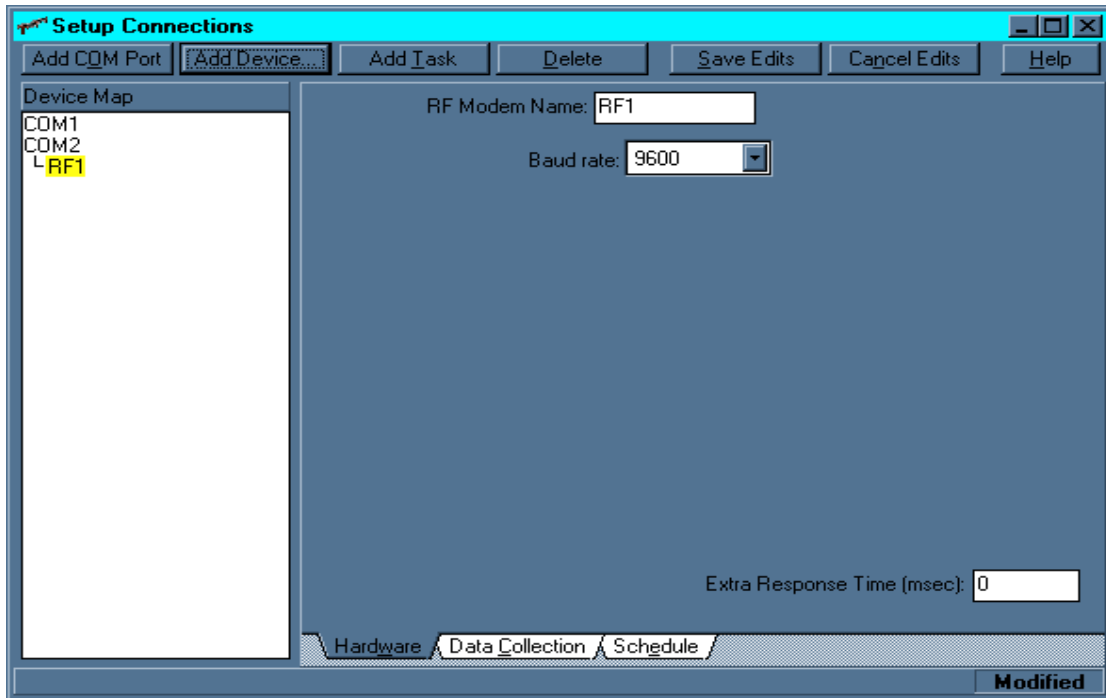
This window shows the RF modem (RF1) attached to RS-232 communication port 2. Next use the Add Device button again to connect the datalogger to RF1.
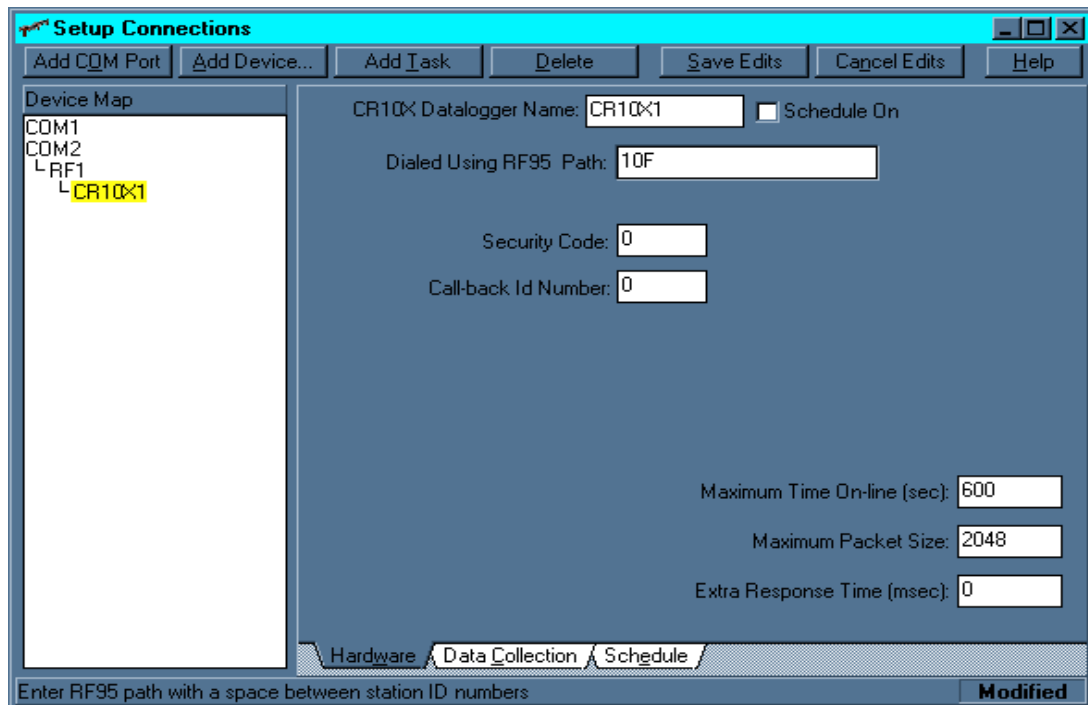
This window shows the CR10X datalogger connected to the RF modem. Notice the Dialed Using RF95 path has been set to 10F. The RF95 path is unique to the RF310M dip switch settings.

2.3 Install Nearest Repeater/Field Station

Now to install the nearest field station. If it communicates with the base station via a repeater, the repeater station must also be installed.

Following is the order in which a general RF field station should be installed. A repeater station is installed in the same order. For instructions on installing any particular component, refer to either Section 3 of this manual or the Weather Station Manual.

1. Tripod or tower

2. Enclosure and datalogger

3. Antenna - Orient correctly; remember direction and polarization

4. Solar Panel

5. Power Supply

6. Sensors

7. RF Modem - Set the Station ID according to the map

8. Radio - Make sure to connect to RF Modem, to power supply, and turn on power supply

2.4 Test the Radiotelemetry Link

With the field station installed, return to the base station for initial testing of the communication link. An RF link can also be tested at the field site with a portable base station; hardware requirements for the portable base station are described in Appendix B.

Testing begins with turning the RF310B base station on. A quick check of connections is in order. Start PC208W software and open the Connect Window. The "Station List" will show all dataloggers or field stations available. Using the mouse, highlight the datalogger of interest then click on the Connect button. The software requires about 15 seconds to establish a PC to datalogger RF link. The computer is "talking" with the datalogger when the first button to the right of the Connect button changes from Terminate to Disconnect.

If you do not click on the Disconnect or Terminate button before closing the Connect window, PC208W will automatically start calling the datalogger when the Connect window is reopened.

2.4.1 A Successful Test

The test is considered successful if you establish communications between the PC and the datalogger.

2.4.2 An Unsuccessful Test

When an RF test is unsuccessful, there are three ways to troubleshoot the system:

1. Verify everything is connected properly. See Section 2.5.1 for more suggestions.

2. Use the error messages in the error file to identify where the link is breaking down. See Section 2.5.2 for more information.

3. Try communicating from the base station to the field station, one step at a time. Identify where communications failed. See Section 2.5.3 for more information.

2.5 Troubleshooting Unsuccessful Communication Attempts

2.5.1 Troubleshooting Physical Link Between Base and Field Station

When communication is not established, troubleshooting begins with the simplest RF link in the system, which is usually communication with the nearest field station. There is NO substitute for first checking the hardware connections, Station IDs, and everything listed in the previous section. Below are a few additional items to check:

1. Antenna is used in proximity of metal.

2. Transmitting inside a building.

3. Damaged or shorted cables.

4. Bad or improper connections.

5. Antenna frequency does not match the radio frequency.

6. Base and field station radios aren't using same frequency.

7. Datalogger power drops below 9.6 Volts during RF transmission. Use datalogger Instruction 10 or volt meter to measure battery voltage.

If the field station's RF310M Modem's Carrier Detect light goes on, then at least a signal is reaching the site. If this occurs, check the following:

1. RF modem's ID matches ID in the RF Path.

2. Field station's radio and datalogger have sufficient power.

3. Radio is connected to RF modem.

4. RF modem is the only thing connected to datalogger's 9-pin connector.

2.5.2 Error Messages

PC208W will log all activity related to each Communications port (COM port). There are two ways to view the messages. On the PC208W main tool bar, click the Status button. The lower right part of the Status window has a button labeled "View Messages". Click the View Messages button. The message window lists all events. The Status window has a check box to allow these messages to be logged to disk. The log file is a text file.

One possible error message is "RF1 Failed to Get Attention." This message indicates PC208W cannot communicate with the RF310M modem. Check the following items:

1. RF310B Base Station plugged into computer and wall outlet?

2. RF310B Power Switch turned on?

3. Has PC208W been set up correctly?

4. Is the proper COM port specified in the Setup window?

5. Is the SC12 9-pin cable inside the RF310B connected from the small circuit board to the RF310M Modem?

6. Is there other software open that uses a COM port?

Another possible error message is "CR10X_1 Failed to Connect" (where "CR10X_1" is the station name). If this message is given without the previous message, "RF1 Failed to Get Attention", PC208W did connect with the RF modem but not the datalogger. In this case, check the following items:

1. Are the radios plugged in to the RF modems?

2. Are the radios connected to power?

3. Verify that nothing but an RF modem is connected to the datalogger's 9-pin connector.

4. Are Station IDs set properly in the RF Modems?

5. Is the RF Path in the Setup Window correct?

6. Are the antennas oriented correctly?

7. Check all antenna cable connections.

8. Turn radio off. Unplug the SC12 9-pin cable from the RF310M in the RF310B, reconnect the SC12 cable and watch the carrier detect light. Does the light stay on for one second, off for one second, on for one second, and then off? If not, the RF310M could have bad RAM or ROM. Also check the field/repeater station modems.

9. Is the field station datalogger turned on and does it have sufficient power?

VERIFY NEXT ERROR MESSAGE

The error message "RF Modem Does Not Respond" can occur if communication is not returned to the base station. Check the following items:

1. Are all RF Modems connected to radios and dataloggers?

2. Are the antennas oriented properly?

3. Is the SDC switch open?

4. Is the proper COM port being specified?

2.5.3 Troubleshooting with the Terminal Emulator

A general understanding of the communication sequences is necessary to properly trouble-shoot an RF link. The base station RF modem (RF310M) is called the Start Of Link modem, or SOL modem. The field station RF modem is called the End Of Link modem, or EOL modem. When powered up, the SOL modem immediately goes into a Wait Mode. The RF310M Modem has five different modes of operation; these are described in Section 3 of this manual.

PC208W, Connect window has two tabs: Tools and Terminal Emulator. With the Tools tab active, select the datalogger of interest in the "Station List". Select the "Terminal Emulator" tab. Once in the Terminal Emulator window, select "Open Port". Terminal Emulator allows you to send individual commands to each device in the communication path. This will allow you to test each piece of the communication path separately.

Try the following TASKs in order.

TASK A, Contact RF310B: Press [ENTER] a few times, to set the baud rate between the Base Station's RF modem and the computer. This baud rate can be set at 300, 1200, or 9600 baud. The RF310M will detect the computer's baud rate and match it.

RESPONSE IF SUCCESSFUL: "!" prompt given, SOL modem is now in the Local Command Mode. This is where PC208W is communicating with the RF310B base station.

If TASK A is unsuccessful, check:

1. Communication port (COM port) could be configured improperly, computer setup.

2. The wrong COM port may be specified in the Station File, PC208W setup.

3. Communication cable may be connected to the wrong port. Use the correct serial port, not the parallel port.

4. Computer mouse driver could be interfering with COM port.

5. The base station or radio may not be powered sufficiently.

6. The radio and RF modem may not be connected properly.

7. Communications cable between computer and RF310B must be standard RS-232 cable.

TASK B: Task A must be successful before Task B can be tested. To test the RF link; enter the 'RF Path' at the "!" prompt. For example, "S5 8F" communicates to a field station with a Station ID of 8 through a repeater with an ID of 5. After typing the 'RF Path', press [ENTER].

RESPONSE IF SUCCESSFUL: "$" prompt given. The dollar sign prompt is returned by the EOL modem. The "$" indicates you are now communicating with the modem at the field site.

Things to check if TASK B is unsuccessful:

1. Improper antenna orientation.

2. Bad connections on the antenna cables, or improper antenna cables.

3. Insufficient current supply at the base station. Is AC power good?

4. Field station radio is not connected to power or power supply is weak.
    Check battery voltage under load, should be no less than 11.7 volts.
    Battery voltage no load and no charging source should be about 12.4 volts.

5. Field station radio and RF modem may not be connected properly. Check
    cable.

6. Field station RF modem is not receiving 5 Volts from datalogger
    connection on pin 1 of the 9-pin cable. The RF modem must be connected
    to the datalogger Serial I/O or CS /IO port with a straight through cable,
    SC12.

7. Using wrong RF path. Are the RF310M dip switches set correctly?

TASK C: Establish link and baud rate between RF Modem and Datalogger by
slowly pressing [ENTER] a few times. Pause about 2 seconds between each
press of the enter key.

RESPONSE IF SUCCESSFUL: "*" from datalogger. The Asterisk prompt
indicates the datalogger is now communicating with the computer at the base
station.

Things to check if TASK C is unsuccessful:

1. Datalogger is on and has sufficient power.

2. Datalogger does not think it is still communicating with some other device
    like a CR10KD keypad or phone modem.

3. Datalogger and RF Modem are the only devices connected together on the
    9-pin connections.

Upon successful completion of TASK C, the datalogger is now in standard
Telecommunications Mode. See Section 5 of the datalogger manual for more
information about the Telecommunication mode. At this point the SOL modem
and EOL modem will be in the Transparent Mode of operation. Type "A," wait
2 seconds, and then type [ENTER] to receive a status sequence from the
datalogger. If everything is successful, type "E" to drop the link. If task C is
successful, PC208W should be able to call the field site.

Section 3. Radiotelemetry Network Components

3.1 RF310M Modem

The RF310M is an interface between the computer and the radio when used at a base station, and an interface between the radio and the datalogger at a field station. In a repeater station, the RF310M is an interface between two other communication stations. The RF310M is an RF modem. PC208W will refer to the RF310M as either "RF Modem" or "RF95".

3.1.1 Physical Description

The front panel of the RF310M is shown in Figure 3-1. There are two ports for interfacing external devices. The port labeled TRANSCEIVER connects to the radio, and the port labeled SERIAL I/O connects to the datalogger. In the case of a repeater or phone-to-RF base station, The SERIAL I/O port will connect to the PS512M or CH512R null modem port. The red light labeled CARRIER DETECT is used primarily to indicate when a carrier frequency has been detected by the radio.

3.1.2 RF310M States

The RF310M Modem operates in one of two separate states. The RF310M can be utilized in either the RF310M-ME (Modem Enable) state or the RF310M-SDC (Synchronous Device Communication) state. The proper state must be determined before employing the RF310M in the field. A switch inside the RF310M needs to be set accordingly.

The RF310M-ME state is ALWAYS used with 21X and CR7 dataloggers. The RF310M-ME state is NORMALLY used with all dataloggers. SDC compatible dataloggers (CR10, CR10X, CR23X, CR510, and CR500) can also use the RF310M-SDC state. The SDC state has the advantage that a phone-to-RF base station can have measurement capability. Only the RF310M at a phone-to-RF base station with measurement should to be switched to the RF310M-SDC state.

A switch with nine different dip switches is inside the RF310M; the RF310M cover must be removed to locate the switch. The ninth switch sets the RF310M state. The RF310M-ME state is chosen by setting the ninth dip switch open, represented by 1. The RF310M-SDC state is chosen by setting the ninth dip switch closed, represented by 0. Refer to Figure 3-2.
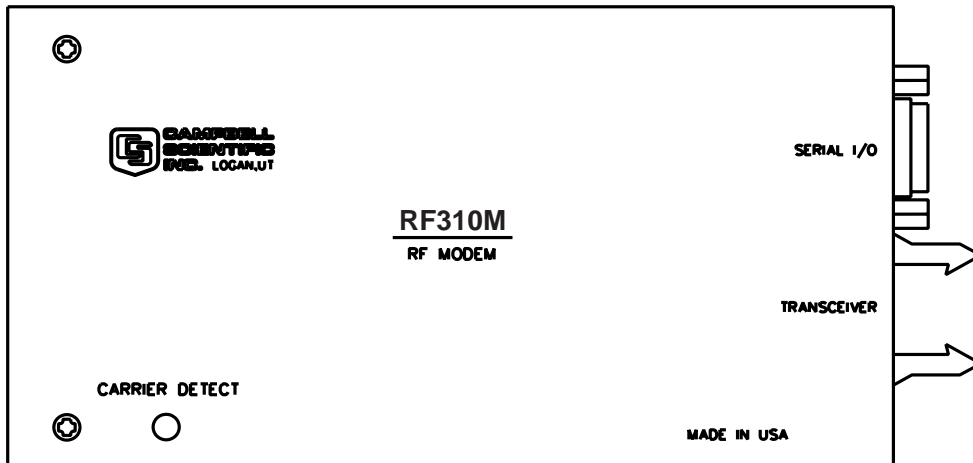
FIGURE 3-1. The RF310M Modem

TABLE 3-1. A Sample of Station ID Numbers and the Corresponding Switch Settings		
Station ID	Switch Settings 1234	56789
0	0000	0000X
10	0101	0000X
20	0010	1000X
30	0111	1000X
40	0001	0100X
50	0100	1100X
60	0011	1100X
70	0110	0010X
80	0000	1010X
90	0101	1010X
100	0010	0110X
110	0111	0110X
120	0001	1110X
130	0100	0001X

*Station ID 255 is reserved for phone-to-RF base stations.

The RF310M is shipped with the switch set for the RF310M-ME state and station ID of 1.

3.1.3 Setting Station ID

Each RF310M, including the one in the RF base station, must have a unique Station ID. The station ID is similar to a phone number. This allows one base station to communicate with any one particular field station.

The Station ID can be any number from 1 to 255. The Station ID is set with the switch inside the RF310M. The first eight dip switches are used to set the Station ID. Table 3-1 shows the switch settings for several Station ID numbers. Appendix A shows all possible Station ID numbers. The dip switches can

either be open, represented by 1, or closed, represented by 0; X in Table 3-1 refers to "don't care." The ninth dip switch is set according to the desired RF310M state, see Section 3.1.2 "RF310M States." The RF310M is shipped with a Station ID of 1 and are set in the RF310M-ME state. The RF310M inside the RF base station (RF310B) is shipped with a station ID of 254 and RF310M-ME state.
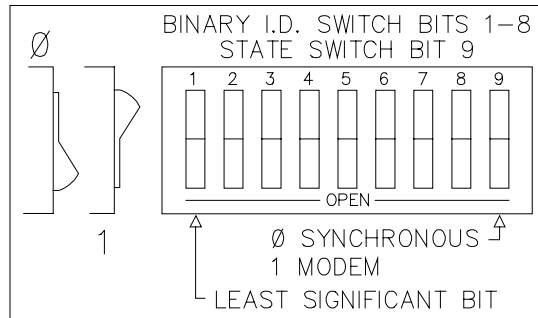
FIGURE 3-2. Setting the Station ID

3.1.4 The Carrier Detect Light

The Carrier Detect light on the front panel of the RF310M has several purposes. The primary function of the light is to indicate when data is being received or transmitted. The light will stay on when a network frequency originating from another RF310M is detected. If a signal is detected which isn't intended for that station, the light will shut off after about two-tenths of a second.

The Carrier Detect light can also be used to check the RAM (Random Access Memory) and ROM (Read Only Memory) of the RF310M. With the radio disconnected and the datalogger in the LOG (*0) Mode, connect the datalogger to the RF310M CS I/O Port with a 9-pin cable. The sequence of the light flashing after connection indicates the RAM and ROM status.

Both the RAM and ROM are good if the light goes on for one second, off for one second, and then back on for one second. The RAM is faulty if the light is on for one half second and off for one half second, continuously. The ROM is faulty if the light goes on for one second, off for one half second, on for one half second, and then off for one half second, continuously.

3.1.5 Data Transfer Rate

The data transfer rate is the time it takes to get data from the datalogger to the computer. In general, data can be transferred at a rate of about 30 data points/second (60 bytes/second) without a repeater. If a repeater is used, an approximate data transfer rate is 22 data points/second.

3.1.6 RF310M Modem Communication Protocol

Comprehension of this section is not necessary for routine operation of the RF310M Modem. The PC208W Datalogger Support Software accounts for the necessary communication protocol.

There must be an RF310M Modem at both the calling (or computer) end of the transmission link, and at the answer (or datalogger) end of the transmission link. The modem at the calling end is the Start Of Link (SOL) modem, and the modem at the answer end is the End Of Link (EOL) modem.

RF310M Modems must also be used at repeater stations. These RF310M Modems are termed Middle Of Link (MOL) modems.

The RF310M Modem has five general modes of operation:

- Wait Mode

- Local Command Mode

- Repeater Mode

- End of Link Mode

- Transparent Mode.

The RF310M is in the **Wait Mode** of operation when it is waiting to enter one of the four other modes of operation. The Wait Mode is entered 1) after the power-up sequence is completed, 2) following the "T" command when in the Local Command Mode, and 3) when the system is reset by the Time-out Timer. The Time-out Timer is a 60-second timer which is set every time a valid transmission block is received on the RF link. The datalogger, being in Telecommunications Mode, will override the Time-out Timer.

The **Local Command Mode** is used to set up and shut down an RF link. The Local Command Mode is entered when the datalogger goes into Telecommunications Mode after being in the Wait Mode. In this mode the RF310M responds to command characters received on the Serial I/O port.

The RF310M is in the **Transparent Mode** after the RF link has been established. In the Transparent Mode, any data received on the Serial I/O port are organized into data blocks for transfer through the RF link.

The **Repeater Mode** is entered by MOL RF310M Modems. The function of the Repeater Mode is to receive and then transmit data blocks. The signature of each data block is checked before being sent to the next RF station. The block is discarded if the signature of the data block is incorrect. The RF310M enters the Repeater Mode when it receives a valid setup block that sets the RF310M as a repeater.

The **End Of Link Mode** is entered when the RF310M receives a valid setup block that sets the RF310M as the EOL modem. Upon entering the EOL Mode, the RF310M brings the Serial I/O Ring line high which raises the datalogger ME line, thus causing the RF310M to enter the Transparent Mode. The Ring line is reset after the ME line comes high.

3.1.7 RF310M Modem and the RF Link

The RF link is the communication path which is opened between the Start Of Link modem and the End Of Link modem, along with any Middle Of Link modems. Any RF link must first be established, then maintained, and finally shut down.

When collecting data, PC208W establishes, maintains, and shuts down the RF link as discussed below.

3.1.7.1 Establishing the RF Link

The SOL RF310M is first brought into the Local Command Mode of operation. In the RF310M-ME State, this is done when the ME line is high on the Serial I/O port and the SOL modem is in the Wait Mode of operation. After the ME line is brought high, the baud rate of the SOL modem is set by repetitively pressing [ENTER]. The SOL modem can operate at 300, 1200, or 9600 baud. When the baud rate is set, the SOL modem will respond by sending a carriage return line feed (CR-LF) and an exclamation point (!). In the RF310M-SDC State, the Local Command Mode is entered after addressing. Some explanation is contained in Appendix E "RF310M States."

In the Local Command Mode, the SOL modem responds to command characters received from the terminal or computer. The command characters are summarized in Table 3-2. All command characters must be capital letters.

TABLE 3-2. RF310M Command Character Summary	
Command	Description
E	Exit Link Command. The "E" command causes the datalogger to drop its ME line and shut down the RF link.
F	Fast Command. The "F" Command is placed at the end of the string of setup numbers. In the RF310M-ME State, the Serial I/O port of the EOL modem will communicate with the datalogger at 9600 baud with the "F" Command. In the RF310M-SDC State, the baud rate from the computer to the SOL modem will be 9600.
R	Read Command. The "R" Command reads back the Shutdown Block.
S	Link Setup Command. The Link Setup Command is followed by a string of setup numbers representing the ID numbers of the modems in the RF link.
T	Terminate Command. The "T" Command will reset the SOL modem to the Wait Mode of operation.
W	Wait Command. The "W" Command will force the RF modem to wait until there is no carrier detect before transmitting.

The first step in setting up an RF link, once in the Local Command Mode, is to create a setup block using the "S" command. The setup string is entered via the computer as follows:

Sxxx yyy

where:

xxx = ID number of the RF310M which is acting as the repeater in the link. If no repeater is used then xxx is omitted.

yyy = ID number of the EOL modem.

xxx and yyy are numbers from 1 to 255, inclusive. The user can have up to 12 repeaters in any RF link. Example 3-1 shows the setup block for an RF link which will communicate through three repeaters to an EOL modem, with Station ID numbers of 10, 25, 50, and 30, respectively. The Fast Command is used to speed data transfer.

EXAMPLE 3-1. A Sample Setup Block

S10 25 50 30F

Notice that it is not necessary to include the station ID of the SOL modem.

Press [ENTER] following the setup string of station IDs to transmit the setup block. When the RF link is established, a verification block is sent from the EOL modem to the SOL modem. Upon receiving this verification block, the SOL modem and EOL modem have entered the Transparent Mode of operation. At this point, the dollar sign prompt "$" will be returned to the computer screen. The datalogger connected to the EOL modem is now in the Telecommunications Mode and will respond to the standard datalogger telecommunications commands. If the verification block does not return shortly, pressing [ENTER] will cause the SOL modem to return to the Local Command Mode.

3.1.7.2 Maintaining the RF Link

Data can be transferred once the RF link is established. Data blocks are created and transmitted by the SOL and EOL modems according to the following two rules. First, characters received on the Serial I/O port are placed into data blocks of 238 characters each. The block is then closed and transmitted. Any remaining or new characters received at this point are placed into a new data block. Second, if during this loading process a delay of 290 ms occurs between characters, the data block will be closed and transmitted.

Most of the time, the SOL modem will be sending command strings which will be answered by the EOL modem and the datalogger. The response from the datalogger is not instantaneous. If a command is sent before the response from the previous command has been received, the current command will be sent and a possible collision of the RF signal may occur. This results in a loss of the response and the current command. The general rule is that the person sending characters should wait for the response to come back before issuing further commands.

3.1.7.3 Shutting Down the RF Link

Sending the "E" character to a datalogger causes the datalogger to drop its ME line, which causes a shutdown of the RF link.

A shutdown block is created by the EOL modem which can be sent to the computer as an indicator of communication quality. The shutdown block consists of three RF Link Quality Accumulators (RLQA). Each RF310M in the link will have three RLQAs which are appended to the shutdown block. The RLQA from each RF310M are representative of the active period of the link. The first three RLQAs represent the EOL modem connected to the datalogger, the following sets of numbers will be for any MOL modems (in order of occurrence from the EOL modem), and last will be the SOL modem. A description of the shutdown block is contained in Table 3-3.

TABLE 3-3. Summary of the Shutdown Block

xxxx yyyy zzzz

xxxx	=	Number of communication failures.
yyyy	=	Noise level indicator.
zzzz	=	Noise level indicator.

A communication failure occurs when a signature of a block of data doesn't match its original signature. These blocks are subsequently retransmitted. The noise level indicators should be 102 ($\pm$70) at the standard 3.0K baud rate, or 124 ($\pm$70) at 2.4K baud.

The noise level indicators are reset and subsequently become active in the respective EOL and SOL modems as the Transparent Mode is entered (immediately after setup). The MOL modems are reset and become active when the setup block is propagated to the next station in the RF link.

After the "E" character is received by the datalogger a CR-LF is sent through the RF link to the SOL modem. The shutdown block follows after a one second delay. When the shutdown block is received and verified the SOL modem will leave the Transparent Mode and re-enter the Local Command Mode, indicated by sending an exclamation point (!) to the computer.

The shutdown block can be viewed by sending the "R" command. Example 3-2 illustrates a shutdown block for three RF95s.

EXAMPLE 3-2. Sample Shutdown Block

!R

EOL modem - >	0004 0110 0097
MOL modem - >	0002 0108 0090
SOL modem - >	0000 0105 0093
!	

The first line of numbers, which are the first three RLQAs, represent the EOL modem. The second line represents a MOL modem, and last is the RLQAs for the SOL modem. The 0004 indicates that four interruptions occurred on the EOL modem while the link was active. Interruptions are non-data blocks such

as voice transmissions on the same carrier frequency. All noise level indicators are within acceptable bounds in this example.

The "T" command should now be used to reset the SOL modem to the Wait Mode of operation. This step should not be done if further calls are going to be made through a phone modem.

3.1.8 RF310M Connections

The 9-pin Serial I/O connector is normally used to connect the RF310M to the datalogger, PS512M or CH512R. Table 3-4 describes the 9-pin connections. The 10-pin rectangular connector is for connection to the transceiver.

TABLE 3-4. RF310M Serial I/O to Datalogger Connector Description

Pin	Description
1	+5 V: Supply from external source
2	GND: Ground
3	Ring: Ring to datalogger
4	RXD: Transmit from RF310M
5	ME: Modem Enable from datalogger
6	Printer Enable: Not used
7	Unload Enable: Not used
8	Tape Enable: Not used
9	TXD: Received by RF310M

3.2 RF310 Radios

3.2.1 Radio Description

The RF310 and RF312 radios are compatible with the RF310M RF modem and the RF310B base station. The RF310 and RF312 radios differ only in the carrier frequency range. The RF310 is a VHF radio and the RF312 if a UHF radio. References to the RF310 generally apply to the RF312.

The RF310 is used in Campbell Scientific's RF applications to transmit and receive data blocks. The radios are shipped from Campbell Scientific secured on a mounting bracket designed to fasten on the top of the RF modem (see Figure 3-3).

The mounting bracket also supports a BNC Jack connector from the radio. The coax cable that is required to connect the radio to its antenna should be connected to the radio at this BNC connector. See Section 3.3 for more information on the antenna cable.

The RF310 Radios are connected to the RF modem by a special radio cable. The 9-pin connector has a red and black wire coming out of the connector. The 9-pin connector should be connected to the radio. The red and black power wires should be connected to 12V and Ground respectfully. The 10-pin connector should be connected to the RF modem.

3.2.2 Radio Specifications

The RF310 radios are manufactured by Maxon Data Telemetry. See the Appendix section for radio specifications.
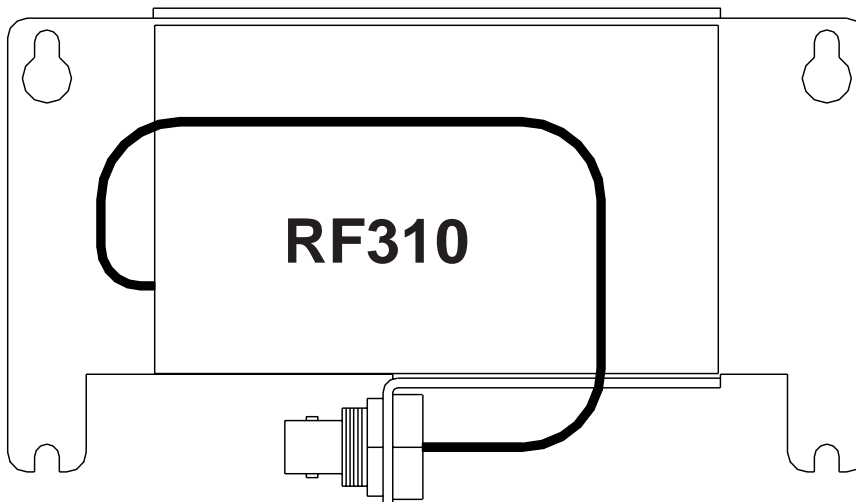
FIGURE 3-3. RF310 On Bracket With Connector

3.2.3 Radio Installation

The RF310 Radios are shipped from Campbell Scientific mounted on a special bracket with a cable going from the radio to a BNC connector (see Figure 3-3). The following steps will install a radio for a field or repeater station. Power should be off before installing radios.

1. Secure the radio and its bracket to the RF310M using screws from the RF310M Modem's lid.

2. Connect the 9-pin connector (with the red and black power leads coming out of it) of the radio/RF modem cable into the radio.

3. Connect the 10-pin connector of the cable into the RF modem.

4. Connect the red and black power leads from the radio cable to the 12V and Ground.

5. Route the BNC end of the antenna cable through the enclosure conduit. Connect the cable to the BNC Jack connector secured on the radio mounting bracket.

3.3 Antennas and Cables

Antennas radiate and receive the radio signals. Each radio in an RF telemetry system must have an antenna. Coax cable is used to connect the antenna to the radio.

3.3.1 Antenna Mounts

Antennas must be mounted above any surrounding buildings or obstacles. Antennas must be properly oriented in relationship to the other antennas for RF communications to work. Antennas have various mounting options. Table 3-7 lists mounting specifications for several common Celwave antennas. Specific questions regarding antennas can be directed to Campbell Scientific, Inc. or Celwave. Celwave's address and phone numbers are:

> Celwave
> Route 79
> Marlboro, NJ 07746
> (908) 462-1880 or (800) 321-4700
> FAX (908) 462-6919

3.3.2 Antenna Orientation

Antennas must be oriented correctly to allow communication between RF sites. First determine if your antenna is omnidirectional or unidirectional.

An omnidirectional antenna will transmit/ receive in a full 360 degree circle. Generally, an omnidirectional antenna will be a straight cylindrical rod which is to be mounted vertically at the top of a tripod.

A unidirectional antenna is designed to transmit/receive in a particular direction, or in a specified sector. There are various shapes of unidirectional antennas. The most common is the Yagi antenna (see Figure 1-2). The elements of a Yagi antenna can be mounted either vertically or horizontally, corresponding to either vertical or horizontal polarization.
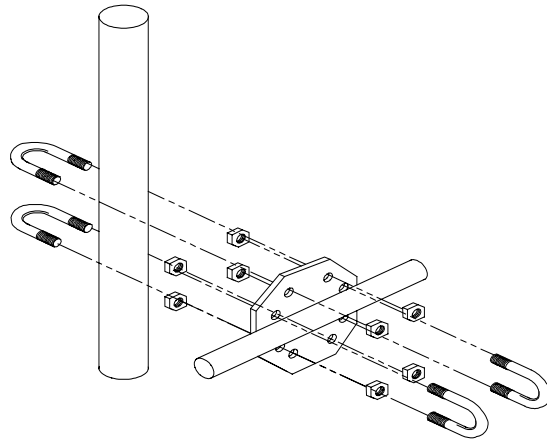
FIGURE 3-4. The PD237 Crossover Plate Antenna Mount

Normally, all antennas will be mounted with vertical polarization. Whichever polarization is used, be sure to keep antennas at all sites identically polarized.

3.3.3 Antenna Cables and Connectors

The most common cable type to connect a radio to the antenna is a coaxial RG-8A/U cable. Two connectors are required for each length of cable. The connector for the radio is a BNC type connector. The connector for the antenna is usually either a Type-NM or Type-NF. The BNC, Type-NM, and Type-NF connectors are shown in Figure 3-6. The Type-NM (male) connector is for antennas with a female receptacle, and Type-NF (female) for antennas with male receptacles.

A Campbell Scientific antenna cable complete with connectors is specified as either COAX NM-L or COAX NF-L. COAX NF-L is a coaxial RG-8A/U cable with a BNC connector on one end and a Type-NF connector on the other. See Table 3-5 for cable requirements for common antennas.

Due to power loss through the cable, the length of coax cable cannot be extended to any desired length. The amount of power loss is dependent on the radio frequency. RG-8A/U will lose approximately 3.1 dB/100 ft. at 200 MHz and 5.0 dB/100 ft. at 400 MHz. Power loss calculations are reviewed in Appendix C.
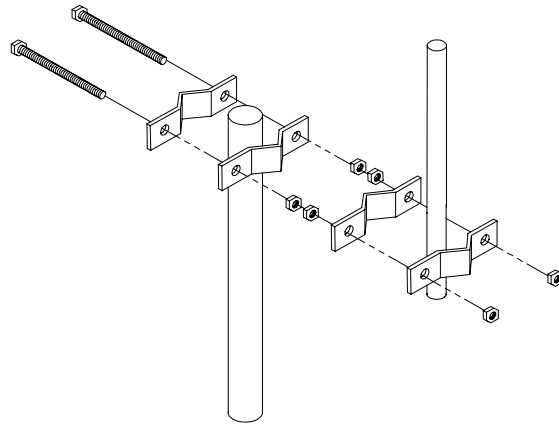
FIGURE 3-5. The PD46 Clamp Mount

TYPE-NM   BNC CONNECTOR   TYPE-NF
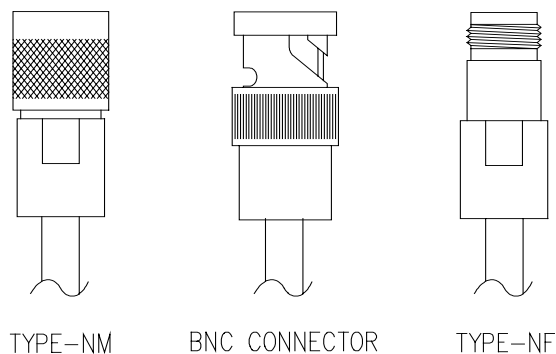
FIGURE 3-6. Type-NM (male), BNC, and Type-NF (female) Connectors

TABLE 3-5. Common Antennas and Characteristics						
Antenna	Type	VHF or UHF	Cable	Gain(dB)	Pipe O.D.	Mounting Type
BA1010	Omni	VHF	Coax NM-L	Unity	3/4" - 2 1/8"	U-Bolts
BA1012	Omni	VHF	Coax NM-L	Unity	1" - 2 1/4"	U-Bolts
BA1312	Omni	VHF	Coax NM-L	3.0	1" - 2 1/4"	U-Bolts
BA6012	Omni	UHF	Coax NM-L	Unity	1" - 2 1/4"	U-Bolts
BA6110	Omni	UHF	Coax NM-L	Unity	3/4" - 2 1/8"	U-Bolts
BA6312	Omni	UHF	Coax NM-L	3.0	1" - 2 1/4"	U-Bolts
PD200	Omni	VHF	Coax NF-L	5.8	1" - 2 3/4"	PD46 (Fig 3-5)
PD201	Omni	UHF	Coax NF-L	5.0	1" - 2 3/4"	PD46 (Fig 3-5)
PD220	Omni	VHF	Coax NF-L	5.25	1" - 2 3/4"	PD46 (Fig 3-5)
PD344	Dipole	VHF	Coax NF-L	4.5	2 1/2"	Clamps
PD390S	Yagi	VHF	Coax NF-L	8.0	1 5/16, 2 1/4, or 2 3/8	PD37 (Fig 3-4)
PD400	Omni	VHF	Coax NM-L	7.5	1" - 2 3/4"	PD46 (Fig 3-5)
PD688S	Yagi	UHF	Coax NF-L	10.0	1 5/16" - 2 1/4"	U-Bolts
PD1107	Omni	VHF	Coax NF-L	3.0	1" - 2 3/4"	PD46 (Fig 3-5)
PD1121	Dipole	VHF	Coax NF-L	3.0	2 1/2"	Clamps

3.4 Tripods, Towers, Enclosures, and Power Supplies

There are several methods of mounting and housing sensors and other equipment for a station.

3.4.1 Tripods and Towers for Mounting

For the different mounting requirements, Campbell Scientific offers the CM6 Tripod, CM10 Tripod, UT10 Tower, and UT30 Tower. All mounting options available from Campbell Scientific are rugged instrument mounts that provide sturdy support for Campbell Scientific sensors, enclosures, and measurement electronics. The CM6 and CM10 Tripods can be used as a portable instrument mount in a variety of applications. The UT10 and UT30 Towers provide a more sturdy long-term support.

3.4.2 Enclosures

Enclosures are needed to keep water and debris from damaging the data acquisition equipment. Campbell Scientific, Inc. enclosures are designated as "rain-tight," and are designed to mount to a tripod or tower. Following is a description of the standard enclosures.

3.4.2.1 CR10X and CR23X Enclosures

Campbell Scientific offers two enclosures for housing a CR10X or CR23X and peripherals. The fiberglass enclosures are classified as NEMA 4X (water-tight, dust-tight, corrosion-resistant, indoor and outdoor use). A 1.25" diameter entry/exit port is located at the bottom of the enclosure for routing cables and

wires. The enclosure door can be fastened with the clasp for easy access. The enclosure's clasp door can be secured with a basic lock. Both enclosures are white for reflecting solar radiation, reducing the internal temperature.

The Model ENC 12/14 fiberglass enclosure houses the CR10X and power supply, and one or more peripherals. Inside dimensions of the ENC 12/14 are 14" x 12" x 5.5", outside dimensions are 18" x 13.5" x 8.13" (with brackets); weight is 11.16 lbs.

The model ENC 16/18 fiberglass enclosure houses the CR10X or CR23X and power supply, and two or more peripherals. Inside dimensions of the ENC 16/18 are 18" x 16" x 8.5." Outside dimensions are 21.75" x 21" x 11" (with brackets); weight is 17.2 lbs.

3.4.2.2 CR7 Enclosures

Most CR7 radiotelemetry applications have special needs depending on the individual system. The ENC-24 is normally used in CR7 RF applications. Contact Campbell Scientific's customer service department for special applications.

3.4.3 Power Supply

A radiotelemetry network requires a reliable power supply at each station. A solar panel or 110/220 VAC charging source is normally required due to the large current drain of the radio.

3.4.3.1 Lead Acid Batteries

Lead acid batteries are designed to be float charged by a solar panel or AC power source. The role of the lead acid battery is to supply power when the charging source is absent, e.g., in case of power failures (AC charging), or during times of zero charge with a solar panel.

21XL and CR7 lead acid batteries do not have the required capacity for a typical RF station, they are only 2.5 Amp-hour batteries. Generally, we recommend a minimum of 7 Amp-hour batteries for RF applications.

3.4.3.2 PS12LA Lead Acid Power Supply

The PS12LA power supply includes a 12V, 7.0 Amp-hour lead acid battery, AC transformer, and a temperature-compensated charging circuit with a charge indicating diode. An AC transformer or solar panel should always be connected to the PS12. The charging source trickle charges the lead acid batteries which power the datalogger. The internal lead acid battery continues to power the datalogger if the charging source is interrupted. The PS12LA specifications are given in Table 3-6.

The two leads from the charging source should be inserted into the CHG ports, polarity doesn't matter. A tranzorb provides transient protection to the charging circuit. A sustained input voltage in excess of 40V will cause the tranzorb to limit voltage.

Some solar panels are supplied with a connector. This connector must be clipped off so the two wires can be inserted into the two terminal ports.

The red charge light is on when AC power or a solar panel is connected to the PS12. If the input voltage is high enough, the battery will charge even when the datalogger is on.

CAUTION	Switch the power to OFF before disconnecting or connecting the power leads to the Wiring Panel. The Wiring Panel and PS12LA are at power ground. If 12V is shorted to either of these, excessive current will be drawn until the thermal fuse opens.

The external port, labeled EXT, is not meant to be used with the PS12LA. The primary power source is the charging source, and the secondary power source is the internal lead acid battery. Connecting a lead acid battery to the external source is the same as connecting two lead acid batteries in parallel, causing one battery to drop voltage and the other to raise voltage. Alkaline batteries connected to the external port would be charged by the charging source, which can cause an explosion.

CAUTION	Never connect more than one battery to the PS12LA.

Monitor the power supply using datalogger Instruction 10. Users are strongly advised to incorporate this instruction into their data acquisition programs to keep track of the state of the power supply. If the system voltage level consistently decreases through time, some element(s) of the charging system has failed. Instruction 10 measures the voltage of the lead acid battery. External power sources must be disconnected from the CR10 and charging circuit in order to measure the actual lead acid battery voltage.

TABLE 3-6. PS12LA Battery and AC Transformer Specifications

Lead Acid Battery

Battery type	Yuasa NA 7-12
Float life @ 25°C	5 years typical
Capacity	7.0 Amp-hour
Shelf life, full charge	Check twice yearly
Charge time, (AC Source)	40 hr. full charge 20 hr. 95% charge

AC Transformer

Input:	120V AC, 60 Hz
Isolated output:	18V AC @ 880 mA max.

3.4.3.3 PS512M Voltage Regulator with Null Modem Ports

The PS512M 12 Volt Lead Acid Power Supply with Charging Regulator and Null Modem Ports is used when 5 Volts is needed to power external modems besides the capabilities of the PS12LA. The PS512M supplies 5 Volts to pin 1 of the 9-pin null modem ports, otherwise the capabilities and functions are identical to the PS12LA. A common use for the PS512M is in radiotelemetry

networks. The PS12LA cannot be modified to the PS512M. The maximum current drain on the 5 Volt supply of the PS512M is 150 mA.

3.5 RF310B Base Station

3.5.1 RF310B Introduction

The RF310B Base Station provides a "single box" desktop base station with the following features:

- Internal RF modem.

- 25-pin RS-232 port for connection to IBM PC.

- 110 VAC/12 VDC transformer and mount for the base radio.

- Easy access to radio for antenna cable connection.

The RF310B Base Station includes an RF Modem with a carrier detect light. The RF Modem sits directly behind the RF310B front panel. For a description of the Carrier Detect Light and the communication protocol, refer to Section 3.1. The RF Modem comes shipped from the factory with a Station ID number of 254. Under most circumstances there is no need to change this address.

The RF310B 25-pin female port connects to the computer RS-232 port. The computer RS-232 port may be either 9 or 25 pin. The RF310B's 25-pin port is configured as Data Communications Equipment (DCE) for direct cable connection to Data Terminal Equipment (DTE), such as an IBM-PC serial port. Table 3-7 shows the pin description.

3.5.2 220, 230, and 240 VAC Conversion

The RF310B can be used with 220, 230, or 240 VAC if a small wiring modification is done.

1. First, disconnect any AC power!

2. Lift the cover off the RF310B and locate the power supply (P/N 4918) as shown in Figure 3-8.

3. Unscrew the four Phillips head screws on top of the power supply and turn the power supply upside down.

4. Clip the wire ties holding the power supply leads to the base.

5. With the power supply on its back, locate pins 1 through 5. The power supply is shipped from the manufacturer configured for 120 VAC with pins 1 and 3 jumpered, pins 2 and 4 jumpered, and AC power coming onto pins 1 and 4. These connections must be desoldered.

6. Resolder the pins as shown in Table 3-8 for the Power Conversion you require.

TABLE 3-7. Pin Description for RF310B 25-Pin Port		
Pin	I/O	Description
1	–	Ground
2	I	TX
3	O	RX
4	I	RTS
20	I	DTR
22	O	RING

TABLE 3-8. RF310B Power Conversions		
	Pins Jumpered	Apply AC
110 VAC	1-3, 2-4	1-4
120 VAC	1-3, 2-4	1-4
220 VAC	2-3	1-5
230 VAC	2-3	1-4
240 VAC	2-3	1-4
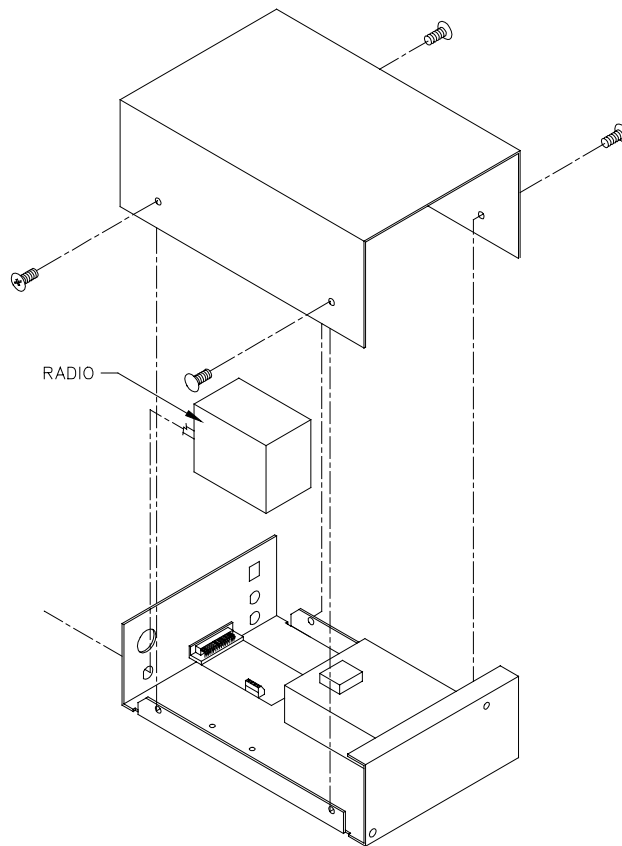
FIGURE 3-7. The RF310B Base Station

RF310B TOP VIEW

PCB P/N 4971

RADIO

12V

POWER SUPPLY
P/N 4918

RF95A
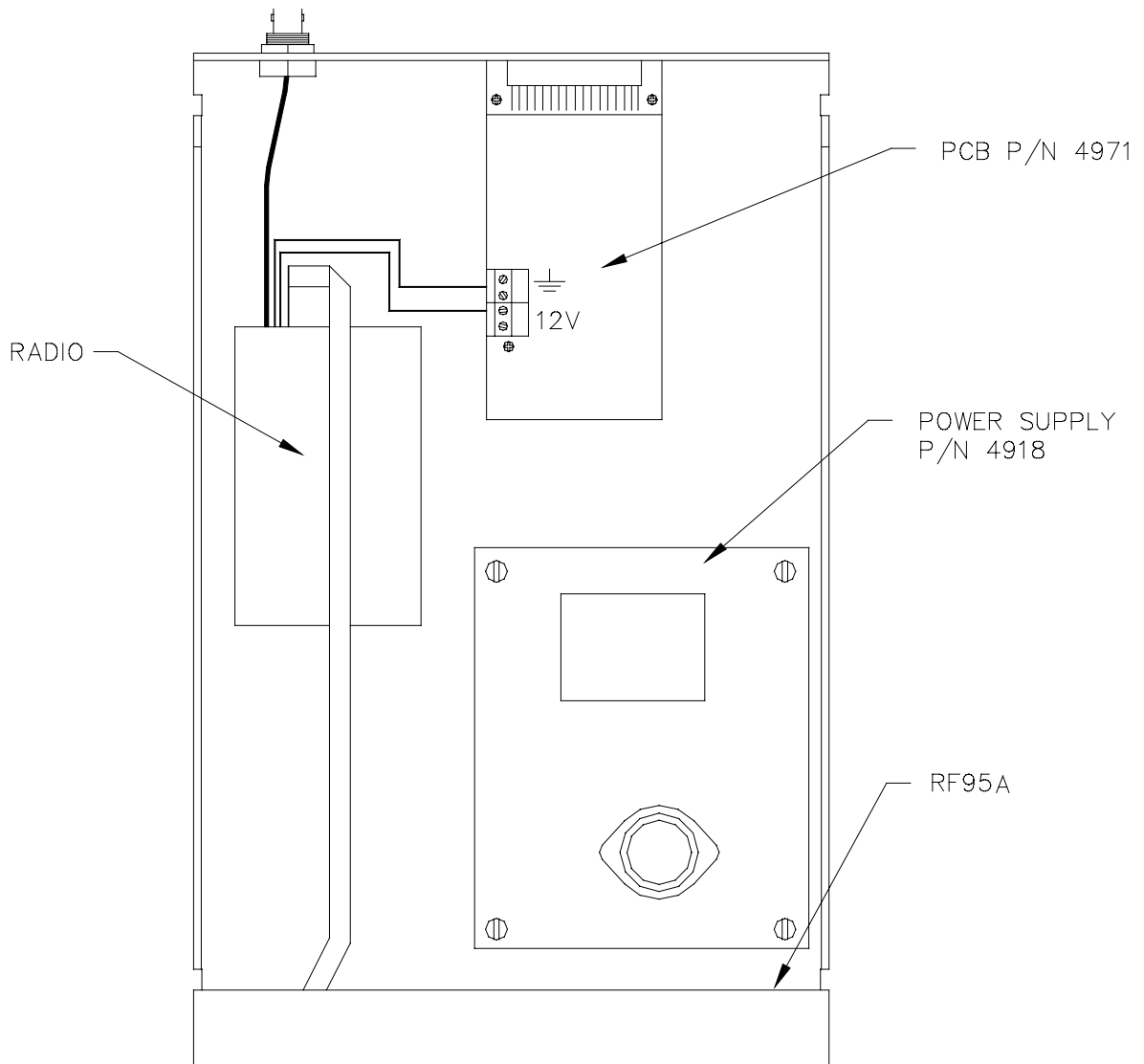
FIGURE 3-8. Top View of the RF310B Base Station

Section 4. Operation of the Radiotelemetry Network

All field stations can be accessed and monitored from the central base site. Regular visits to the field sites are required to ensure that all sensors are in place, enclosures are dry, solar panel is clean, and that the tripod and antenna are secure. Frequency of visits to the field sites are variable depending on environmental conditions and the sensors utilized.

This section of the manual includes a description of the PC208W Datalogger Support Software as it applies to RF applications, as well as a description of some special RF applications.
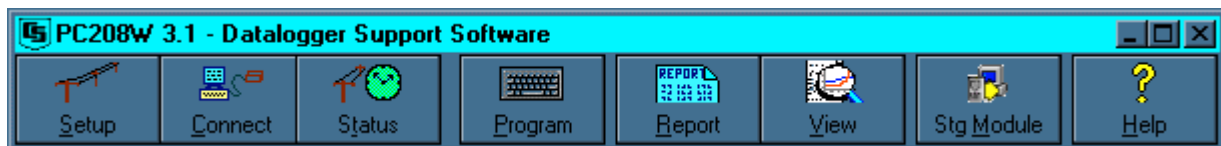
FIGURE 4-1. PC208W Main Tool Bar

4.1 Monitoring and Collecting Data - PC208W RF Notes

The PC208W Datalogger Support Software is the key to communicating with the field stations. Complete information on the PC208W Software is included in the PC208W Manual. This section gives a brief description of software setup, specific RF application notes, and data collection methods.

4.1.1 Basic Concepts

PC208W is designed to use a unique communication path for each datalogger field site. Setup communication parameters and a communication path for each datalogger you will service. In the Setup Window of PC208W, see the Device Map. The Device Map shows each communication path. A typical RF communication path will start with the RS-232 port, usually listed as COM1 or COM2. The next item in the typical communication path is the RF Modem, RF310M. After the RF Modem, each datalogger is connected to the RF Modem. The name and address ("Dialed using RF Path") of each datalogger can be changed.

4.1.2 Using PC208W Setup Window

This section covers the basic RF Communications Path. The RF path must be setup for PC208W to communicate with an RF field site. See section 2.2.2 for additional information about the setup window. To create an RF communication path, open the Setup Window of PC208W. Next select the

COM port. If you need an RS-232 port other than COM1, use the "Add COM Port" button. Use the "Add Device…" button to add your RF modem or Phone modem to the COM port. The Add Device button opens the "Add New Device" Dialog box. Once a device is selected the "Attach Selected Device to" box is opened. When adding a device you must attach it to a device in bold lettering. The last device to add is a datalogger. Using the Add Device button, add the appropriate datalogger. The dataloggers are attached to the RF Modem. Many dataloggers can be attached to one RF Modem. If a mistake is made, highlight the mistaken device in the Device Map and use the Delete button.

There are several fields requiring unique settings. PC208W Setup window shows different options based on which device is selected in the Device Map. Select a device by left clicking your mouse on the device. Do not change any settings for the COM port unless you are doing Callback. Select the RF modem, the default name is RF1. Using the "RF Modem Name" box, you can change the name of the RF modem. The "Baud rate" box can be used to change the communication rate between the RF modem and the datalogger. Select 9600 baud for the RF310M RF modems. The datalogger has one setting that must be changed. Select the "Dialed Using RF Path" box and enter the address of the RF310M. The address is the value set with the dip switches inside the RF310M. See Section 3.1.3 for details. An example of a simple RF path is "32F". The 32 is the value of the dip switch settings inside the RF310M. If your datalogger is using a security code, add the code to the "Security Code" box.

4.1.3 Automated Data Collection - PC208W

One feature of PC208W is automated/scheduled data collection. PC208W can be setup to call each station based on time. To setup the scheduler click on the setup button of the main PC208W tool bar. Using the mouse, highlight the datalogger of interest in the device map. If the device map does not have the datalogger listed, you must setup the datalogger including the correct RF path. See Section 2.2.2 of your PC208W manual for details. Using the Schedule tab of the Setup window, set your Calling Interval, Next time to Call, etc. If you have questions concerning a field, press F1 while your cursor is in the field. Figure 4-2 shows the Setup window on the Schedule tab. The current settings show a data collection interval of 7 days, next time to call is October 31 at 10:00 p.m. If this time is in the past, PC208W will start calling when the scheduler is turned on. See the check box next to the datalogger name, the check box is used to turn scheduled data collection on and off.

The Primary Retry Interval is the time between calls when the first call attempt failed. The Retries Using Primary Interval is how many times the software will continue to call when the call fails. The time between each call is the Primary Retry Interval. After the Retries Using Primary Interval are used up, PC208W will go into the Secondary Retry Interval. The Secondary Retry Interval will continue until the call is successful or the scheduler is turned off. The Secondary Retry Interval is usually set to a longer period, such as a day. The Clock Check Interval, is used to set the datalogger clock to match the computer clock. The automatic clock update should be used with caution, computer clocks are notoriously bad. The "After Call Do" box can be used to run data management software after PC208W is finished collecting data. See your PC208W manual for details.
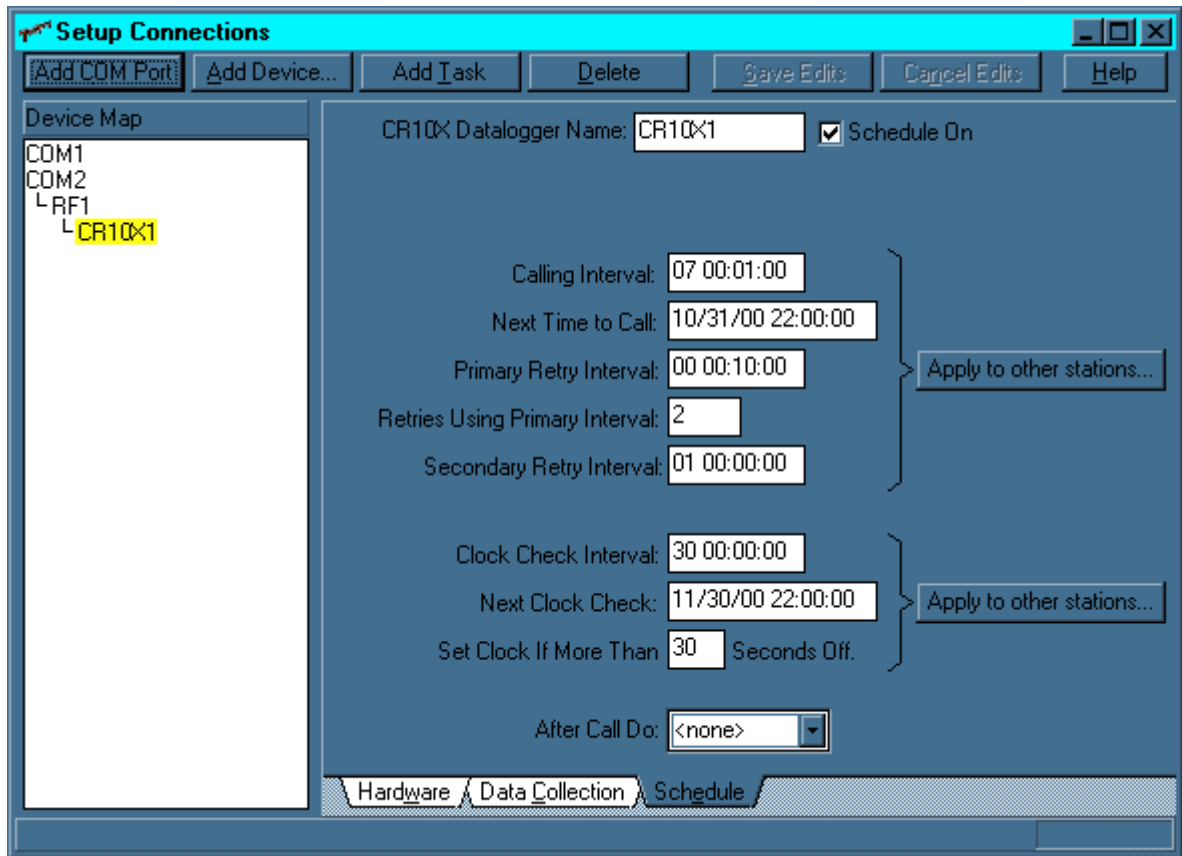
FIGURE 4-2. PC208W Setup Window/Schedule Tab

4.1.4 General Communication - PC208W Connect Window

General communications include: collect data, send and retrieve programs, monitor measurements in real time, graph real time data, etc. PC208W/Connect window supports these general communication tasks. First establish a communication link. This can only be done after the RF communication path has been setup in the Setup Window. To establish a communication link, open the Connect Window. The Connect Window has two tabs along the bottom. First select the tools tab then select the datalogger of interest in the Station List. Using the mouse, click on the Connect button of the Connect Window. The computer is communicating with the datalogger (on line) when the Terminate button changes to Disconnect. With the datalogger on line, the Collect or Collect All buttons will collect data from the datalogger. The Send and Receive buttons will send a program to the datalogger or receive a program from the datalogger respectively. The set datalogger clock button will set the datalogger clock to match the computer clock. The Launch Graphs section has three buttons used to Launch Graphs of real time data. The Numeric Display button will show real time data. See your PC208W manual for details on using PC208W.
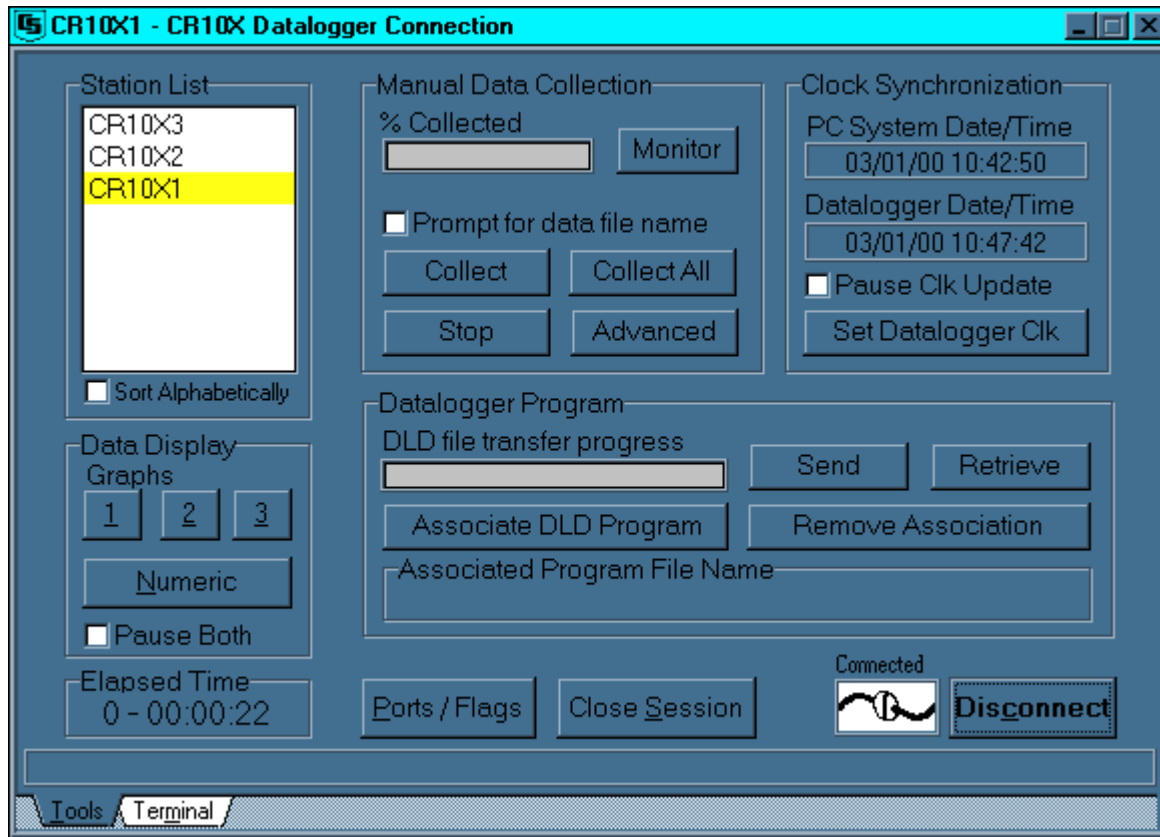
FIGURE 4-3. PC208W Connect Window, Tools Tab

4.2 Datalogger Initiated Communications

The datalogger can call the computer to initiate data collection, sometimes termed "call back." Instruction 97, Initiate Telecommunications, is used for this purpose. Call back is commonly used to initiate data collection under emergency situations (e.g., water level falls below lower limit). Call back is not the preferred method for routine data collection.

The computer must be left on and dedicated to RF communication to implement the call back option. Call back instructions are explained in the datalogger manual. The PC208W Manual explains the use of call back in a telecommunications network.

Appendix A. Setting the Station ID

*Each RF310M, including the one in the RF base station, must have a unique Station ID.
Each RF modem has nine dip switches; the first eight must be set for a particular Station
ID. Following is a list of all possible Station IDs with the corresponding setting of the dip
switches. Here, 1 represents open, 0 is closed, and X is "don't care."*

	SWITCHES			SWITCHES			SWITCHES	
ID	1234	56789	ID	1234	56789	ID	1234	56789
			43	1101	0100X	86	0110	1010X
1	1000	0000X	44	0011	0100X	87	1110	1010X
2	0100	0000X	45	1011	0100X	88	0001	1010X
3	1100	0000X	46	0111	0100X	89	1001	1010X
4	0010	0000X	47	1111	0100X	90	0101	1010X
5	1010	0000X	48	0000	1100X	91	1101	1010X
6	0110	0000X	49	1000	1100X	92	0011	1010X
7	1110	0000X	50	0100	1100X	93	1011	1010X
8	0001	0000X	51	1100	1100X	94	0111	1010X
9	1001	0000X	52	0010	1100X	95	1111	1010X
10	0101	0000X	53	1010	1100X	96	0000	0110X
11	1101	0000X	54	0110	1100X	97	1000	0110X
12	0011	0000X	55	1110	1100X	98	0100	0110X
13	1011	0000X	56	0001	1100X	99	1100	0110X
14	0111	0000X	57	1001	1100X	100	0010	0110X
15	1111	0000X	58	0101	1100X	101	1010	0110X
16	0000	1000X	59	1101	1100X	102	0110	0110X
17	1000	1000X	60	0011	1100X	103	1110	0110X
18	0100	1000X	61	1011	1100X	104	0001	0110X
19	1100	1000X	62	0111	1100X	105	1001	0110X
20	0010	1000X	63	1111	1100X	106	0101	0110X

21	1010	1000X	64	0000	0010X	107	1101	0110X
22	0110	1000X	65	1000	0010X	108	0011	0110X
23	1110	1000X	66	0100	0010X	109	1011	0110X
24	0001	1000X	67	1100	0010X	110	0111	0110X
25	1001	1000X	68	0010	0010X	111	1111	0110X
26	0101	1000X	69	1010	0010X	112	0000	1110X
27	1101	1000X	70	0110	0010X	113	1000	1110X
28	0011	1000X	71	1110	0010X	114	0100	1110X
29	1011	1000X	72	0001	0010X	115	1100	1110X
30	0111	1000X	73	1001	0010X	116	0010	1110X
31	1111	1000X	74	0101	0010X	117	1010	1110X
32	0000	0100X	75	1101	0010X	118	0110	1110X
33	1000	0100X	76	0011	0010X	119	1110	1110X
34	0100	0100X	77	1011	0010X	120	0001	1110X
35	1100	0100X	78	0111	0010X	121	1001	1110X
36	0010	0100X	79	1111	0010X	122	0101	1110X
37	1010	0100X	80	0000	1010X	123	1101	1110X
38	0110	0100X	81	1000	1010X	124	0011	1110X
39	1110	0100X	82	0100	1010X	125	1011	1110X
40	0001	0100X	83	1100	1010X	126	0111	1110X

	SWITCHES			SWITCHES			SWITCHES	
ID	1234	56789	ID	1234	56789	ID	1234	56789
41	1001	0100X	84	0010	1010X	127	1111	1110X
42	0101	0100X	85	1010	1010X	128	0000	0001X
129	1000	0001X	172	0011	0101X	215	1110	1011X
130	0100	0001X	173	1011	0101X	216	0001	1011X
131	1100	0001X	174	0111	0101X	217	1001	1011X
132	0010	0001X	175	1111	0101X	218	0101	1011X
133	1010	0001X	176	0000	1101X	219	1101	1011X
134	0110	0001X	177	1000	1101X	220	0011	1011X
135	1110	0001X	178	0100	1101X	221	1011	1011X
136	0001	0001X	179	1100	1101X	222	0111	1011X
137	1001	0001X	180	0010	1101X	223	1111	1011X
138	0101	0001X	181	1010	1101X	224	0000	0111X
139	1101	0001X	182	0110	1101X	225	1000	0111X
140	0011	0001X	183	1110	1101X	226	0100	0111X
141	1011	0001X	184	0001	1101X	227	1100	0111X
142	0111	0001X	185	1001	1101X	228	0010	0111X
143	1111	0001X	186	0101	1101X	229	1010	0111X
144	0000	1001X	187	1101	1101X	230	0110	0111X
145	1000	1001X	188	0011	1101X	231	1110	0111X
146	0100	1001X	189	1011	1101X	232	0001	0111X
147	1100	1001X	190	0111	1101X	233	1001	0111X
148	0010	1001X	191	1111	1101X	234	0101	0111X
149	1010	1001X	192	0000	0011X	235	1101	0111X
150	0110	1001X	193	1000	0011X	236	0011	0111X
151	1110	1001X	194	0100	0011X	237	1011	0111X

152	0001	1001X	195	1100	0011X	238	0111	0111X
153	1001	1001X	196	0010	0011X	239	1111	0111X
154	0101	1001X	197	1010	0011X	240	0000	1111X
155	1101	1001X	198	0110	0011X	241	1000	1111X
156	0011	1001X	199	1110	0011X	242	0100	1111X
157	1011	1001X	200	0001	0011X	243	1100	1111X
158	0111	1001X	201	1001	0011X	244	0010	1111X
159	1111	1001X	202	0101	0011X	245	1010	1111X
160	0000	0101X	203	1101	0011X	246	0110	1111X
161	1000	0101X	204	0011	0011X	247	1110	1111X
162	0100	0101X	205	1011	0011X	248	0001	1111X
163	1100	0101X	206	0111	0011X	249	1001	1111X
164	0010	0101X	207	1111	0011X	250	0101	1111X
165	1010	0101X	208	0000	1011X	251	1101	1111X
166	0110	0101X	209	1000	1011X	252	0011	1111X
167	1110	0101X	210	0100	1011X	253	1011	1111X
168	0001	0101X	211	1100	1011X	254	0111	1111X
169	1001	0101X	212	0010	1011X	255	1111	1111X
170	0101	0101X	213	1010	1011X			
171	1101	0101X	214	0110	1011X			

A-4

Appendix B. Alternate Base Station Configurations

The basic base station consists of a computer and the RF310B Base Station. There are other options for a base station including a portable base station, a phone-to-RF base station, and a phone-to-RF base station with measurement capability.

B.1 The Portable Base Station

The portable base station is an aid in setting up a large radiotelemetry network, or in trouble-shooting RF network communication problems. A portable base station allows any of the field or repeater stations to act as a base station. Therefore, to try any particular RF link, it is not necessary to travel to the fixed base station.

Figure B-1 is a block diagram of a portable base station. The computer, with PC208W installed, is the user interface to the RF network. Remember that the "RF Path" designation will be changed often to test various RF links. The SC532A is the interface from the laptop computer to the RF310M Modem. The transformer on the SC532A should be cut off 6" up the cable. The two leads on the SC532A should be stripped and tinned for connection to a battery. Most laptops have a 9-pin RS-232 port, so a 9- to 25-pin RS-232 cable is needed to connect the computer to the SC532A.

B.2 Phone-to-RF Base Station

When an RF network is a great distance from the desired place of data collection, a phone modem can be used to call the RF base station. A computer, with PC208W Datalogger Support Software, and a Hayes compatible phone modem can call a phone-to-RF base station. The configuration is shown in Figure B-2.

The Device Map in the Setup Window of PC2082 must include the following communication path: COM Port, Phone Modem, RF Modem, Datalogger. The phone number and RF Path need to be filled in to match your setup. The PS512M Power Supply and Charging Regulator supplies 5 V to the RF310M, supplies 12 V to the COM200 Phone modem and RF310 Radio, and acts as a null modem between the COM200 and the RF310M. The PS512M and CH512R need to supply 12 volts on Pin 8 of the 9 pin connectors. PS512M with serial number less than 1712 require a power adapter, part number 10704. CH512R serial number less than 1075 also require the same power adapter. The RF310M and COM200 are both connected to a separate 9-pin port on the PS512M. The RF310M Station ID at the phone-to-RF base station **must be 255** to allow more than one field station to be called without terminating the initial phone link. The RF310M in the RF310M-ME State recognizes Station ID 255 as a command to answer the phone and hold the ring line high which keeps the Modem Enable line high after the Ring from the phone modem has quit.
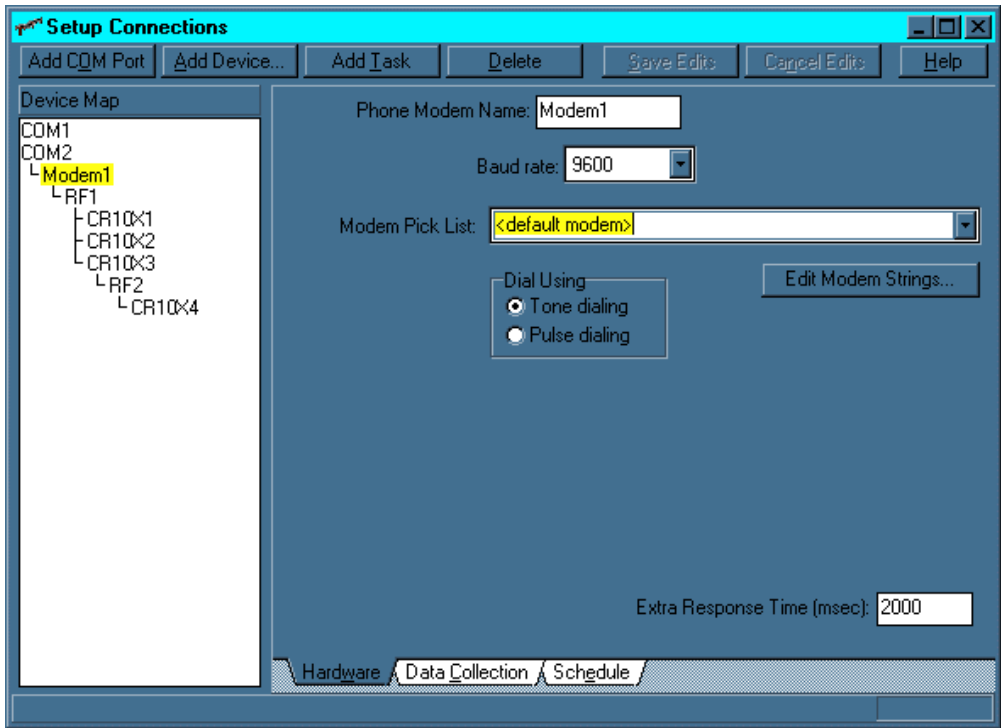
Phone to RF: Select the proper calling modem from the "Modem Pick List".
The calling modem is connected to the computer. Use 9600 baud for the
COM200, 4800 baud for the COM100 and 1200 baud for the DC112.
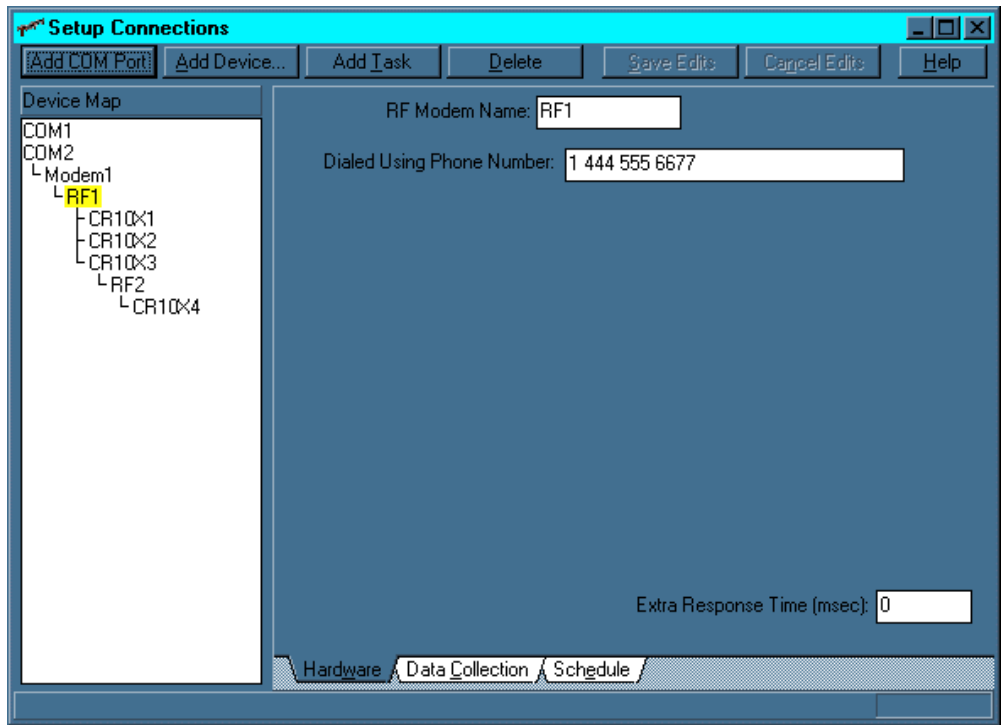
Phone to RF setup. The RF modem needs the "Dialed Using Phone Number"
set.
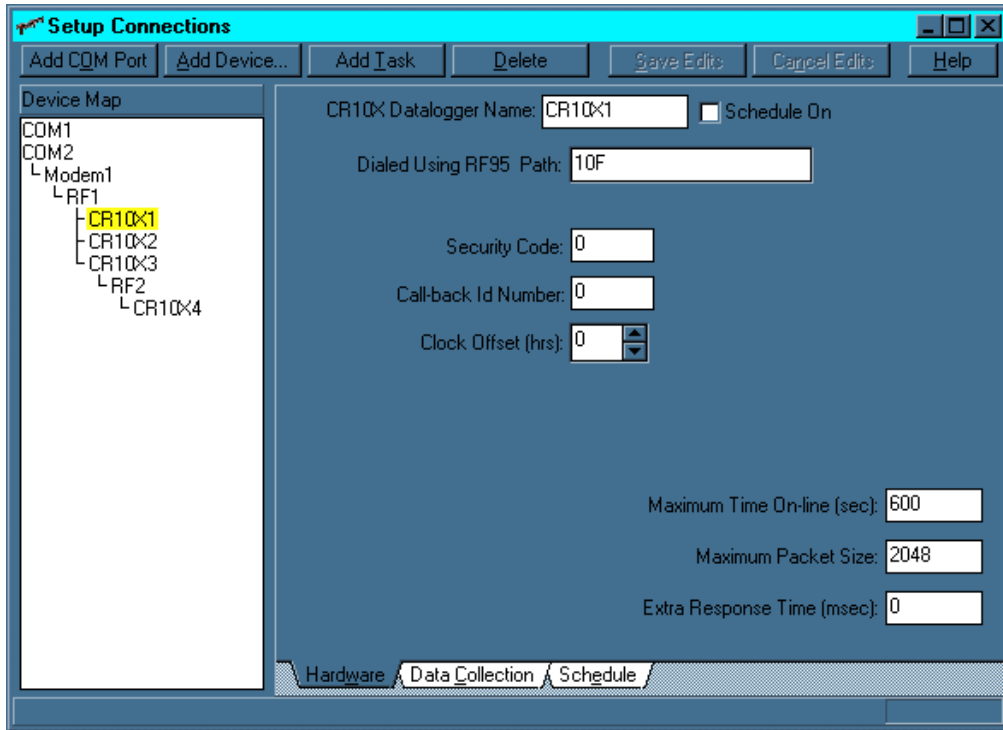
Phone to RF: Each datalogger field site needs the "Dialed Using RF95 Path:" set. This is the address set in the RF310M RF Modem.
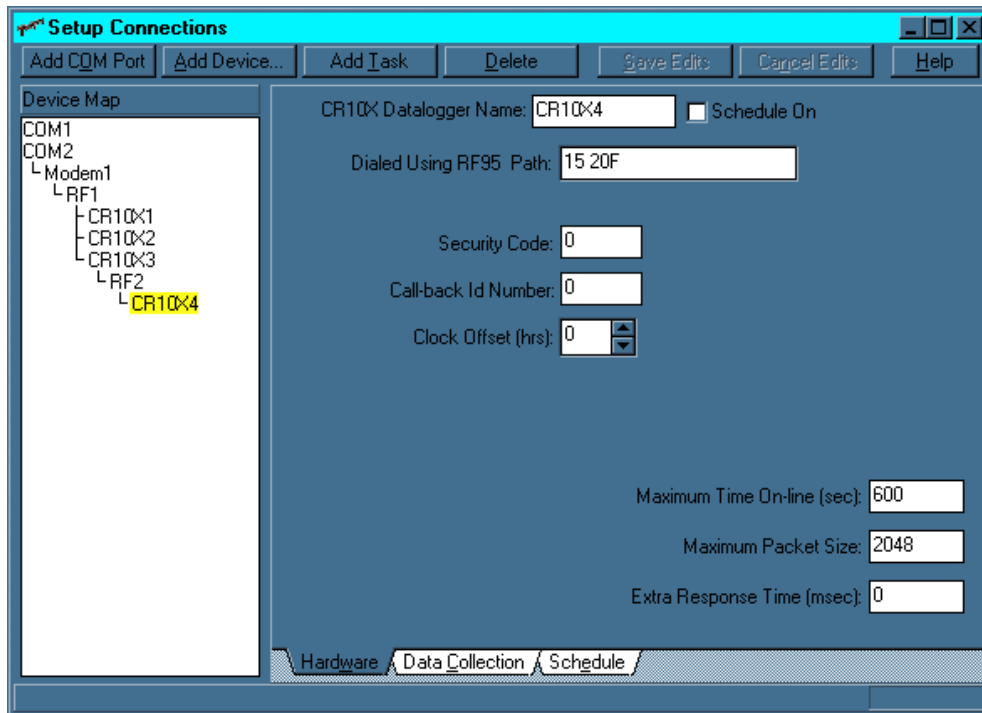
Phone to RF: When a repeater is used, the "Dialed Using RF95 Path:" includes the path of the repeater followed by the path of the field site. In this case CR10X4, address 20 is called through CR10X3, address 15.

FIGURE B-1. Portable Base Station

B.3 Phone-to-RF Base Station with Measurement Capability

When it is desired to have a datalogger at a phone-to-RF base station, the datalogger must be a CR10, CR10X, CR23X, CR510, or CR500 and the RF310M must be in the RF310M-SDC State. This con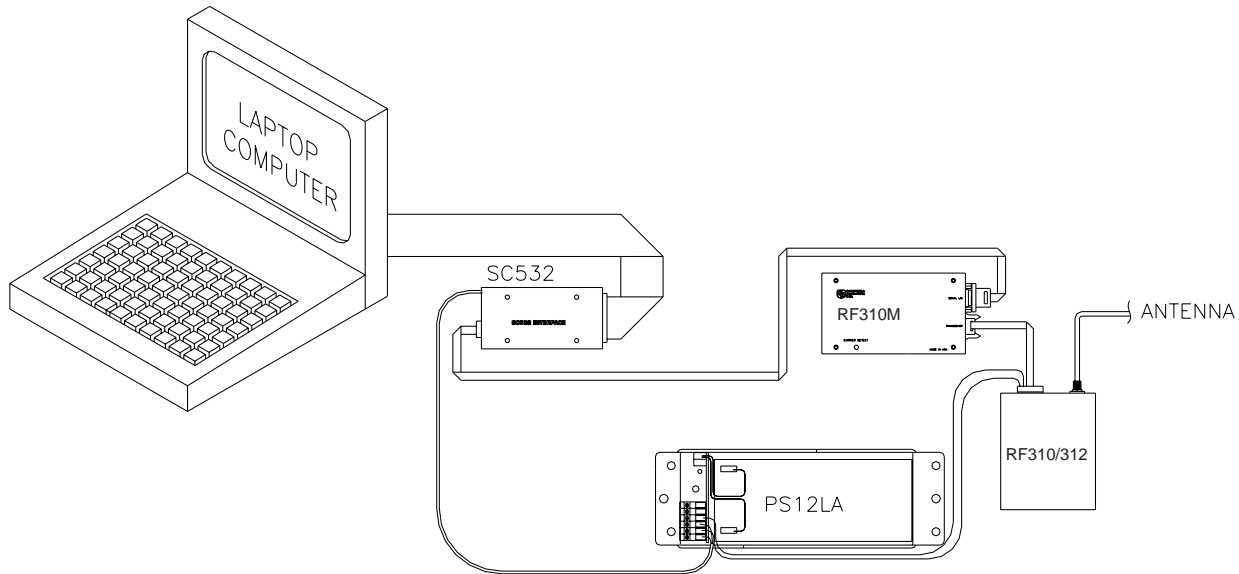figuration is used when the computer uses a phone modem to call the RF base station which is also being used as a field station (because measurements are being made at the station). The configuration is shown in Figure B-3.

The Device Map in the Setup Window of PC208W must include the following interface devices: COM Port, Phone Modem, Datalogger, RF Modem, and finally each Datalogger field site. The Phone number and RF Path must be set. The COM200 Phone Modem and the RF310M are connected to and powered by the Datalogger. The RF310M Station ID at the phone-to-RF base station does not have to be 255 in this case. This is because the Datalogger will automatically hold the Modem Enable line high, not being reliant on the RF310M.

The datalogger at the base station should have security set. See the Datalogger manual for the details of security. With security set, a pass-word (number) is required before data can be collected. Without security set, data can inadvertently be collected from the base Datalogger if an RF link fails during communication with another datalogger.

The following PC208W windows show a typical phone to RF with measurement setup.
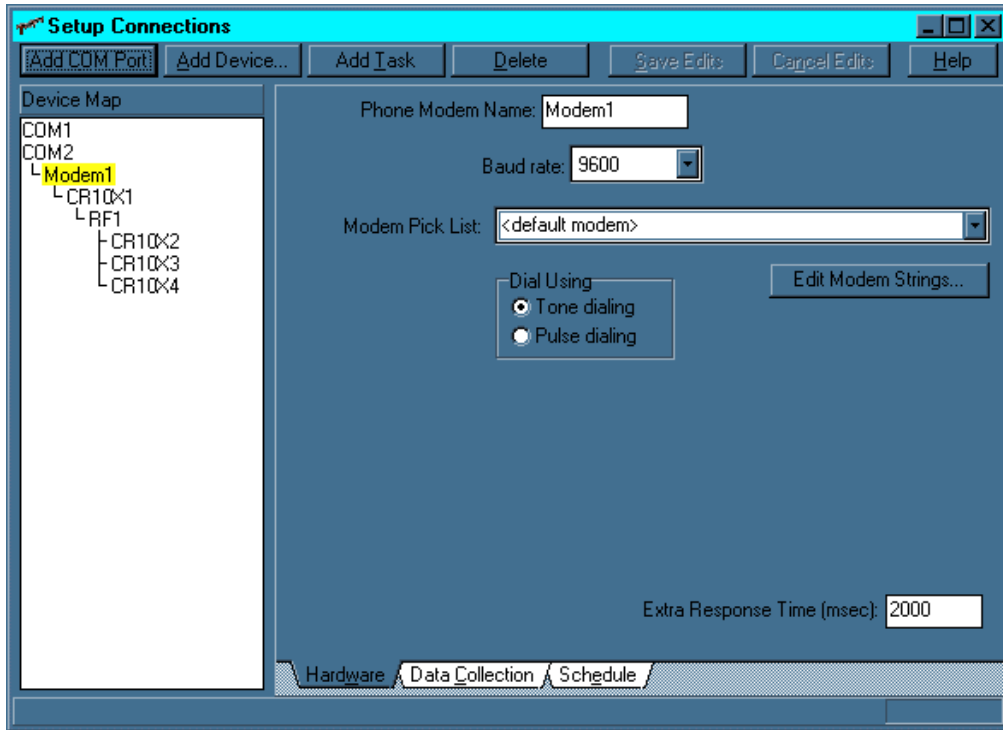
The correct calling modem (connected to computer) should be selected from the "Modem Pick List". The COM200 uses 9600 baud, DC112 uses 1200, COM100 uses 4800.
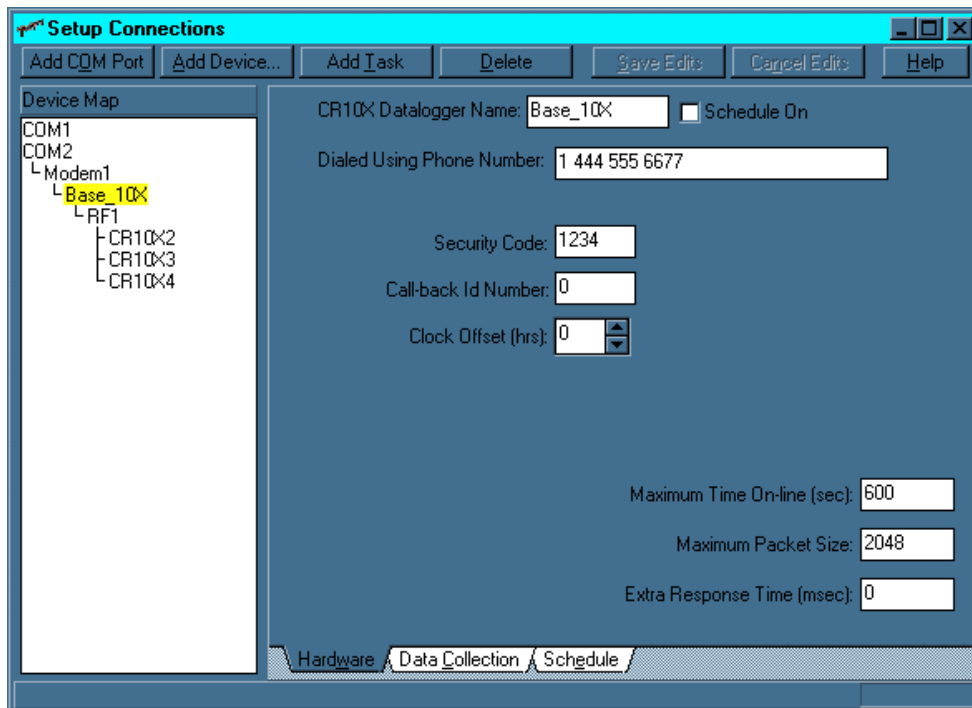
The "Base CR10X" must have the phone number and security code set.
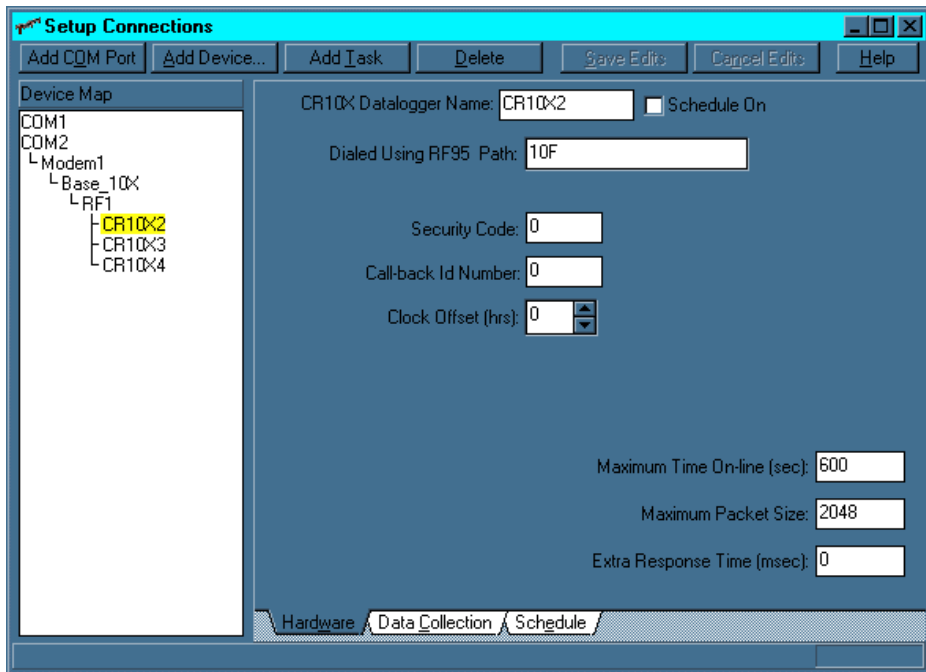
The RF Modem (RF1) works with the default settings. Each datalogger field site needs the "Dialed Using RF95 Path:" set. This is the same address set in the RF310M RF Modem.
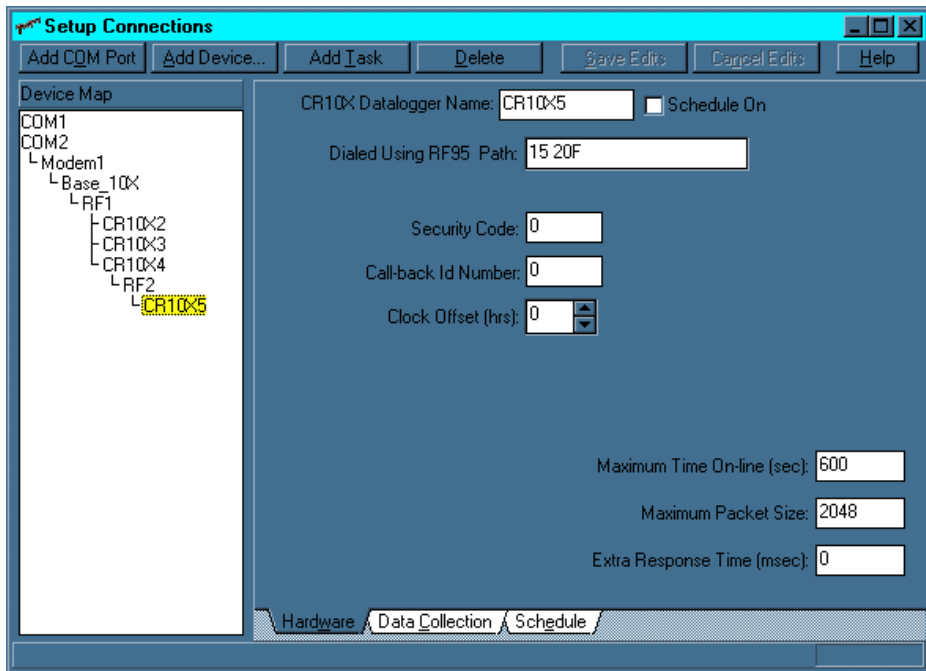
This window shows a phone to RF base with measurement using a repeater to get to CR10X5. Note the second RF modem connected to the CR10X4. CR10X4 is used as a repeater. The "Dialed using RF95 Path:" includes the CR10X4 address (15F) and the CR10X5 address (20F).
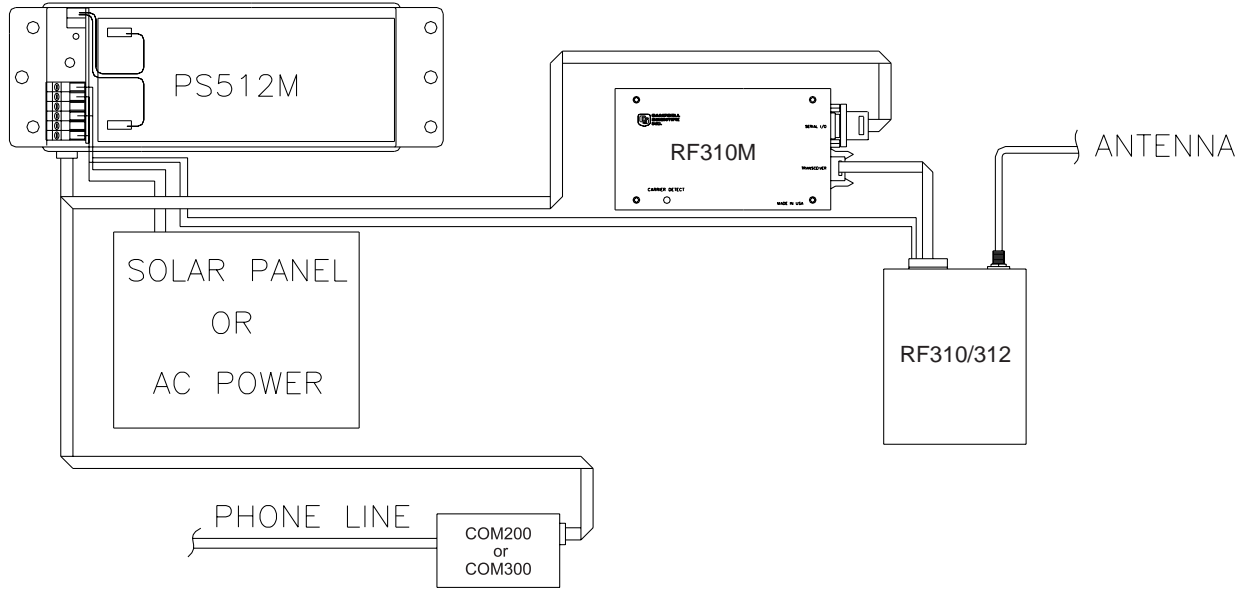
FIGURE B-2. Phone-To-RF Base Station
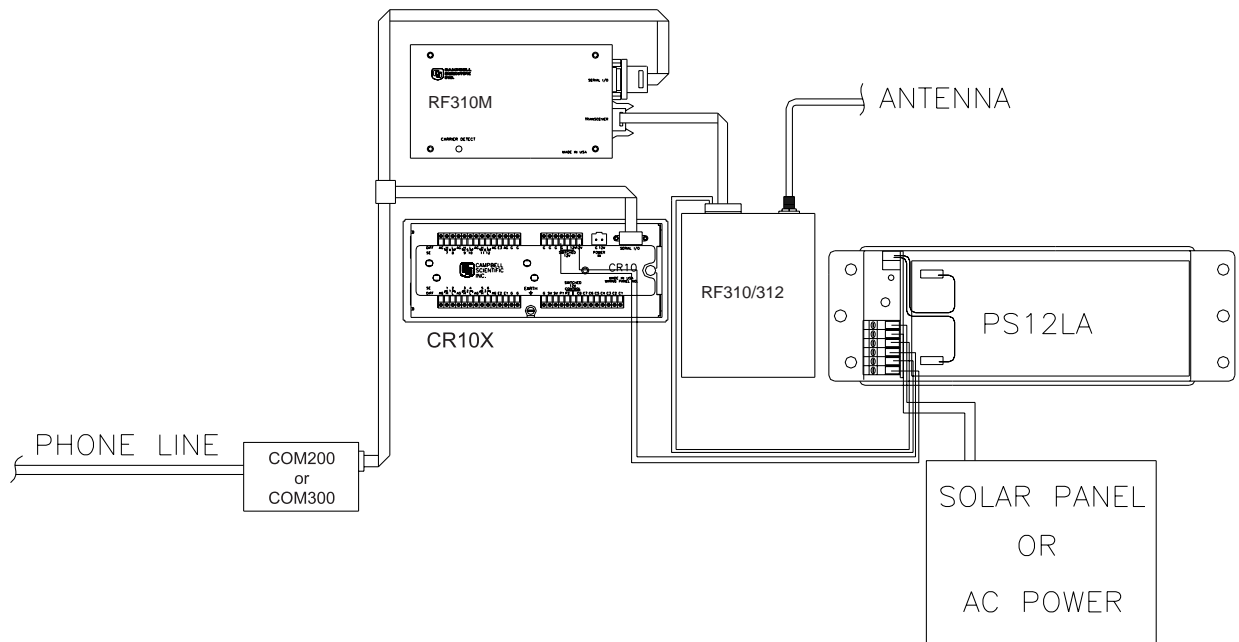
FIGURE B-3. Phone-To-RF Base Station With Measurement Capability

Appendix C. Power Calculations

There must be enough transmission power in any RF link to complete communication. The sources of power are the radio and the antennas. Conversely, power is lost both through the cables (coax loss) and over the distance of communication (path loss). The power of the signal received (Signal Power) can be calculated as stated below.

The signal power must be greater than -95 dBm (-80 dBm @ 2.4K baud) to have a good radiotelemetry link. Decibel milliwatts (dBm) is a scale of power, 0 dBm represents one milliwatt of power. The lower limit of power for good data transmission is approximately 0.0000000000003 Watts (3X10-13), which represents -95 dBm.

Signal Power

$$SP = TP + AG - PL - CL$$

| where,	SP	=	Signal Power (dBm) Power of the signal received,
	TP	=	Transmit Power (dBm) Rated output power of transmitting radio,
	PL	=	Path Loss (dB) Power lost over the distance of communication (calculated below),
	AG	=	Antenna Gain (dB) Total power gained by both the transmit and receive antennas,
and,	CL	=	Coax Loss (dB) Total power lost through both lengths of cable connecting the transmit and receive radios to the antennas.

Path Loss

$$PL = 36.6 + 20*Log(F) + 20*Log(D)$$

where,	PL	=	Path Loss,
	F	=	Frequency (MHz),
and,	D	=	Distance (miles).

Coaxial Cable Loss

Typical coaxial cable losses are listed below.

	200 MHz		400 MHz
Cable Type		Loss/100 ft.	
RG-8A/U	3.1 dB		5.0 dB
RG-58A/U	6.2 dB		9.5 dB

Transmit Power

5 Watt Radio	36.99 dBm
4 Watt Radio	36.02 dBm

Power Conversion

Conversion of Watts to dBm can be done with the following formula.

$$dBm = 10 * Log((Watts)/0.001)$$

Appendix D. Fundamentals of Radiotelemetry

D.1 Radio Waves

Radiotelemetry is the process of transferring information (data) in the form of radio waves. The data is transferred on a carrier wave which normally has a sinusoidal form. Therefore, the carrier wave can be described entirely by the frequency, amplitude, and phase with respect to a reference.

The commonly used term for radiotelemetry, RF, refers to radio frequency, which in actuality is the frequency of the carrier wave.

Radio waves can be divided into three categories: 1) ground waves, 2) direct waves, and 3) sky waves. All communication with Campbell Scientific's RF networks are done via direct waves. Direct waves travel "line-of-sight" at a maximum distance of approximately 25 miles.

Low frequency radio waves (5-10 mHz) can travel for thousands of miles using the ground wave portion of the radio wave. The ground wave is that portion of the radio wave which travels just above the surface of the ground. Conversely, the sky wave radiates to the ionosphere where a certain percentage of the energy is reflected back to earth. At the higher frequencies used for data transmission the ionosphere is penetrated by the radio wave and too small of a percentage is reflected back to earth. However, neither the ground wave or sky wave is used in Campbell Scientific's RF networks.

Energy is lost from radio waves as they travel away from the transmitting antenna. One reason for this is the loss due to dispersion of energy over a larger area; analogous to water waves reducing in size (energy) as they get farther from the source. Second, is that energy is absorbed by the earth over the distance of travel. Eddy currents cut down signal power, and intervening terrain and buildings can prevent a signal from being strongly received.

The higher the frequency, the stronger the radiation field. However, at higher frequencies more energy is absorbed by the surface. The VHF and UHF frequencies can travel only a short distance between radio stations. The direct wave, where there is no obstacles between stations, will transmit farther than any indirect waves which have been transmitted through or reflected from obstacles.

The carrier wave can be thought of as the radio wave which "carries" the data from one radio to the next. The "data" consists of an electrical signal which rides with the carrier wave. The process of placing the signal on the carrier wave is called modulation. The signal is also in the form of a wave, but usually the signal has a much lower frequency. The carrier with the modulating signal is called the modulated carrier.

The signal wave isn't used as a carrier wave because radio transmission must be of a high frequency to keep radio components small, antennas small, filtering

efficient, and to isolate the radio waves from the common low frequency man-made noise.

The main forms of modulation are amplitude, frequency, and pulse modulation. Frequency modulation (FM) is used by Campbell Scientific.

D.2 Antennas

An antenna is a device which captures and radiates radio waves. The antenna at the transmitting station is excited by the transmitting radio. The antenna converts energy from the radio to radiated energy. Electrons within the antenna oscillate at the frequency of the radio thereby producing radio waves. These radio waves radiate out from the antenna at the speed of light (299,800 km/s).

The transmitted radio wave will cause electrons in the receiving antenna to oscillate at the carrier frequency. The AC current thereby produced in the antenna is transferred to the radio for demodulation.

The antenna is constructed for a particular frequency, operating radius, and gain. Length, diameter, number of elements, and element spacing are among the items that can be changed to alter antenna performance at the design stage.

Every antenna has a known horizontal and vertical pattern of radiation. The horizontal radiation pattern consists of any segment of a 360 degree circle surrounding the antenna. The horizontal pattern is important to consider when a RF station is to communicate with more than one other RF station. The vertical pattern is the radiating pattern in the upward and downward directions.

Any two communicating RF stations must have a minimum level of signal power. Power is normally expressed in decibels (dB), or decibel milliwatts (dBm). Power is lost through transmission cables (transmitting and receiving) and over the communicating distance. Power is gained through the transmitting radio, and the two antennas. Antenna gain is specified in decibels in reference to a dipole, and can vary from 0 to 10 dB in common antennas. A unity gain antenna has a 0 dB gain, therefore no additional power is added by using these antennas.

Antenna gain is accomplished by either concentrating the radiating power in a small sector, or using multiple radiating elements with additive patterns.

D.3 RF310M Modem

The RF310M Modem is the main communication control device in a radiotelemetry network. The RF Modem enables a central base site to communicate with up to 254 different RF stations.

The RF Modem is a microprocessor controlled device which codes all transmissions for a specific communication path. Each has a hardware ID switch for identifying different stations.

The purpose of the RF Modem is to control operation of the radio and provide protection for data integrity. The RF Modem controls the communication sequences, sets data to be transferred into data blocks, creates signatures of data

blocks, modulates the radio's carrier wave, and stores information on communication quality.

The user at the computer is responsible for naming the desired communication path with a setup string. This setup string contains any repeater (MOL) modem IDs and the destination (EOL) modem ID in sequence. After sending this information out through the RF system, all of the RF Modems in the specified link will set themselves in the proper mode. The RF Modem has different modes to distinguish responsibilities at various localities within a link. These modes are described in Section 3.1.6.

Establishment of an RF link consists of getting all of the RF Modems in the proper mode and receiving a verification block from the EOL modem.

D.4 Transceiver

The purpose of a transceiver (radio) is to transmit and receive the modulated carrier wave.

A radio is both a transmitter and receiver. The main component in the transmitter is the oscillator of which the frequency of oscillation is provided by a crystal. The crystal oscillates at a desired frequency, which is specific for the carrier frequency. The oscillator converts DC power to an AC signal. This signal is then amplified, modulated with the signal, and transmitted to the antenna system. The receiver consists of an amplifier, frequency converter to slow signal, limiter to give constant amplitude but same frequency, and discriminator or demodulator.

The radio has a known impedance, or resistance. Maximum power is transferred if the impedance of the radio matches the impedance of the antenna and cable. This impedance is generally 50 ohms. Mismatching of impedance will cause a lesser transmit power and result in a higher VSWR (Voltage Standing Wave Ratio).

When the transmission cable and antenna does not match the impedance of the output circuit of the radio, not all of the energy fed down the cable will flow into the antenna. A percentage of the energy will be reflected back forming standing waves on the cable. The ratio of voltage across the line at the high voltage points to that at the low voltage points is known as the VSWR. When the VSWR is 3.0:1 or greater, the percentage of errors per data value is greater than 50%. The VSWR should be kept below 1.5:1 for error free radiotelemetry.

Appendix E. RF310M States

The RF310M Modem operates in one of two separate states. The RF310M can be utilized in either the RF310M-ME (Modem Enable) State or the RF310M-SDC (Synchronous Device Communication) State. The RF310M-ME State is normally used for all RF networks. The RF310M-SDC State must be used when there is a phone-to-RF base station with a datalogger. Note: the 21X and CR7 dataloggers don't support the SDC state. A switch inside the RF310M needs to be set according to the chosen state.

E.1 RF310M-ME State

The RF310M-ME State is always used with 21X and CR7 dataloggers, and normally with all other dataloggers.

RF310M-ME State Description

The RF310M rings the datalogger until the datalogger raises the ME line. The Datalogger waits approximately 40 seconds to receive carriage returns to establish the baud rate. After the baud rate is set the Datalogger transmits a carriage return, line feed, "*", and enters the Telecommunications Mode. If the carriage returns are not received within the 40 seconds, the Datalogger hangs up.

When the datalogger is in the Telecommunications Mode, the ME line is high, and the RF310M is subsequently in the Transparent Mode or EOL Mode depending on the relative location of the RF310M.

E.2 RF310M-SDC State

The RF310M-SDC State can be used to enable a Datalogger to be recording measurements at a phone-to-RF base station. The SDC State is never used with 21X or CR7 dataloggers.

RF310M-SDC State Description

The RF310M obeys all Synchronous Device Communication (SDC) protocol when set in the RF310M-SDC State. Most dataloggers have the ability to address synchronous devices. The 21X and CR7 do not support the SDC state. The Datalogger and the RF310M use a combination of the Ring (pin 3), Clock/Handshake (pin 7), and Synchronous Device Enable (SDE, pin 6) lines to establish communication rather than just the Modem Enable line.

When the Datalogger is connected to the RF310M, a 1N command is sent to the datalogger at setup. The baud rate is set and the Datalogger completes connections with the RF310M. The Datalogger sets the RF310M in an addressing state by raising the CLK/HS followed by or simultaneously raising the SDE line. The RF310M drops the ring line and prepares for addressing.

The Datalogggger then synchronously clocks 8 bits (the address) onto TXD using CLK/HS as a clock. The least significant bit is transmitted first, each bit

is transmitted on the rising edge of CLK/HS. The RF310M completes addressing when the eighth bit is received.

The synchronous device capability enables the Datalogger to have measurement capability at a phone-to-RF base station. A command within the address sent to the RF310M can tell the RF310M to connect to the phone modem which requires the RF310M to switch its TXD and RXD lines. Therefore all characters are routed through the phone modem to the RF310M which controls the radio accordingly.

The RF310M then enters the Active State. The receiver is enabled when SDE and CLK/HS are high. The transmitter is enabled when SDE is high and CLK/HS is low.

In the Active State, the RF310M responds to the commands S, R, T, F, and U.

Appendix F. Specifications

Specifications - RF310 and RF312 Radios	General
Equipment Type	Data Radio
Performance Specifications	TIA/EIA-603 & ETS 300-113
Channel Spacing	25 kHz, 12.5 kHz Programmable
RF Output Power	5 or 1 Watt
Modulation Type	F3D, F3E
Intermediate Frequency	45.1 MHz & 455 KHz
Number of Channels	16
Frequency Source	Synthesizer
Operation Rating	Intermittent, 90:5:5 (Standby: RX: TX)
Power Supply	Ext.. Power Suppy (12 VDC Nominal) 9.0 VDC - 15.0 VDC Extreme
Temperature Range Storage Operating	 -40° C to +80° C -30° C to +60° C
Current Consumption Standby (Muted) Transmit 5 Watts RF Power Transmit 1 Watt RF Power	 <65 mA <2.0 A <1.0 A
Frequency Bands VHF RX and TX UHF RX and TX	 148.000 - 174.000 MHz 440.000 - 470.000 MHz
Dimensions	30mm H x 62 mm W x 118 mm D
Weight	253 Grams

Specifications	Transmitter
Carrier Power Hi Low	Nom Max Min 5 W <6W >4.5W 1 W <1.5W >0.8W
Sustained Transmission	Nominal Conditions Time: 5 10 20 Seconds Power: >90% >85% >80%
Frequency Error	< 0.5 kHz Nominal Condition for VHF < 0.75 kHz Nominal condition for UHF -3.0 ppm Extreme Condition for UHF -5.0 ppm Extreme Condition for VHF
Frequency Deviation: 25 kHz Channel Spacing 12.5 kHz Channel Spacing	 Peak -5.0, Min. -3.8 Peak -2.5, Min -1.9

Audio Frequency Response	Within +1/-3dB of 6dB octave @300 Hz to 2.55 kHz for 12.5 kHz C.S. @300 Hz to 3.0 kHz for 25 kHz C.S.
Adjacent Channel Power 25 kHz 12.5 kHz	<70 dBc @ Nominal Condition <65 dBc @ Extreme Condition <60 dBc @ Nominal Condition <55 dBc @ Extreme Condition
Conducted Spurious Emission	<-57 dBc
Modulation Sensitivity	100 mB RMS @ 60 % Peak Dev.
Hum & Noise 25 kHz Channel Spacing 12.5 kHz Channel Spacing Modulation Symmetry	>40 dB (with no PSOPH) > 40 dB (with PSOPH) <10 %osc at >= 10:1 VSWR all phase angles and suitable antenna. No destroy at >= 20:1 all phase angle
Peak Deviation Range Adjustment @ 1 kHz, Nom. Dev + 20dB 25 kHz Channel Spacing 12.5 kHz Channel Spacing	 Min. 3.5, Max 6.0 Min 1.5, Max 4.0

Specifications	**Receiver**
Sensitivity (12 dB Sinad)	UHF <-117 dBm, VHF <-118 dbM @ Nom cond. UHF <-115 dBm, VHF <-116 dBm @ Ext. Cond
Amplitude Characteristic	<-3dB
Adjacent Channel Selectivity: 25 kHz Channel Spacing 12.5 kHz Channel Spacing	 >60 dB @ Nom., > 55 dB @ ext. condition >50 dB @ Nom., > 45 dB @ ext. condition
Spurious Response Rejection	> 70 dB (100 kHz - 4 GHz)
Image Response	> 70
IF Response	> 70
Intermodulation Response Rejection: + - 25 kHz/ 50 kHz + - 50 kHz/ 100 kHz	 65 dB 65 dB
Conducted Spurious Emission @ Nominal Conditions: 9 kHz - 1 GHz 1 GHz - 4 GHz	 < - 57 dBm < -47 dBm
RX Spurious Emissions (Radiated) @ Nominal Conditions: 9 kHz - 1 GHz 1 GHz - 12.75 GHz	 < - 57 dBm <- 47 dBm
AF Distortion	< 5% @ Nom., < 10% @ Extreme condition
RX Hum and Noise 25.0 kHz CP	 <40dB No PSOPH

12.5 kHz CP	< 40Db with PSOPH
Receiver Response Time	<16 mS
Squelch Opening Range	RF level for 6 to 14 dB Sinad
Squelch Closing Range (Hysteresis)	0 - 6 dB Sinad @ Nominal Condition
Squelch Attack Time: RF Level at Threshold RF Level at Threshold + 20 dB	< 40 ms <30 mS
Squelch Decay Time	5 mS Min., 20 mS. Max.
Antenna Socket Input Match	10 dB Return Loss
L.O. frequency Temperature Stability	1st <5ppm, 2nd < 15ppm from -30 to 60°C
L.O. Frequency Aging rate	-2ppm/year
Specifications	Reference Crystal
Frequency	12.8 MHz
Holder Type	HC-18
Temperature Characteristic	-5.0 ppm from -30 C to +60 C
Aging Rate	< 2 ppm/year in 1st Year, < 1 ppm/year thereafter
Lock Time	< 10 mS
TX to RX	< 20 (No Power Saving)
RX to TX	< 20

Due to continuing research and development the company reserves the right to alter these specifications without prior notice.

Glossary

Antenna - Device for radiating and receiving radio signals.

Attenuation - The reduction of an electrical signal without appreciable distortion.

Base Station - The destination for accumulated data; where data is received via radio from one or more field stations.

Baud Rate - A unit of data transmission speed, normally equal to one bit per second.

Block - Group of ones and zeroes which represent data or commands.

BNC Connector - A commonly used "twist type" connector on radios.

Carrier Wave - A radio wave upon which the signal is transmitted.

Coaxial Cable - An insulated RF transmission line consisting of two conductors separated by a dielectric.

COM Port (Communication Port) - The serial port of the computer where communication is intended.

Decibel - A unit of power equal to 10 times the common logarithm of the ratio of two amounts of signal power.

End of Link Modem - An RF modem which is at the field station.

Field Station - The place of origin of the data, from which the data is then transmitted by radiotelemetry.

Forward Power - Energy that is transmitted from a radio, through coaxial cable, and through the antenna without being reflected back to the radio.

Line of sight - Straight path between the transmitting and receiving antenna when unobstructed by the horizon.

Megahertz - Cycles per second multiplied by 1,000,000.

Middle of Link Modem - Any modem in an RF link which is not at the base station or the designated field station.

Modem ID Number - A communication identification number for an RF Modem, also an aid in specifying the RF path.

Modulation - Process by which one waveform (carrier) is caused to vary according to another waveform (signal).

Omnidirectional - Capable of operating in all directions.

Radio - Device which transmits and receives electrical signals by means of radio waves.

Radio Frequency - The number of cycles per second with which the carrier wave travels, usually specified in Megahertz.

Radiotelemetry - Process of transmitting data by radio communication.

Radiotelemetry Link - A temporary communication path within a network.

Radiotelemetry Network - A group of stations which communicate by radio and are used to indicate or record data.

Reflected Power - Energy that is transferred back into the radio after it has been transmitted by the same radio.

Remote Site - See Field Station.

Repeater - An intermediate station in an RF link used for the sole purpose of relaying data.

RF - An abbreviation for radio frequency, commonly used in place of radiotelemetry.

RF Modem - Device which modulates an electrical signal on the carrier wave, and codes all transmissions for a specific path.

RF Path - The designation of an RF link with modem ID Numbers and modem commands.

RLQA (RF Link Quality Accumulators) - Numbers which represent the quantity of communication interruptions and the level of communication noise.

Shutdown Block - Block of numbers which contain the RF Link Quality Accumulators for each modem in a terminated radiotelemetry link.

Signal Power - Power of a signal at the receiving radio, after power is lost through transmission.

Start of Link Modem - The modem located at the base station.

Squelch - Setting on the radio which specifies the minimum power level which signals must be received.

Sub Link - Any segment of an RF link which begins and ends with an RF station.

Telecommunications Mode - A datalogger status which enables communication from a computer directly to the datalogger.

UHF (Ultra High Frequency) - Carrier frequencies commonly in the range of 406 to 512 MHz.

VHF (Very High Frequency) - Carrier frequencies commonly in the range of 130 to 174 MHz.

VSWR (Voltage Standing Wave Ratio) - The ratio of the standing wave voltage across the RF transmission cable at the high voltage points to that at the low voltage points.

Unidirectional - Capable of operating only in a single direction.

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