

INSTRUCTION MANUAL



Radiotelemetry Network

C a m p b e l l S c i e n t i f i c , I n c .

RADIOTELEMETRY NETWORK INSTRUCTION MANUAL

9/95

CAMPBELL SCIENTIFIC, INC.

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CAMPBELL SCIENTIFIC, INC.

815 W. 1800 N.
Logan, UT 84321-1784
USA
Phone (435) 753-2342
FAX (435) 750-9540
www.campbellsci.com

Campbell Scientific Canada Corp.
11564 -149th Street
Edmonton, Alberta T5M 1W7
CANADA
Phone (403) 454-2505
FAX (403) 454-2655

Campbell Scientific Ltd.
14-20 Field Street
Shepshed, Leics. LE12 9AL
ENGLAND
Phone (44)-50960-1141
FAX (44)-50960-1091

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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 network. Dataloggers can be accessed by radiotelemetry which requires no physical connection from the computer to the datalogger. The radiotelemetry link reduces the number of visits to a remote site for data collection.

The radiotelemetry network is designed for complete computer control. One computer can establish communication with up to 254 remote sites. The PC208 Datalogger Support Software allows data collection from the datalogger, transmitting datalogger programs, and displaying current readings from the datalogger.

The requirements specific to a radiotelemetry 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). 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 approximately 130 to 174 MHz or UHF (Ultra High Frequency) ranging from approximately 403 to 512 MHz. A typical RF system is shown in Figure 1-1.

Telemetry network's three basic components are:

- Field Station
- Base Station
- Repeater Station

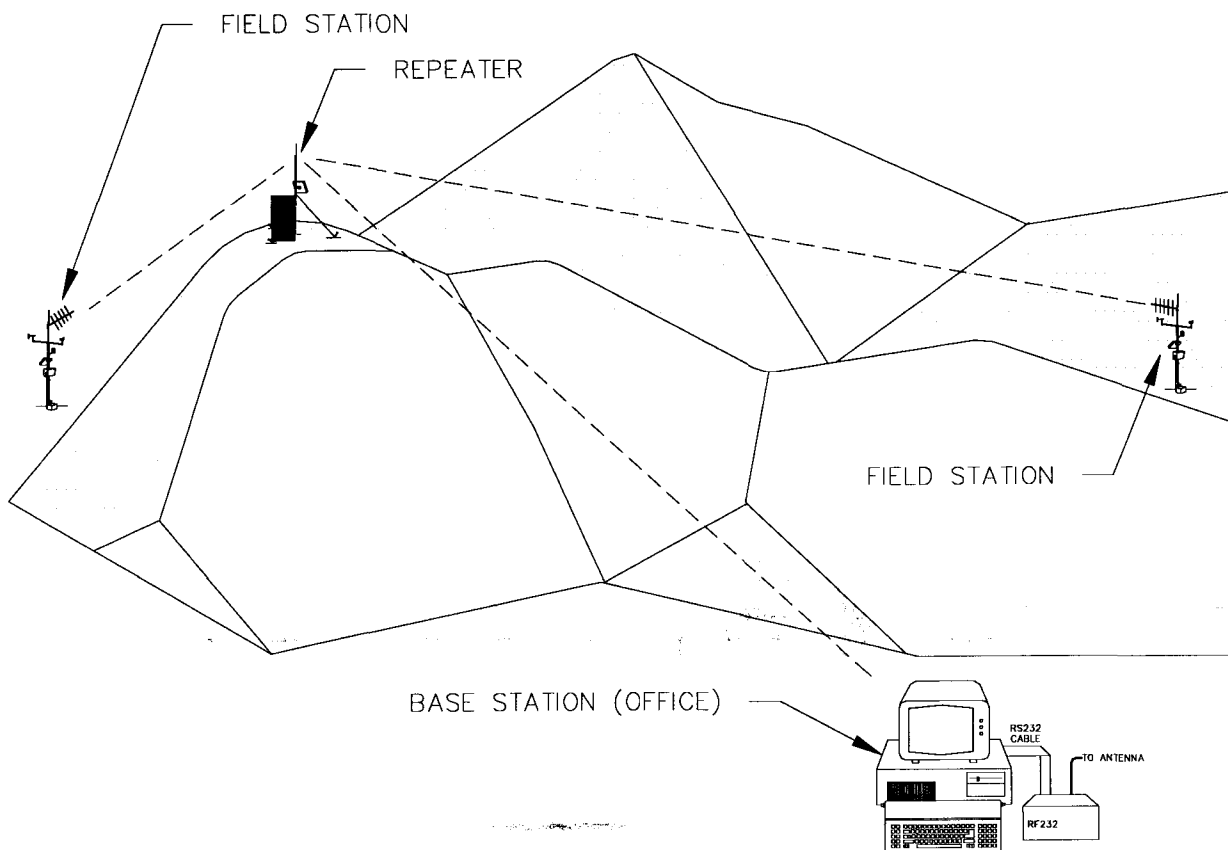


FIGURE 1-1. A Basic Radiotelemetry Network

SECTION 1. GENERAL RADIOTELEMETRY 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

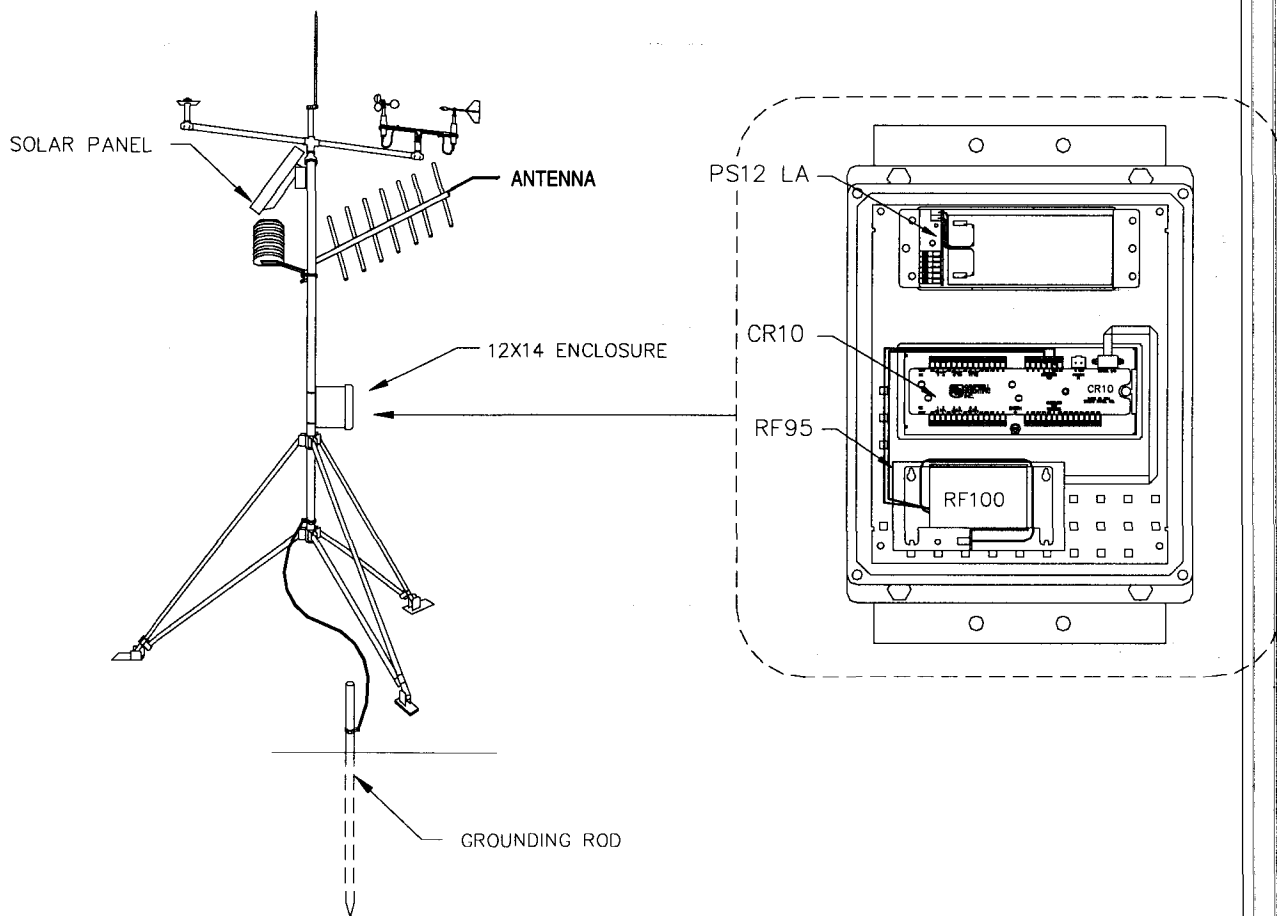


FIGURE 1-2. A CR10 Field Station

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 PC208 software
- Antenna and antenna cable
- AC power

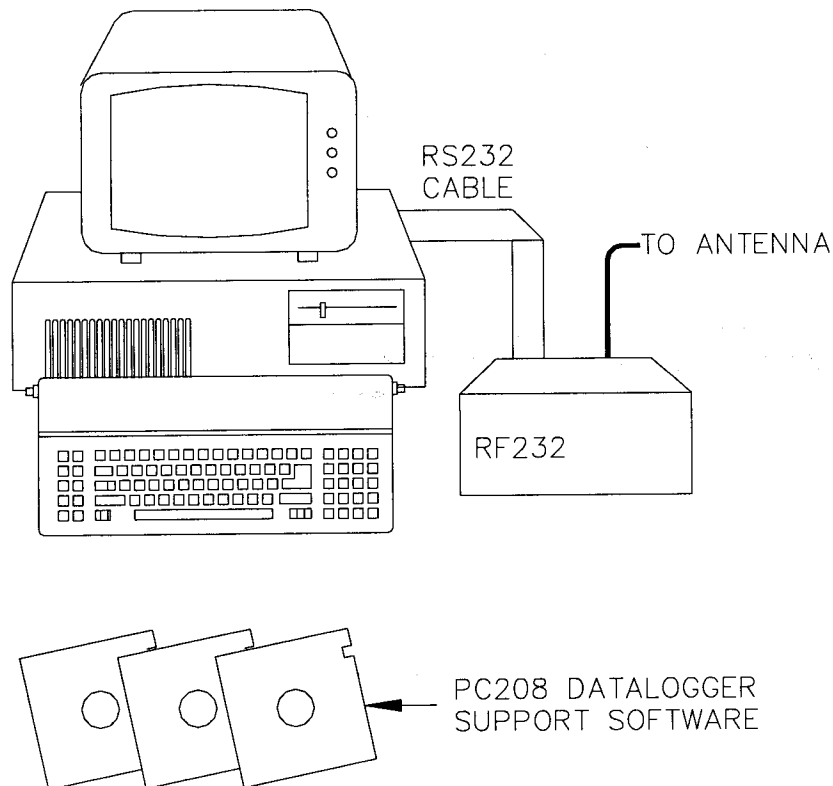


FIGURE 1-3. A Radiotelemetry Base Station

SECTION 1. GENERAL RADIOTELEMETRY NETWORK

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 a radiotelemetry network. A field station can also function as a repeater.

Equipment Required:

- Radio
- RF Modem
- Antenna and antenna cable
- 12V and 5V power supply (PS512M)
- Enclosure and other mounting needs

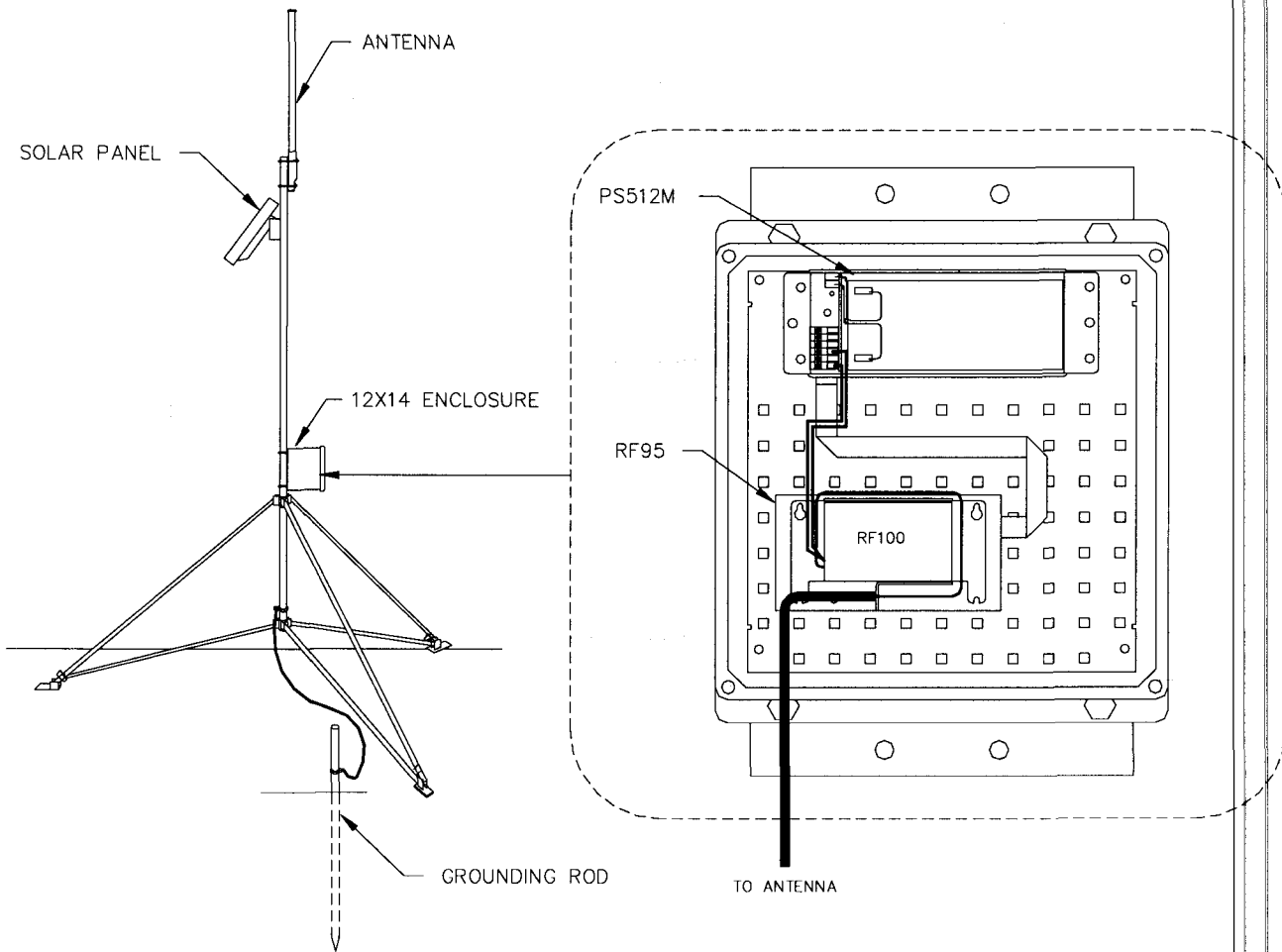


FIGURE 1-4. A Typical Repeater Station

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." This component section 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 RF232 Base Station. Refer to Section 3.5 for locational drawings and a description of the RF232 Base Station.

1. Remove the top of the RF232 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 RF232. Secure the BNC connector from the radio's cable to its hole on the back of the RF232. See Figure 3-7 for assistance.
3. Connect the radio to 12 V, ground, and the RF Modem. 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 RF232.
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 RS232 cable from the computer serial port to the RF232.
9. After verifying that the RF232 power switch is off, plug in the RF232's wall transformer.

2.2.2 PC208 DATALOGGER SUPPORT SOFTWARE

Once the base station hardware is installed, the PC208 software must be setup to allow communications. If PC208 is not installed on the computer, you will need to install it by placing the PC208 Disk 1 in the drive and typing INSTALL, preceded by the disk drive. Refer to the PC208 Manual if you have questions about the installation procedure or details on specific programs included with PC208.

There are five main programs in PC208:

- TELCOM - Collects data from field stations.
- GT - Used to troubleshoot, look at current readings, and download programs.
- SPLIT - Generates reports and reduces data stored on computer.
- EDLOG - Editor to aid in writing datalogger programs.
- SMCOM - Communicates with Campbell's Storage Modules.

SECTION 2. ASSEMBLING THE RADIOTELEMETRY NETWORK

Ultimately, a TELCOM Station File is needed for each field station to establish the communication paths and conditions for calling a particular field station. Procedures for creating an RF Test Station File are explained in this section.

To set up a TELCOM Station File, type "TELCOM" at your DOS prompt. Enter the file name "RFTEST/E" when asked for a station or script file name. The "/E" is used to edit the Station File named "RFTEST." A menu of parameters will then appear on the screen listing datalogger type, collection method, etc. The default values will be automatically listed after the parameter description. When the cursor is on a value, pressing the space bar will toggle different options for that particular parameter.

Following the Station File Example 2-1, change the default values of the listed parameters to match your system. Some of the parameters require a number entry (e.g. the parameter 'Primary call interval' simply needs a number of minutes that is desired between calls). For these parameters, just type over the default value which is shown. After completing Station File RFTEST, your display should be similar to Example 2-1. Exceptions would include the datalogger type, date and time after 'Next time to call.' Also, COM1 under 'Interface Devices' may be COM2, 3, or 4, depending on the address of the intended serial port.

The RF Path at the bottom of the Station File designates which field station to call. In the example shown, the base station will call the field station with a Station ID 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 will be explained later. The base station is now ready to communicate with a field station.

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 - Turn on datalogger.
3. Antenna - Orientate 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 and to power supply.

Example 2-1. TELCOM Station File - RFTEST

```
Station File name:      RFTEST
Datalogger or Command Type: CR10      Security Code: 0
Fix Datalogger Clock Using PC Clock: No
Final Storage Area to Collect From: 1st Area
Data Collection Method: Since Last Call; Append File;
Nbr of arrays to Backup on First Call: 1
Data File Format:      Comma Delineated ASCII
Primary Call Interval (minutes): 1
Recovery Call Interval #1 (minutes): 1
Repetitions of Recovery Interval #1: 1
Recovery Call Interval #2 (minutes): 1
Maximum Time Call Will Take (minutes): 3
Next Time to Call:     11/18/93 0:13:10

Interface Devices:
COM1      Baud Rate: 9600
RF Modem  RF Path: 10 F
End

^O = Save/Resume      ^P = Save/Done      ESC = Abandon Edit
```


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.

The Station File RFTEST must first contain the proper RF path. Edit the Station File RFTEST by typing "TELCOM RFTEST/E", typing "/E" after "RFTEST" puts you directly in the Station File for editing. Repeatedly press [ENTER] until the cursor reaches the RF path. Enter the proper RF path to communicate with the desired station. For help, refer to Example 4-1 or the PC208 Manual.

After entering the 'RF Path', press [CTRL] "P" to save the Station File. TELCOM will automatically call the field station after it is saved. If everything is set up properly, the base station will call the field station, receive a datalogger status line on the computer, collect any data that is in the datalogger, and receive RLQA quality accumulators. The RLQA numbers are explained in Section 3.1 "RF95 Modem."

2.4.1 A SUCCESSFUL TEST

Two files are created by calling the station if the RF link was setup properly. One file is RFTEST.CQR which includes the RLQA numbers (RF Link Quality Accumulators), and the other is a data file named RFTEST.DAT. RFTEST.CQR will consist of one line of numbers for each time the station was called. The first two numbers are the Julian date and time of call, followed by three numbers for each modem in the link. If there is no repeater in the link, there will be eight numbers: one for date, one for time, three for the field station RF modem, and three for the base station modem. The first number from each modem should be small (close to 0), the second and third numbers should be 102 (± 70).

RFTEST.DAT will contain the data, if any, that was collected from the datalogger. To call the same field station again, simply type "TELCOM RFTEST/C." After the successful test, set up the next nearest field station and test that radiotelemetry link.

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 to try to identify where the link is breaking down. 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.

If the field station's RF95 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.

SECTION 2. ASSEMBLING THE RADIOTELEMETRY NETWORK

2.5.2 ERROR MESSAGES

An error file is created as a result of communication problems. Each time a communication error occurs, the message is stored in a file called `FILENAME.ERR`. The filename is the name of the Station File, in this case `RFTEST.ERR`. Listed in the error file will be the date and time the error occurred along with the error message. As errors occur, they are appended to the existing error file.

One possible error message is "Communication not established with RF Modem." In this case check the following items:

1. RF232 Base Station plugged into computer and wall outlet?
2. RF232 Power Switch turned on?
3. Does the TELCOM Station File match Example 2-1?
4. Is the proper COM port specified in the Station File?
5. Is the SC12 9-pin ribbon cable inside the RF232 connected from the small circuit board to the RF95 Modem?

Another possible error message is "RF Modem Set Link Failed" which is seen after the software attempts to establish communication three times. In this case, check the following items:

1. Are the radios plugged into the RF modems?
2. Are the radios connected to power?
3. Verify that nothing else 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 Station File correct?
6. Are the antennas oriented correctly?
7. Check all antenna cable connections.
8. Turn radio off. Unplug the SC12 9-pin ribbon cable from the RF95 in the RF232, 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 RF95 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?

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 COMMUNICATION WITH GT

GT is the general purpose communication package. Unlike TELCOM, GT does not always automatically set up or shut down an RF link. The advantage of GT is that it is possible to try and retry the individual steps successively by using the Terminal Emulator option.

GT uses portions of the Station File already setup in TELCOM. To edit the GT Station File type "GT name/E" where "name" is the Station File name; in this case it is `RFTEST`. Be sure the correct COM port and RF path are entered. After corrections are made, save the Station File and a list of options will appear. Option T (Terminal Emulator) is the option to use for troubleshooting.

A general understanding of the communication sequences is necessary to properly troubleshoot an RF link. The base station RF modem (RF95) 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 RF95 Modem has five different modes of operation; these are described in Section 3 of this manual.

At the main GT menu, chose Option T to go into the Terminal Emulator Mode. Once you are in Terminal Emulator Mode, try the following TASKs in order.

TASK A: 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.

SECTION 2. ASSEMBLING THE RADIOTELEMETRY NETWORK

RESPONSE IF SUCCESSFUL: "!" prompt given, SOL modem is now in the Local Command Mode.

Things to check if TASK A is unsuccessful:

1. Communication port (COM port) could be configured improperly.
2. The wrong COM port may be specified in the Station File.
3. Computer mouse driver could be interfering with COM port.
4. The base station or radio may not be powered sufficiently.
5. The radio and RF modem may not be connected properly.

TASK B: The RF link must first be set up; enter the 'RF Path' for communication with that field station. 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.

Things to check if TASK B is unsuccessful:

1. Improper antenna orientation.
2. Bad connections on the antenna cables.
3. Insufficient current supply at the base station.
4. Field station radio and RF modem may not be connected properly.
5. Field station radio is not connected to power.
6. Field station RF modem is not receiving 5 Volts from datalogger connection on pin 1 of the 9-pin cable.

TASK C: Establish link and baud rate between RF Modem and Datalogger by slowly pressing [ENTER] a few times.

RESPONSE IF SUCCESSFUL: "***" from datalogger.

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 keyboard 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, and then type [ENTER] to receive a datalogger status sequence from the datalogger. If everything is successful, type [CTRL] "_" or [ESC], then "Q" to quit.

SECTION 3. RADIOTELEMETRY NETWORK COMPONENTS

3.1 RF95 MODEM

The RF95 is an interface between the computer and the radio when used at a base station, and an interface between the radio and the data-logger at a field station. In a repeater station, the RF95 is an interface between two other communication stations.

The RF95 replaces Campbell Scientific's old DC95 and SDC RF Modems. The RF95 is compatible with both the DC95 and SDC Modems. Refer to Appendix F "Equipment Compatibility" for compatibility considerations.

3.1.1 PHYSICAL DESCRIPTION

The front panel of the RF95 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, PS512M or CH512R in the case of a repeater or phone-to-RF base station. The red light labeled CARRIER DETECT is used primarily to indicate when a carrier frequency has been detected by the radio. This is explained later in further detail.

3.1.2 RF95 STATES

The RF95 Modem operates in one of two separate states. The RF95 can be utilized in either the RF95-ME (Modem Enable) state or the RF95-SDC (Synchronous Device Communication) state. The proper state must be determined before employing the RF95 in the field. A switch inside the RF95 needs to be set accordingly.

The RF95-ME state is always used with 21X and CR7 dataloggers. The RF95-ME state is normally used with CR10s, also. The CR10 can also use the RF95-SDC state. The CR10 combined with the RF95 in the RF95-SDC state has the advantage that a phone-to-RF base station can have measurement capability. Only the RF95 at a phone-to-RF base station needs to be switched to the RF95-SDC state.

A switch with nine different dip switches is inside the RF95; the RF95 cover must be removed to locate the switch. The ninth switch sets the RF95 state. The RF95-ME state is chosen by setting the ninth dip switch open, represented by 1. The RF95-SDC state is chosen by setting the ninth dip switch closed, represented by 0. Refer to Figure 3-2.

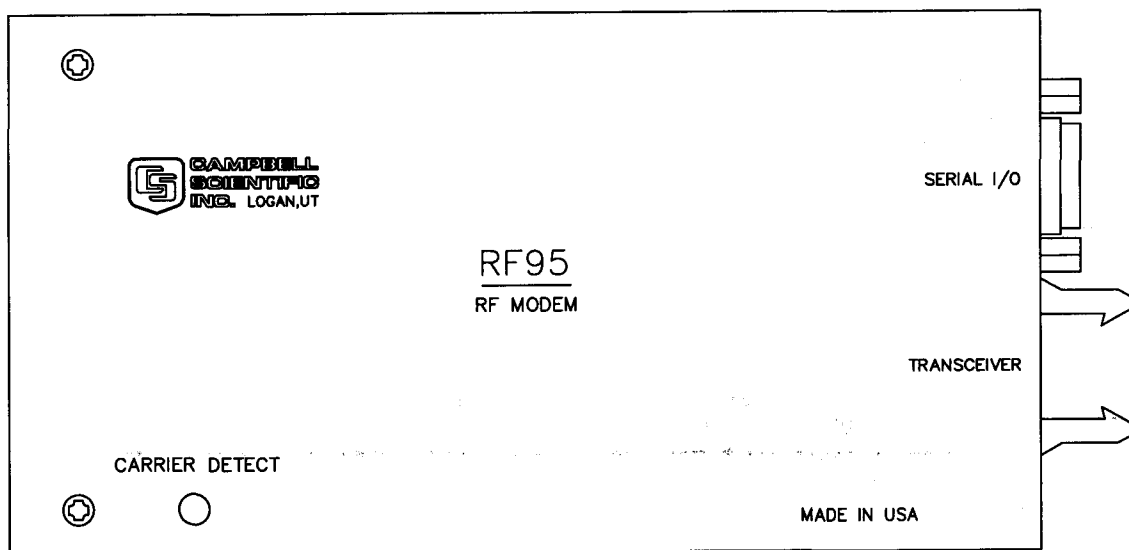


FIGURE 3-1. The RF95 Modem

SECTION 3. RADIOTELEMETRY NETWORK COMPONENTS

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 RF95 is shipped with the switch set for the RF95-ME state.

Further information on the RF95 compatibility with older Campbell Scientific equipment can be found in Appendix F "Equipment Compatibility."

3.1.3 SETTING STATION ID

Each RF95, 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 RF95. 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 RF95 state, see Section 3.1.2 "RF95 States." All RF95s are shipped with a Station ID of 1 and are set in the RF95-ME state. RF95s inside the RF base station ship with a station ID of 254.

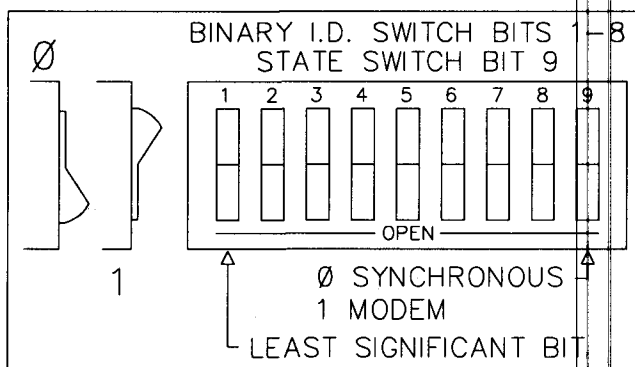


FIGURE 3-2. Setting the Station ID

3.1.4 THE CARRIER DETECT LIGHT

The Carrier Detect light on the front panel of the RF95 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 RF95 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 RF95. With the radio disconnected and the datalogger in the LOG (*0) Mode, connect the datalogger to the RF95 Serial I/O Port with a 9-pin ribbon 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 RF95 MODEM COMMUNICATION PROTOCOL

Comprehension of this section is not necessary for routine operation of the RF95 Modem. The PC208 Datalogger Support Software accounts for the necessary communication protocol.

There must be an RF95 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.

RF95 Modems must also be used at repeater stations. These RF95 Modems are termed Middle Of Link (MOL) modems.

Five general modes of operation of the RF95 Modem are:

- Wait Mode
- Local Command Mode
- Repeater Mode
- End of Link Mode
- Transparent Mode.

The RF95 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 RF95 responds to command characters received on the Serial I/O port.

The RF95 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 RF95 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 RF95 enters the Repeater Mode when it receives a valid setup block that sets the RF95 as a repeater.

The **End Of Link Mode** is entered when the RF95 receives a valid setup block that sets the RF95 as the EOL modem. Upon entering the EOL Mode, the RF95 brings the Serial I/O Ring line high which raises the datalogger ME line, thus causing the RF95 to enter the Transparent Mode. The Ring line is reset after the ME line comes high.

3.1.7 RF95 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, TELCOM establishes, maintains, and shuts down the RF link as discussed below.

3.1.7.1 Establishing the RF Link

The SOL RF95 is first brought into the Local Command Mode of operation. In the RF95-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 RF95-SDC State, the Local Command Mode is entered after addressing. Some explanation is contained in Appendix E "RF95 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.

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TABLE 3-2. RF95 Command Character Summary

<u>Command</u>	<u>Description</u>
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 RF95-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 RF95-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.
U	Old Link Command. The "U" Command will force RF communication between radios to 2400 baud rather than 3000 baud. DC95s purchased before February 1989 can only be used at 2400 baud. For further information see Appendix F.
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 RF95 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 RF95 in the link will have three RLQAs which are appended to the shutdown block. The RLQA from each RF95 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 (± 70) at the standard 3.0K baud rate, or 124 (± 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

```

                                IR
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 RF95 CONNECTIONS

The 9-pin Serial I/O connector is normally used to connect the RF95 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 3-6 contains the pinout for the radio to modem cable descriptions.

TABLE 3-4. Serial I/O Connector Description

Pin	Description
1	+5 V: Supply from external source
2	GND: Ground
3	Ring: Ring to datalogger
4	RXD: Transmit from RF95
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 RF95

3.2 RF100/RF200 RADIOS

3.2.1 RADIO DESCRIPTION

The RF100 and RF200 are 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).

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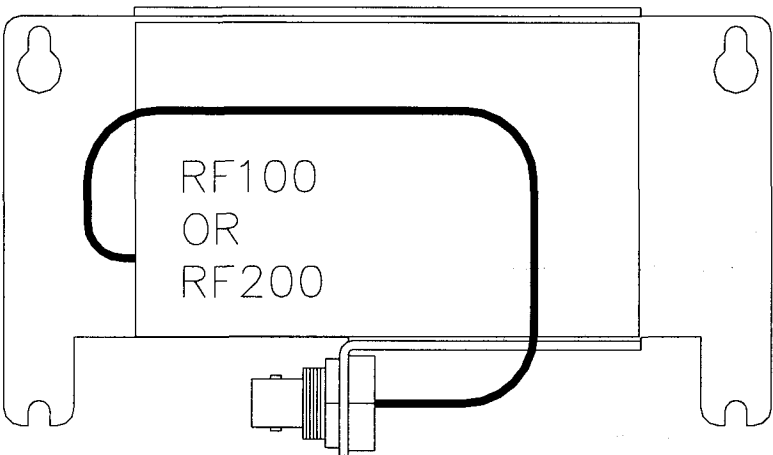


FIGURE 3-3. RF100 On Bracket With Connector

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 RF100/RF200 Radios are connected to the RF modem by a special radio cable. The first 10-pin connector on this radio cable has a red and black wire coming out of the connector. This is the 10-pin connector (labeled "radio") that should be connected to the radio. The red

and black power wires should be connected to 12V and Ground respectfully. The second 10-pin connector (labeled "RF modem") should be connected to the RF modem. Table 3-6 contains the pin out of this radio cable.

3.2.2 RADIO SPECIFICATIONS

The RF100 and RF200 radios are manufactured by E.F. Johnson. Campbell Scientific modifies the radios to work with the RF95 Modem. Table 3-5 contains a list of the main radio specifications.

TABLE 3-5. RF100/RF200 Radio Specifications

	RF100 VHF	RF200 UHF
E.F. Johnson Model No.	3420	3410
Power Output	4W	5W
Frequency (MHz)*	132-142, 142-150, 150-162, 162-174	403-430, 430-450, 450-470, 470-512
Channel Capability	1	1
Dimensions (w/o mounting)	3.6" x 2.9" x 2.2"	3.6" x 2.9" x 2.2"
Operating Temperature Range	-30°C to +60°C	-30°C to +60°C
Emissions Designator	16KOF2D	16KOF2D
Deviation	± 2.5 kHz	± 2.5 kHz
<u>Current Drain</u>		
Quiescent	30mA	30mA
Active	1.7 A	1.5 A

* DOC Compliance for 138-174 MHz and 403-470 MHz only.

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TABLE 3-6. Radio to RF Modem Pin Descriptions

RF100/RF200 Radio 10-pin	RF95 RF Modem 10-pin
1	7
2	3
3 +12V (Red)	open (4)
4	6
5	8
6	9
7	2
8	5
9 GND (Black)	open (10)
10	1

3.2.3 RADIO INSTALLATION

The RF100 and RF200 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.

1. Secure the radio and its bracket using the four screws from the RF95 Modem's lid.
2. Connect the 10-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 second 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 a radiotelemetry 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.

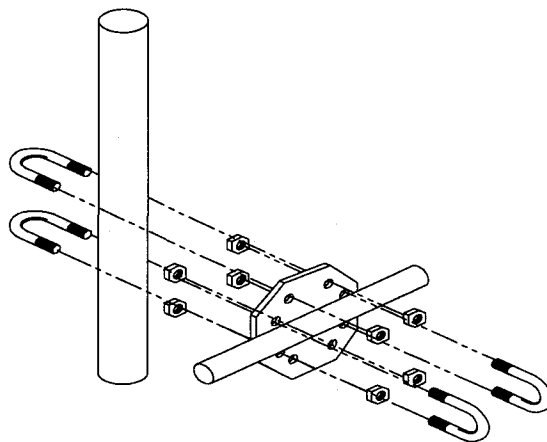


FIGURE 3-4. The PD237 Crossover Plate Antenna Mount

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

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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 3-7 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.

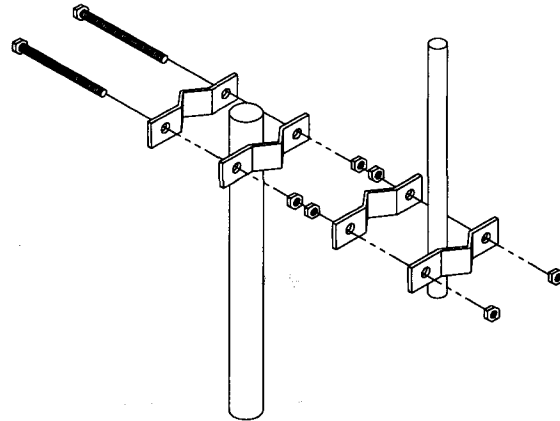


FIGURE 3-5. The PD46 Clamp Mount

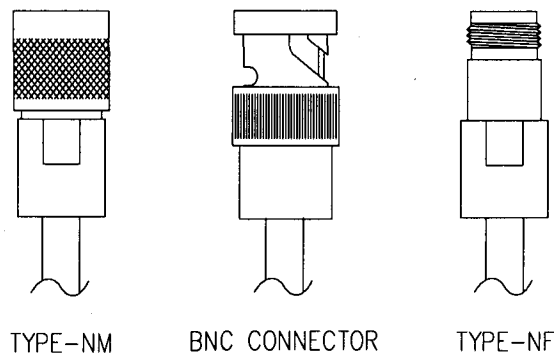


FIGURE 3-6. Type-NM (male), BNC, and Type-NF (female) Connectors

TABLE 3-7 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, UT3 Tower, and UT930 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 UT3 and UT930 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 "raintight," and are designed to mount on a tripod. Following is a description of the standard enclosures.

3.4.2.1 CR10 and 21X Enclosures

Campbell Scientific offers two enclosures for housing a CR10 or 21X 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 CR10 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 CR10 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 5 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 3-8.

The two leads from the charging source can be inserted into either of 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.

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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: Do not use the external port, labeled EXT, with 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 3-8. 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 RF232 BASE STATION

3.5.1 RF232 INTRODUCTION

The RF232 Base Station provides a "single box" desktop base station with the following features:

- Internal RF modem.
- 25-pin RS232 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 RF232 Base Station includes an RF Modem with a carrier detect light. The RF Modem sits directly behind the RF232 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 RF232's 25-pin female port connects to the computer's 25-pin RS232 port. The RF232'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 3-9 shows the pin description.

SECTION 3. RADIOTELEMETRY NETWORK COMPONENTS

3.5.2 220, 230, AND 240 VAC CONVERSION

The RF232 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 RF232 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 3-10 for the Power Conversion you require.

TABLE 3-9. Pin Description for RF232's 25-Pin Port

<u>Pin</u>	<u>I/O</u>	<u>Description</u>
1	—	Ground
2	I	TX
3	O	RX
4	I	RTS
20	I	DTR
22	O	RING

TABLE 3-10. RF232 Power Conversions

	<u>Pins Jumpered</u>	<u>Apply AC</u>
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

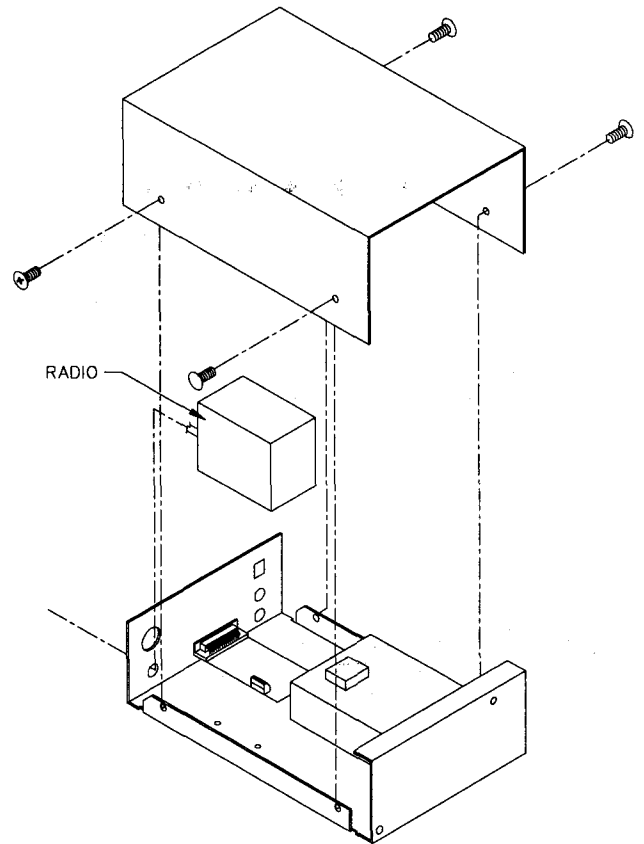


FIGURE 3-7. The RF232 Base Station

SECTION 3. RADIOTELEMETRY NETWORK COMPONENTS

RF232 TOP VIEW

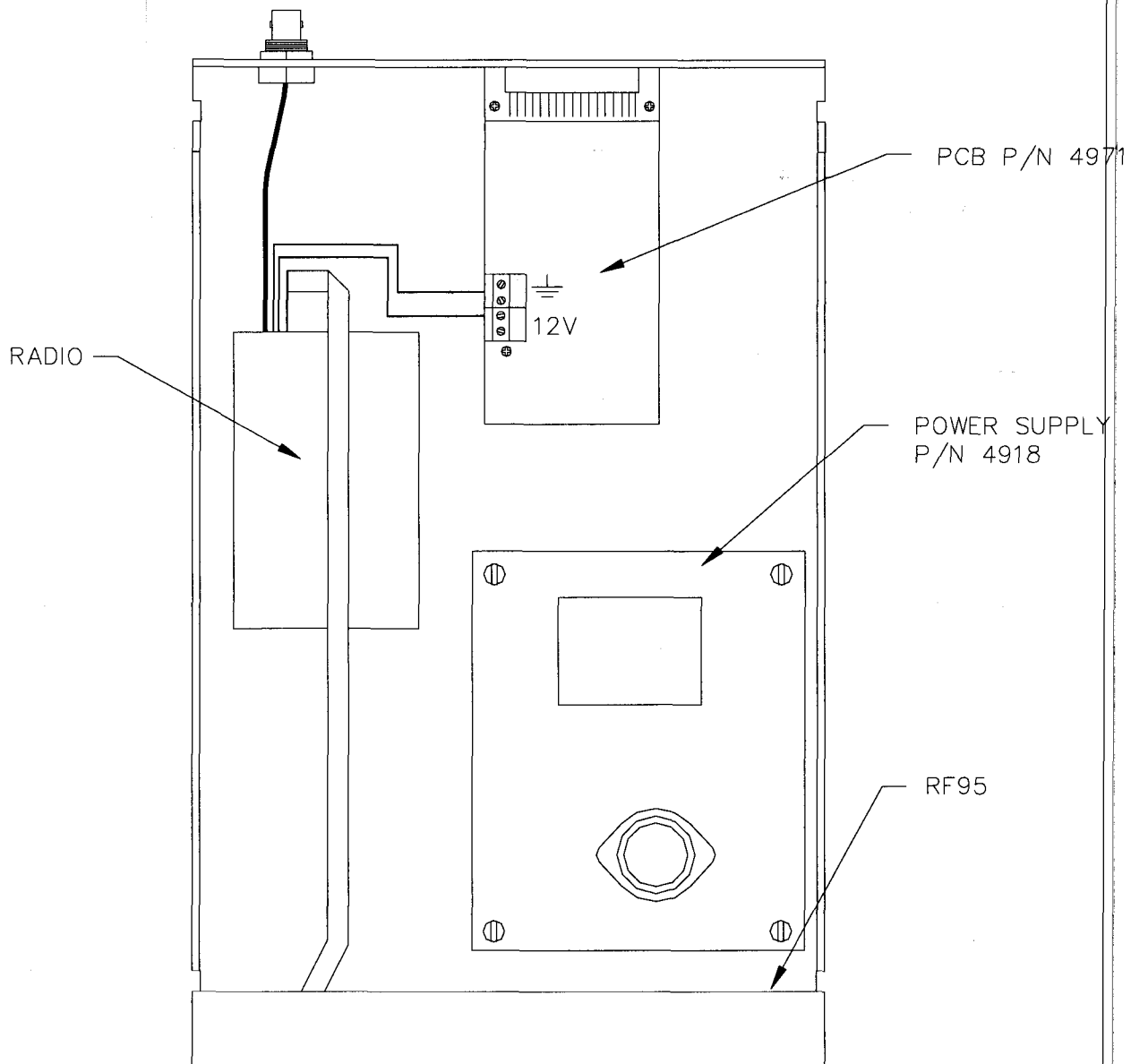


FIGURE 3-8. Top View of the RF232 Base Station

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 PC208 Datalogger Support Software as it applies to RF applications, as well as a description of some special RF applications.

4.1 MONITORING AND COLLECTING DATA - PC208 RF NOTES

The PC208 Datalogger Support Software is the key to communicating with the field stations. Complete information on the PC208 Software is included in the PC208 Manual. This section gives a brief description of data collection methods, and provides specific RF application notes.

4.1.1 COLLECTING DATA - TELCOM

TELCOM is the program for data collection. The user is required to complete a Station File which stores information such as the frequency of data collection, the datalogger type at the field station, the communication baud rate, the COM port, and the RF path.

Rather than collecting data from each field station separately, it is most efficient to create one Script File (similar to a batch file) to retrieve data from several stations. The next two subsections describe the Station File and Script File, respectively.

4.1.1.1 The Station File

A Station File must be created for each field station. The following questions must be answered in a Station File; options available are listed in parentheses. Most options are obtained by pressing the spacebar, but underlined options are obtained by pressing the "H" key.

Datalogger or Command Type: (CR10, 21X, CR7, 300 Series, DOS Command, Exit TELCOM, 21X (2 PROM), CR7 w/700 CM, CR21, DSP4, None).

Data Collection Method: (Since Last Call- Append File, Since Last Call-Create File, Most

Recent Arrays-Create, Most Recent Arrays-Append).

Final Storage Area: The CR10 Datalogger may be programmed to have two final storage areas. You can select either final storage area or a storage module when using a CR10 datalogger.

Nbr of Arrays to Backup on First Call:
Data File Format: (Comma Delineated ASCII, Printable ASCII, Same as Received From Datalogger).

Fix Datalogger Clock Using PC Clock: (No, Check Only and Report When 30 seconds off, When 30 seconds off).

Primary Call Interval (minutes):

Recovery Call Interval (minutes):

Repetitions of Recovery Interval #1:

Recovery Call Interval #2 (minutes):

Maximum Time Call Will Take (minutes):

Interface Devices: (COM Port, SC32A, Hayes Modem, RF Modem, MD9, RAD Modem, SC95 Short Haul, Generic Modem).

Questions on any of these parameters are explained in the PC208 Manual.

Two options under 'Interface Devices' will be utilized in a simple RF application. These are the COM port and the RF modem. The COM port specification is needed to access the proper RS232 port of your computer. The communication baud rate must be entered with the 'COM Port' option. The RF95 in the RF232 supports 9600 baud communication between the computer and the RF95.

SECTION 4. OPERATION OF THE RADIOTELEMETRY NETWORK

When the 'RF Modem' option is chosen, a prompt for 'Path' will appear. The RF path for any particular field station consists of the Station IDs which are in the link from the base station to the field station, excluding the base station ID number. If no repeaters are used in a link, then the RF path will have only one number which is the Station ID of the field station. If there is one repeater, then two numbers are required with a space, or comma, separating the two. The numbers listed should be the Station IDs of the repeater and field station, respectively. The Station IDs must be in the order of occurrence from the base station, and the entire path cannot exceed 40 characters.

The letter F may be added to the end of the path designation to speed communication. Example 4-1 shows an example of an RF path designation to communicate to a field station through 1 repeater. In this case, the repeater has a Station ID of 10 and the field station an ID of 95.

EXAMPLE 4-1. Sample RF Path Designation

```
Interface Device:
COM1             Baud Rate:9600
RF Modem         Path:10 95F
End
```

This example assumes use of communication port 1, and the Station IDs shown. Refer to the TELCOM section of the PC208 Manual for a description of the other parameters.

Following the creation of the Station File, type "TELCOM name/C" to collect data from the field station, where "name" is the name of the Station File. For example, data can be collected using Station File RFTEST by typing "TELCOM RFTEST/C." The data will be stored in a file called RFTEST.dat. The "/C" option after RFTEST forces TELCOM to call the station NOW whether or not it is time to call according to the calling interval specified in the Station File. Typing "TELCOM RFTEST" without the "/C" will call the field station only if the required time between calls has passed.

4.1.1.2 The Script File

The Script File contains a list of Station Files which are called sequentially for data collection without leaving TELCOM. The Script File is more than a simple batch file. Within the Script File, datalogger calls are optimized and

telecommunication control instructions are executed.

To edit a Script File, type "TELCOM name.SCR/E", where "name" is any Script File name. The extension .SCR must be entered when editing or TELCOM will assume the file is a Station File.

Attended operation allows data collection at any time. Assume there are three field stations in the network with names of HILL1, MTN, and CRK; also assume the Script File is named CALLALL. The Script File would be as follows.

EXAMPLE 4-2. Script File – Attended Data Collection

```
HILL1/C
MTN/C
CRK/C
```

All of the stations could then be called by simply typing "TELCOM CALLALL." The data would be collected and stored in files named HILL1.dat, MTN.dat, and CRK.dat according to the Station File name of each site.

Unattended operation to allow data collection at specific intervals is possible when the computer is left on. A Script File is used with the "/W" wait option. The wait option is entered at the end of the Script File. Example 4-3 shows a Script File which will call the RF Station, and then wait for the next time to call.

EXAMPLE 4-3. Script File – Unattended Data Collection

```
HILL1
MTN
CRK
/W
```

Further details of attended and unattended data collection are explained in the PC208 Manual.

4.1.2 GENERAL COMMUNICATION – GT

With the use of GT, a terminal emulator program, it is possible to download programs to the datalogger and monitor the Input Locations of the datalogger. GT has other capabilities which are explained in the PC208 Manual, but these two capabilities are commonly needed in an RF network.

4.1.2.1 Download Datalogger Programs

It is possible to create datalogger programs with EDLOG and then download the program to the datalogger from the base station. This saves the user from having to travel to the field station to program the datalogger.

Collect all data from a datalogger before you download a new program. When GT loads a program into a datalogger, all final storage memory is erased.

EDLOG is a program within PC208 to create datalogger programs. The use of EDLOG is explained in the PC208 Datalogger Support Software Manual. Once the datalogger program has been created with EDLOG, it is ready to be downloaded to the datalogger.

GT uses a Station File similar to GT; however, GT utilizes parameters from GT's Station File if the GT Station File has already been created. Type "GT name/E" to view the GT Station File, where "name" is the Station File name. Correct the Station File, if needed, and then save the file.

A list of options will appear on the screen. Download the program by selecting the "D" option. When prompted, type the name of the program to be downloaded, press [ENTER], and wait for the transfer to be completed.

4.1.2.2 View Real-Time Measurements

The Monitor Mode of GT is used to view results of instantaneous measurements. Type "GT name/E" to view the GT Station File, where "name" is the name of the Station File. Correct the Station File, if needed, and then save the file.

A list of options will appear on the screen, choose "M" to monitor the Input Locations. The Input Locations that are displayed can be changed by using the 'Locations Displayed' option at the bottom of the Monitor Mode display. While monitoring the locations, you can enter the graphics mode by pressing "G." See the PC208 manual for more information.

The Monitor Mode updates the Input Locations frequently requiring a lot of transmission time. Due to the high current drain of the radios during transmission, it is not recommended to use this form of communication for long periods of time when a solar panel is being utilized at the field station.

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).

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 PC208 Manual explains the use of call back in a telecommunications network.

APPENDIX A. SETTING THE STATION ID

Each RF95, 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
1	1000	0000X	43	1101	0100X	86	0110	1010X
2	0100	0000X	44	0011	0100X	87	1110	1010X
3	1100	0000X	45	1011	0100X	88	0001	1010X
4	0010	0000X	46	0111	0100X	89	1001	1010X
5	1010	0000X	47	1111	0100X	90	0101	1010X
6	0110	0000X	48	0000	1100X	91	1101	1010X
7	1110	0000X	49	1000	1100X	92	0011	1010X
8	0001	0000X	50	0100	1100X	93	1011	1010X
9	1001	0000X	51	1100	1100X	94	0111	1010X
10	0101	0000X	52	0010	1100X	95	1111	1010X
11	1101	0000X	53	1010	1100X	96	0000	0110X
12	0011	0000X	54	0110	1100X	97	1000	0110X
13	1011	0000X	55	1110	1100X	98	0100	0110X
14	0111	0000X	56	0001	1100X	99	1100	0110X
15	1111	0000X	57	1001	1100X	100	0010	0110X
16	0000	1000X	58	0101	1100X	101	1010	0110X
17	1000	1000X	59	1101	1100X	102	0110	0110X
18	0100	1000X	60	0011	1100X	103	1110	0110X
19	1100	1000X	61	1011	1100X	104	0001	0110X
20	0010	1000X	62	0111	1100X	105	1001	0110X
21	1010	1000X	63	1111	1100X	106	0101	0110X
22	0110	1000X	64	0000	0010X	107	1101	0110X
23	1110	1000X	65	1000	0010X	108	0011	0110X
24	0001	1000X	66	0100	0010X	109	1011	0110X
25	1001	1000X	67	1100	0010X	110	0111	0110X
26	0101	1000X	68	0010	0010X	111	1111	0110X
27	1101	1000X	69	1010	0010X	112	0000	1110X
28	0011	1000X	70	0110	0010X	113	1000	1110X
29	1011	1000X	71	1110	0010X	114	0100	1110X
30	0111	1000X	72	0001	0010X	115	1100	1110X
31	1111	1000X	73	1001	0010X	116	0010	1110X
32	0000	0100X	74	0101	0010X	117	1010	1110X
33	1000	0100X	75	1101	0010X	118	0110	1110X
34	0100	0100X	76	0011	0010X	119	1110	1110X
35	1100	0100X	77	1011	0010X	120	0001	1110X
36	0010	0100X	78	0111	0010X	121	1001	1110X
37	1010	0100X	79	1111	0010X	122	0101	1110X
38	0110	0100X	80	0000	1010X	123	1101	1110X
39	1110	0100X	81	1000	1010X	124	0011	1110X
40	0001	0100X	82	0100	1010X	125	1011	1110X
			83	1100	1010X	126	0111	1110X

APPENDIX A. SETTING THE STATION ID

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			

APPENDIX B. ALTERNATE BASE STATION CONFIGURATIONS

The basic base station consists of a computer and the RF232 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 troubleshooting 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 PC208 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 SC532 is the interface from the laptop computer to the RF95 Modem. The transformer on the SC532 should be cut off 6" up the cable. The two leads on the SC532 should be stripped and tinned for connection to a battery. Most laptops have a 9-pin RS232 port, so a 9- to 25-pin RS232 cable is needed to connect the computer to the SC532.

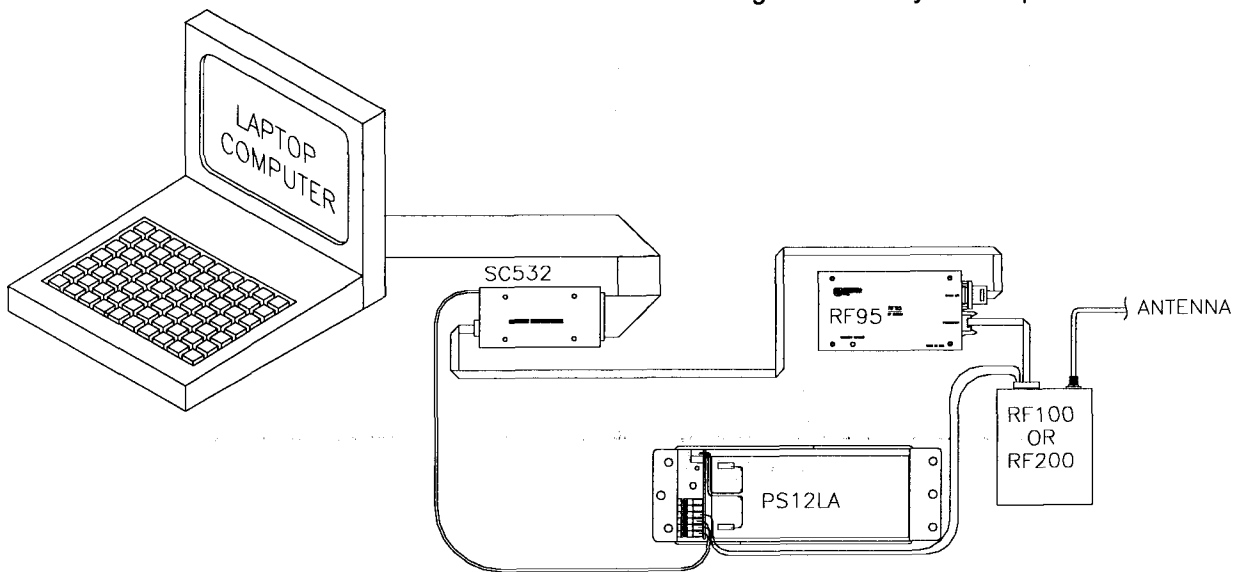


FIGURE B-1. Portable Base Station

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 PC208 Datalogger Support Software, and a Hayes phone modem can call a phone-to-RF base station. The configuration is shown in Figure B-2.

The Station File at the computer must include the following interface devices: COM Port, Hayes Modem, and then RF Path. The PS512M Power Supply and Charging Regulator supplies 5 V to the RF95 and DC112, supplies 12 V to the RF100 or RF200 Radio, and acts as a null modem between the DC112 and the RF95. The RF95 and DC112 are both connected to a separate 9-pin port on the PS512M. The RF95 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 RF95 in the RF95-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 Hayes has quit.

APPENDIX B. ALTERNATE BASE STATION CONFIGURATIONS

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 and the RF95 must be in the RF95-SDC State. This configuration 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 Station File at the computer must include the following interface devices: COM Port, Hayes Modem, and then RF Path. The DC112 Phone

Modem and the RF95 are connected to the CR10, and powered by the CR10. The RF95 Station ID at the phone-to-RF base station does not have to be 255 in this case. This is because the CR10 will automatically hold the Modem Enable line high, not being reliant on the RF95.

The datalogger at the base station should have security set. See the CR10 manual for the details of security. With security set, a password (number) is required before data can be collected. Without security, and with a CR10 at the base, data can inadvertently be collected from the base CR10 if an RF link fails during communication with another datalogger.

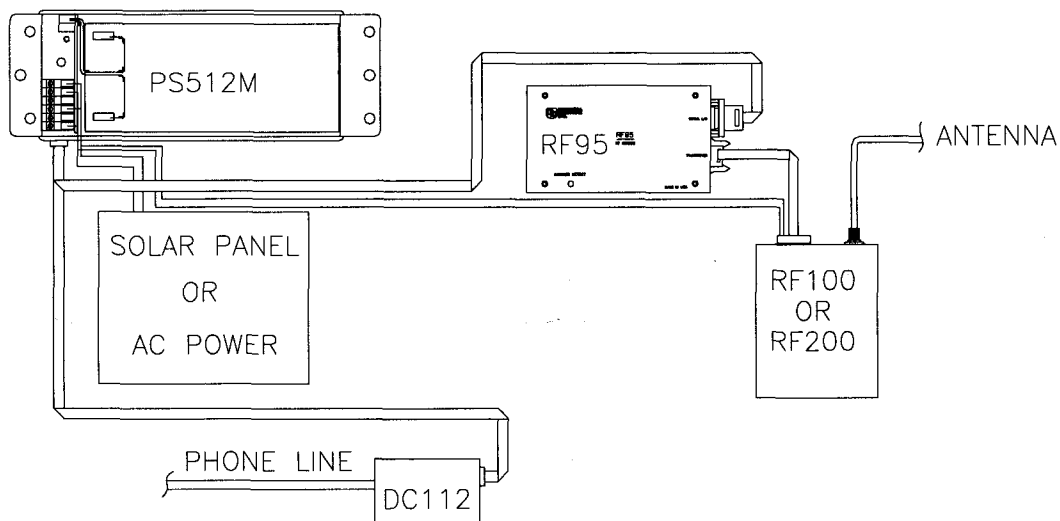


FIGURE B-2. Phone-To-RF Base Station

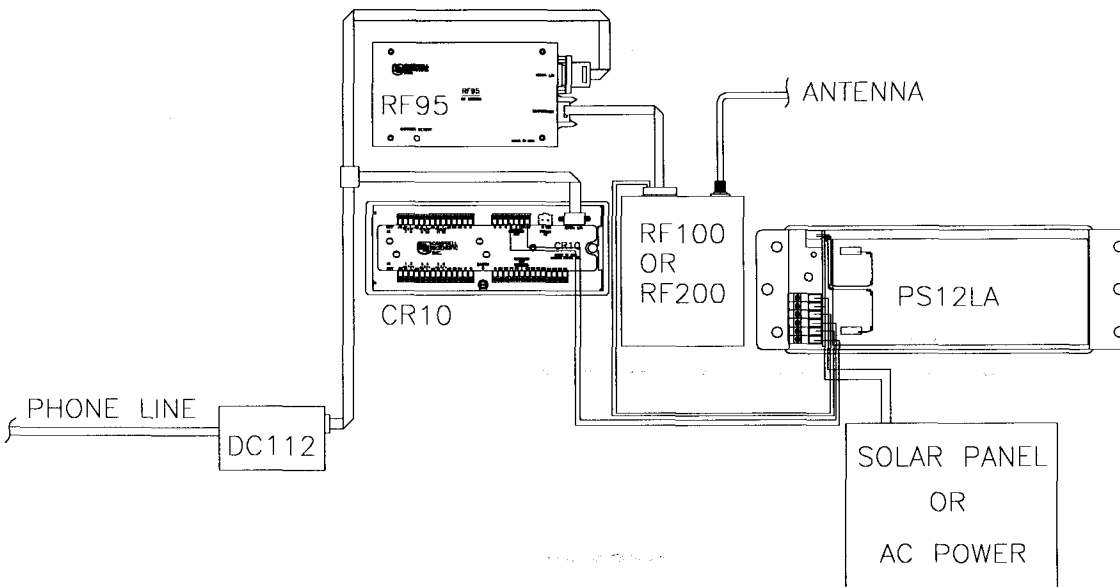


FIGURE B-3. Phone-To-RF Base Station With Measurement Capability

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 0.000000000003 Watts (3×10^{-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

$$PL = 36.6 + 20 \cdot \log(F) + 20 \cdot \log(D)$$

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

Coaxial Cable Loss

Typical coaxial cable losses are listed below.

<u>Cable Type</u>	<u>200 MHz</u>	<u>400 MHz</u>
	<u>Loss/100 ft.</u>	
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.

$$\text{dBm} = 10 \cdot \log((\text{Watts})/0.001)$$

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.

APPENDIX D. FUNDAMENTALS OF RADIOTELEMETRY

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 RF95 MODEM

The RF95 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. RF95 STATES

The RF95 Modem operates in one of two separate states. The RF95 can be utilized in either the RF95-ME (Modem Enable) State or the RF95-SDC (Synchronous Device Communication) State. The RF95-ME State is normally used for all RF networks. The RF95-SDC State must be used when there is a phone-to-RF base station with a CR10 datalogger. A switch inside the RF95 needs to be set according to the chosen state.

E.1 RF95-ME STATE

The RF95-ME State is always used with 21X and CR7 dataloggers, and normally with CR10 dataloggers.

RF95-ME State Description

The RF95 rings the datalogger until the datalogger raises the ME line. The CR10 waits approximately 40 seconds to receive carriage returns to establish the baud rate. After the baud rate is set the CR10 transmits a carriage return, line feed, "***", and enters the Telecommunications Mode. If the carriage returns are not received within the 40 seconds, the CR10 hangs up.

When the datalogger is in the Telecommunications Mode, the ME line is high, and the RF95 is subsequently in the Transparent Mode or EOL Mode depending on the relative location of the RF95.

E.2 RF95-SDC STATE

The RF95-SDC State can be used to enable a CR10 to be recording measurements at a phone-to-RF base station. The SDC State is never used with 21X or CR7 dataloggers.

RF95-SDC State Description

The RF95 obeys all Synchronous Device Communication (SDC) protocol when set in the RF95-SDC State. The CR10 has the ability to address synchronous devices. The CR10 and the RF95 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 CR10 is connected to the RF95, a 1N command is sent to the datalogger at setup.

The baud rate is set and the CR10 completes connections with the RF95. The CR10 sets the RF95 in an addressing state by raising the CLK/HS followed by or simultaneously raising the SDE line. The RF95 drops the ring line and prepares for addressing.

The CR10 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 RF95 completes addressing when the eighth bit is received.

The synchronous device capability enables the CR10 to have measurement capability at a phone-to-RF base station. A command within the address sent to the RF95 can tell the RF95 to connect to the DC112 which requires the RF95 to switch its TXD and RXD lines. Therefore all characters are routed through the DC112 to the RF95 which controls the radio accordingly.

The RF95 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 RF95 responds to the commands S, R, T, F, and U.

APPENDIX F. EQUIPMENT COMPATIBILITY

F.1 COMPATIBILITY OF CURRENT AND PAST RF EQUIPMENT

This section is to aid customers who have older RF equipment from Campbell Scientific. Table F-1 lists the different components of past and current RF systems.

TABLE F-1. Different RF Setups

	<u>Oldest Obs. RF Setup</u>	<u>2nd Obs. RF Setup</u>	<u>Current RF Setup</u>
Radios	HT90/ HT90-SDC	P50	RF100 RF200
RF Modem	DC95	RF95	RF95
Base Station	PS232	RF232	RF232

A site of one setup will communicate with a site of another setup as long as the following conditions are met:

- Both radios are set to the same frequency.
- Both antennas are oriented to receive from the other.
- Both sites are line-of-site of each other.
- Both sites are close enough together for the signal to transmit.

There are a few basic rules to remember when interfacing equipment of different setups at the same site.

1. An RF95 is a direct replacement for a DC95 when used with a 21X or CR7.
2. The RF95 Modem will work with the HT90, P50, RF100, and RF200 radios.
3. The DC95 Modem will not work with the P50, RF100, or RF200 radios.
4. Each Base Station will only physically hold the RF Modem from the same RF Setup. That is, a PS232 holds a DC95 and an RF232 holds an RF95.
5. When replacing an HT90-SDC radio, the CR10 must have current software PROMs.
6. A CR10 with old software can be used with an RF95 in the ME State, however the datalogger loses the "callback" capability as well as the SDC function.

F.2 THE "U" COMMAND

The "U" command, or Old Link command, is only needed if a DC95 with PROM 399B or 399D is being utilized at a field or repeater station and a newer DC95 PROM or an RF95 is used at the base station.

When a remote station with an RF95 (or newer DC95 PROM) is interrogated by a base station with the older DC95 PROM at the 2400 baud rate, the remote station detects the 2400 baud rate and automatically communicates at that baud rate.

When the base station modem is changed to an RF95 (or newer DC95 PROM) and there are still old DC95s in some of the remote stations, then the "U" command must be used to communicate with those stations.

The DC95 PROM numbers 399B and 399D are 2400 baud, PROM 589-1 in the DC95 enables 3000 baud. The PROM number is written on the top of the PROM which is located to the left of the ID switch under the cover of the DC95.

DC95s with the 2400 baud PROMs can be used only at 2400 baud. The "U" command preceding the setup string will force communication at 2400 baud. The "S" command precedes the U command when used with the Terminal Emulator. TELCOM and TERM otherwise add the "S" command automatically. Example F-1 shows the use of the "U" command in a setup block. The default, without a "U" command, is 3000 baud. Alternatively, DC95s can be updated with PROM 589-1 to communicate at 3000 baud.

EXAMPLE F-1. Use of the "U" Command

Path: U5 10 12 7

APPENDIX G. P50 RADIO

G.1 P50 RADIO SETUP AND SPECIFICATIONS

The P50 Radio transmits and receives data blocks. The volume, squelch, and frequency controls on the radio must be set properly.

G.1.1 VOLUME CONTROL

The volume control should be set to approximately 1/2 of the operational range. This is equivalent to approximately 9:00 assuming the off position is at 4:00. Marginal RF links can be enhanced by "fine tuning" the volume control at any respective RF station.

G.1.2 SQUELCH CONTROL

The squelch control determines the input power level that the radio will break squelch. The squelch control should be set fully clockwise or approximately 12:30.

G.1.3 FREQUENCY SWITCH

The frequency switch should always be set to 1, unless you are using a dual frequency system.

G.1.4 P50 SPECIFICATIONS

	VHF	UHF
Power output	5W	4W
Frequency (MHz)	150-174	450-470
Channel capability	2	2
Dimensions	6.7"x2.5"x1.2"	6.7"x2.5"x1.2"
Weight	15.5 oz	15.5 oz
FCC Designation	AZ489FT3729	AZ489FT4724

Current drain

Quiescent	10 mA	1.35 A
Active	15 mA	1.10 A

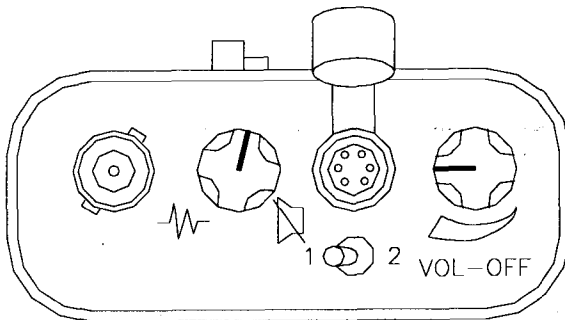


FIGURE G-1. P50 Radio Settings

G.2 ADDITIONAL TROUBLESHOOTING FOR P50 RADIO

To test a station's radio/cable/antenna transmission capabilities, a directional wattmeter is needed such as Bird Electronic Corporation's Model 4304A Wattmeter. Proper connectors are also needed to place the wattmeter in series between the radio and antenna cable. A voltmeter is required to measure the battery voltage of the datalogger with and without radio transmission.

Place the wattmeter in series between the radio and antenna cable. Set the wattmeter to the 15 Watt range, or the next highest wattmeter setting, and point the directional arrow first toward the antenna cable to measure forward power (W_f). Depress the transmit button on the radio, let the wattmeter stabilize, and write down the wattmeter reading. Reverse the directional arrow so it is pointing back toward the radio, depress the transmit button, let the wattmeter stabilize, and write down the wattmeter reading. This second reading is the reflected power (W_r). Take the square root of the quantity reflected power divided by the forward power to arrive at the square root ratio (R). Calculate the Voltage Standing Wave Ratio (VSWR) with the following equation:

$$VSWR = [(1+R) / (1-R)]$$

$$\text{where, } R = (W_r / W_f)^{1/2}.$$

The impedance of the R transmission cable (usually RG-8A/U) and antenna combination should match the impedance (50 ohms) of the radio output circuit. When the transmission cable or antenna does not match the impedance of the output circuit of the radio, not all of the energy supplied to the cable will flow into the antenna. Some of the energy supplied will be reflected back to the radio, causing 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 Voltage Standing Wave Ratio, or VSWR. The VSWR should be kept below 1.5:1 for error-free radiotelemetry.

For example, if the forward power (W_f) is 5 Watts and the reflected power (W_r) is 0.2 Watts, the VSWR is 1.5:1.

APPENDIX G. P50 RADIO

A problem has been found if the VSWR is greater than 1.5:1. The VSWR will increase when:

- The antenna is used in proximity of metal
- Transmitting inside a building
- The cable is bad
- The antenna frequency does not match the radio frequency
- There is a bad connection

If the VSWR is below 1.5:1, then that radio/cable/antenna link is good. However, be sure the antenna is oriented properly.

While at the station also check the voltage on the 12 V port both with and without the transmit button depressed. Regardless of the battery type, the datalogger requires a minimum of 9.6 Volts.

G.3 TROUBLESHOOTING WITH ATTENUATION PADS

If stations can be heard breaking squelch on this base station radio, but communication quality is poor or not being set up properly, there may be a marginal or low signal power inherent in the RF link. In this case, it is a good idea to do a signal power check with attenuation pads for each sublink in a complete RF link. Every RF link has one or more sublinks. For example, if there is one repeater in an RF link then there is a sublink between the base station and the repeater and a sublink between the repeater and the field station. The sublinks should be checked in both directions of communication.

Before proceeding, it is a good idea to calculate the theoretical signal power for each of the RF links. Appendix C of the RF Telemetry manual outlines the calculations.

Signal power must be greater than -95 dBm at the standard 3.0K baud rate transmission rate, or -80 dBm @ 2.4K baud. However, squelch will break on the radios with a power greater than -115 dBm. Therefore, there is a 20 dBm range in which the radios are not working, but may "sound" proper.

An attenuation pad inserted into the link increases the power loss of the system. If a 20 dBm attenuation pad, or two 10 dBm pads in series, is inserted into the link and subsequently the radio will not break squelch, the signal power is between -95 and -115 dBm which is below the power limit for good data transmission.

Similarly, if a 10 dBm attenuation pad is inserted in the link and the radio subsequently will not break squelch, the actual signal power is between -105 and -115 dBm. In this case, the signal power is far below the power limit. First, test the sublink of the base station to the first repeater or field station. Initially treat the base station as the transmitting station and the first field or repeater station as the receiving station. Disconnect the radio's multicolored cable from the RF modem. With somebody at each station, depress the base station transceiver button and listen at the receiving station to hear if squelch is broken. If squelch is not broken, then either the signal power is less than -115 dBm, or something is wrong with the power supply, antenna orientation, or cable connections. If squelch is broken on the receiving radio, the site can be tested with the attenuation pads to determine the approximate signal power if it is between -115 and -95 dBm.

Insert the attenuation pad(s) (20dBm) between the radio and antenna of the receiving station ONLY (most attenuation pads have a limited current capacity). Depress the base station transceiver button. If squelch is broken at the receiving station, this sublink is good in this direction. If squelch is not broken, this sublink has signal power between -95 and -115 dBm which should be corrected. Corrections can involve shortening distances, reorienting antennas, providing a better power supply, or shortening coaxial cable lengths.

If it did not break squelch with the 20 dBm attenuation pad, it is possible to decrease the attenuation to 10 dBm to determine if signal power is between -95 and -105 dBm, or between -105 and -115 dBm. This will identify if the signal power is close or far away from -95 dBm.

If it did break squelch with the 20 dBm attenuation pad, then that sublink is good in that direction. The next sublink can now be tested. Remember to place the attenuation pads at the receiving station only! If all of the sublinks were good, the same sublinks can be tested in the opposite direction. If reversing directions in a sublink gives bad results while the other direction is good, be suspicious of the transmitting radio in the bad direction and the radio's power supply.

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.

GLOSSARY

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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