Radio Test Kit
MANUAL

Goals:

- **Will radios work?**
- **What antennas are needed?**

Revision: 6/17

CAMPBELL SCIENTIFIC®

Safety

- **YOU ARE RESPONSIBLE FOR YOUR SAFETY**
- **YOU ARE RESPONSIBLE FOR THE RADIO TEST KIT**
- **Replacement Cost = $17,825**
  - A service/repair fee will be applied for damaged or lost equipment

DANGER —MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSS ARMS, ENCLOSURES, ANTENNAS, ETC. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com or by telephoning (435) 227-9000 (USA). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a hardhat and eye protection, and take other appropriate safety precautions while working on or around tripods and towers.
- Do not climb tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- You can be killed or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in contact with overhead or underground utility lines.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, whichever is greater, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

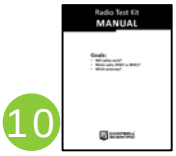
WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS , ETC.

Table of Contents

Packaging Contents

Packaging Contents (qty):

1. Shipping Case (1)
2. Base Radio Box (1)
3. Test Radio Box (1)
4. Antenna Tripod (2)
5. 6 db Yagi Antenna (2)
6. 3 db Omni Antenna (2)
7. Small Whip Antenna (2)
8. Coaxial Antenna Cable (2)
9. Clipboard (1)
10. Radio Test Kit Manual (1)



Note:
- All items need to be returned in good working order (except note sheets and batteries) to avoid repair charges.
- Contact Campbell Scientific if an item is missing, breaks, or arrives broken.

Step: 1 Review Manual

- Test Kit Operation
- Radio Network Design

Step: 2 Setup Base Radio

- Review instructions in the Base Radio lid
- The Base Radio is typically setup at “repeater” locations or at a station that will contact several other stations.

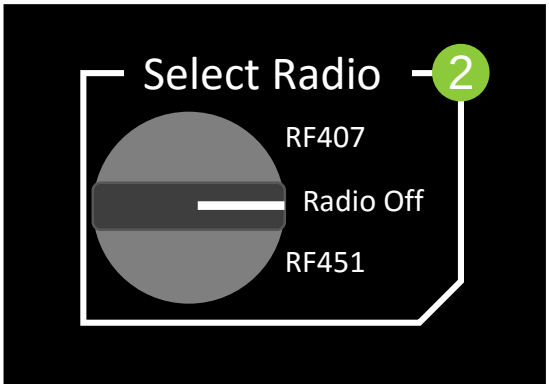
Step: 3 Setup Test Radio

- Review instructions in the Test Radio lid
- The Test Radio is used to perform the radio test and view results.
- The Test Radio can be used to communicate multiple links that all return to the same Base Radio location.
- Both the Base and Test Radio can be left on while moving around or setting up at another location.

Step: 4 Document Results

- Try multiple tests before determining Pass/Fail
- Try different antennas/attenuation before determining Pass/Fail
- Document results on the Radio Survey Sheet (included on clipboard, keep the Radio Survey Sheets, return the clipboard).
- Pass = The Test Radio tried to talk to the Base Radio, the Base Radio heard and replied back, the Test Radio heard the reply and the test is considered a pass.

RF407 vs RF451



Which Radio

Radio	Range[1]	Current Drain[2]	Cost[3]	Notes
RF407	Short Range (generally less than 2 miles)	Transmit: <80 mA Receive: 15 mA Stand-by: <0.5 mA	< $500	The RF407 is 0.25 watt radio, generally used for short distances (< 2 miles). The networks are generally a little simpler because a radio can be configured to talk with any other radio in the network.
RF451	Longer Range (2-60 miles[1])	Transmit: 650 mA Receive: 40 mA Idle: 15 mA Sleep/Remote: 6 mA	< $1,000	The RF451 is 1.0 watt radio, generally used when a little more power is needed, for example: longer distances. Networks are setup with a radio Master/Slave type network. Only one master radio per network.

[1] Distances can significantly increase/decrease depending on site conditions (hence the test)
[1] Vegetation, water, fog, poor line of site, and caves attenuate radio signals
[2] Additional power considerations can be taken to conserve power through programming and settings
[3] Cost is referring to the radio only and is approximate, cost does not include cables, antennas, or mounting equipment

Tips:

- An RF407 **can not** talk with an RF451
- When adding to existing radio networks, use the same radio if possible.
- A more powerful transmit power (RF451) may work better in areas with competing radio noise (cities and industrial areas).

Still want to know more?

Take a look at these other sections in this manual:

- **RF407 Network Basics** (page 10)
- **RF451 Network Basics** (page 11)
- **Radio History** (page 12)

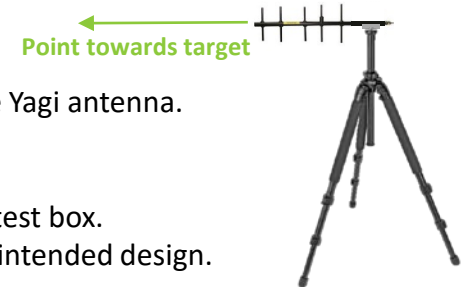
Campbell Scientific also writes product manuals, the RF407 & RF451 manuals contain more in-depth discussions about networks and specific settings. Specific product manuals are available at www.CamplbellSci.com.

Antenna	Comments
Yagi Antenna 	• Must be pointed at target • Mounted outside (requires cable) • Greatest distance radio shot • Antenna can be elevated • Surge protection recommended
Omni Antenna 	• Signal goes all directions • Mounted outside (requires cable) • Good for repeaters/base stations • Antenna can be elevated • Surge protection recommended • Typically mounted vertically
Whip Antenna 	• Signal goes all directions • Mounted in the enclosure (non-metal enclosures) • Good for close communications • Elevation limited to height of box

Antenna Tips:

- The Radio Test Kit includes the three most commonly used antennas with the RF407 & the RF451 radios, other antennas are possible/available.
- If a radio is going to talk to multiple locations, it will likely require an Omni antenna.

Tripod Setup:



- The tripod is used to position the Omni or the Yagi antenna.
- Set tripod at desired height.
- Attach antenna.
- Connect cable between the antenna and the test box.
- Antennas should be positioned similar to the intended design.

Antenna Connection:

- The antenna connection is located on the outside of the box in a protected location.

Test Setup

Base Radio Steps:

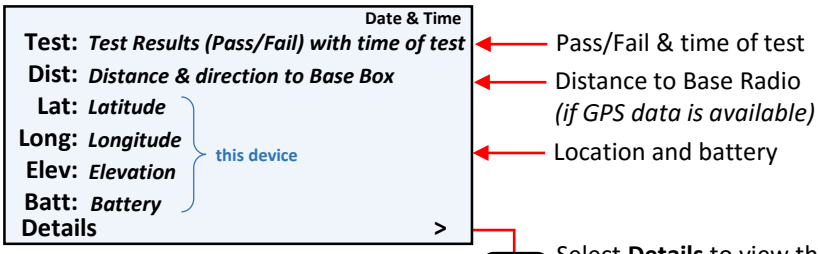
1. Position box
2. Review instructions in the Base Radio lid
   - Connect **Antenna**
   - Choose radio with **Select Radio**
   - Turn on **Power**

Test Radio Steps:

1. Go to the second location, position box
2. Review instructions in the Test Radio lid
   - Connect **Antenna**
   - Choose radio with **Select Radio** (radios must match)
   - Turn on **Power**
   - Push **Test** button
   - Repeat test as necessary with different antennas/attenuation

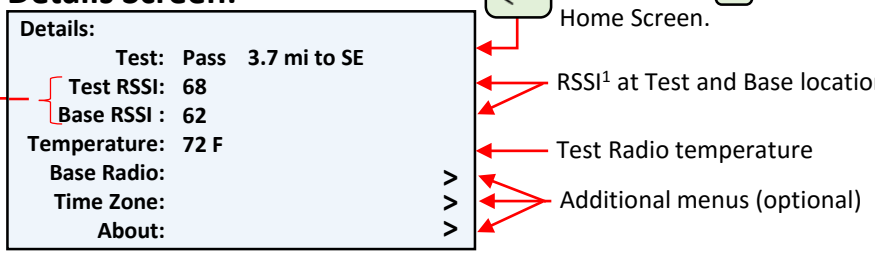
Display Screen:

Home Screen:



Select **Details** to view the details screen. Press Esc to return to Home Screen.

Details Screen:



[1]Received Signal Strength Indicator (RSSI) is a relative indicator of the incoming radio signal quality. RSSI is measured in –dBm and applies to the last received packet from the last RF hop. Because RSSI is a relative indicator, it is difficult to quantify an exact value that should be obtained for a good radio link. The RSSI is useful to evaluate:

- Directional aim of a Yagi antenna
- Effects of antenna height and location
- Alternative (reflective) paths
- The effects of vegetation & weather

RSSI	Signal Quality
< -80	Poor
-80 to -50	Good
> -50	Excellent

Radio Signal Attenuator:

The attenuator is used to determine the amount of margin you have in your radio link. The attenuator can introduce up to 40 dB of attenuation in 10 dB increments. It is recommended to perform a test with no attenuation (switch in down position) and increase attenuation until test failure. A good radio link will support at least 10 dB of attenuation (link margin).

Radio Link Analysis

A radio link contains gains (transmitter power, antenna gains, and receiver sensitivity gain) and losses (cable loss and path loss). For a radio network to work, there must be more gains than losses.

Larger or directional antennas and antenna height increase gains, poor line of sight (trees, hills) introduce losses (path loss). The following equations and values are used to explain a generic link analysis. All numbers are approximate and testing should be used to verify any radio link analysis. It is recommended that 6 to 10 dB of link margin be maintained in a good radio link.

Link Analysis Equation

$$\left(\begin{matrix}\text{Radio}\\\text{Transmit}\end{matrix}\right) - \left(\begin{matrix}\text{Cable}\\\text{Loss}\end{matrix}\right) + \left(\begin{matrix}\text{Antenna}\\\text{Gain}\end{matrix}\right) - \left(\begin{matrix}\text{Free Space}\\\text{Loss}\end{matrix}\right) - \left(\begin{matrix}\text{Receiver}\\\text{Sensitivity}\end{matrix}\right) - \left(\begin{matrix}\text{Cable}\\\text{Loss}\end{matrix}\right) + \left(\begin{matrix}\text{Antenna}\\\text{Gain}\end{matrix}\right) > 0$$

Example Values

Radio Transmit Power		
Radio	Milliwatts	dBm
RF401A	100	20
RF407	250	24
RF451	1000	30

Antenna Gain	
Antenna	Gain (dBd)
Small Omni	0
Large Omni	3
Yagi[1]	6

[1]The Yagi antenna included with the Radio Test Kit has a 6 dB gain, a 9 dB gain is available for the RF407

Cable Loss[1]	
Cable Type	Loss (dBm/10 ft)
COAX RSPMA[2]	1.11
COAX NTN[3]	0.45

[1]The antenna loss does not include additional loss from any other components (for example, surge suppressor).
[2]This is the cable that is included and used in the radio test kit.
[3]This cable is generally recommended for cable lengths above 10 ft.

Receiver Sensitivity (dBm)	
RF401A	–109
RF407	–109
RF451	–108 to 110

Path Loss (915 MHz)[1]	
Distance (mi)	Loss (dBm)
1	96
2	102
4	108
8	114
10	116
16	120
22	123
26	124
30	125

[1]The values presented are generic and intended to show a relative loss. Actual conditions can vary significantly and are influenced by:

- Vegetation
- Water
- Weather
- Surrounding terrain (hills)
- Antenna height

Note:
Please refer to the Campbell Scientific radio manuals for a more complete discussion about specific values for a link analysis.

The included Radio Survey Field Sheets may be used to document radio test results. The last page of the manual (both hard copy and online) contains a blank Radio Survey Field Sheet that can be copied or printed if additional sheets are needed.

Field Notes Example:

RADIO SURVEY FIELD SHEET

Operator: John Hendrix | Project: Ontario Creek Groundwater Study | Page: 1 of 3

Date: Aug 18, 1969 | Weather: +/- 75 F°, Clear skies, light wind from NE

Radio Survey: MW-7 to City Pump House

Testing Results

Attenuator	0	10	20	30	40
PASS	X	X	☐	☐	☐
FAIL	☐	☐	X	☐	☐

Radio Type

☒ RF407 — Test RSSI: 54, Base RSSI: 58

☐ RF451 — (RSSI not available)

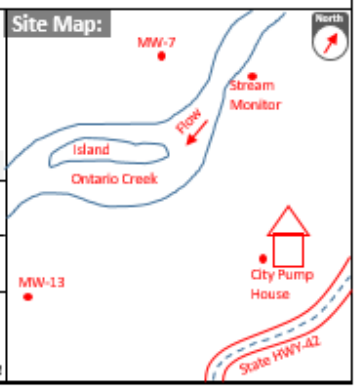
	Location	Latitude	Longitude	Elevation	Antenna
Test Radio	MW-7	41.74025 N	111.84176 W	4586	☒ Small Whip ☐ Large Omni ☐ Yagi
Base Radio	City Pump House	41.78757 N	111.80112 W	4612	☐ Small Whip ☒ Large Omni ☐ Yagi

Notes: The radio at MW-7 has a clear view of the pump house radio location

Radio Distance: 1.1 mile

GPS Datum: WGS84

Site Map:



Radio Survey: MW-7 to City Pump House

Testing Results

Attenuator	0	10	20	30	40
PASS	X	X	X	☐	☐
FAIL	☐	☐	☐	X	☐

Radio Type

☒ RF407 — Test RSSI: 60, Base RSSI: 51

☐ RF451 — (RSSI not available)

	Location	Latitude	Longitude	Elevation	Antenna
Test Radio	Stream Monitor	41.76547 N	111.82458 W	4553	☐ Small Whip ☐ Large Omni ☒ Yagi
Base Radio	City Pump House	41.78757 N	111.80112 W	4612	☐ Small Whip ☒ Large Omni ☐ Yagi

Notes: A larger antenna was required to get above the vegetation located in the stream channel, antenna was approximately 8 feet off the ground.

Radio Distance: 1.1 mile

GPS Datum: WGS84

Site Map: See Above

Radio Survey:

Testing Results

Attenuator	0	10	20	30	40
PASS	☐	☐	☐	☐	☐
FAIL	☐	☐	☐	☐	☐

Radio Type

☐ RF407 — Test RSSI: ____, Base RSSI: ____

☐ RF451 — (RSSI not available)

	Location	Latitude	Longitude	Elevation	Antenna
Test Radio					☐ Small Whip ☐ Large Omni ☐ Yagi
Base Radio					☐ Small Whip ☐ Large Omni ☐ Yagi

Notes:

Radio Distance:

GPS Datum: WGS84

Site Map:

RF407 Network Basics

Summary

An RF407 location (with or without a datalogger) can talk with any other RF407 location within radio communication distance. RF407 locations that can't talk directly with each other can communicate through the use of repeater stations. Generally, PakBus™ communications are used to handle communications between the RF407 locations. A PakBus™ address is a unique number identifier assigned to components within the system. Generally, a single PakBus™ address is used to represent a station (datalogger & radio). Standalone radios (repeaters) will have their own PakBus™ address. In the examples below, the blue numbers represent the PakBus™ address to help illustrate basic network concepts.

Point-to-Point

Point-to-point is the simplest design. It is used to communicate between two locations like datalogger to datalogger (Ex. A) or computer to datalogger (Ex. B).

PakBus™ Note

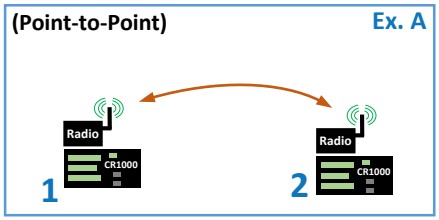
Each station (datalogger + radio) or repeater requires a unique PakBus™ address in the network. Datalogger support software (*LoggerNet*) has a PakBus™ address >4000 to help the network understand communication priorities. The default address of LoggerNet is 4094. If multiple computers talk to a single datalogger, the *LoggerNet* PakBus™ addresses must be unique (Ex. C).

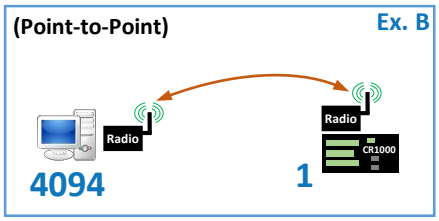
Multi-Point

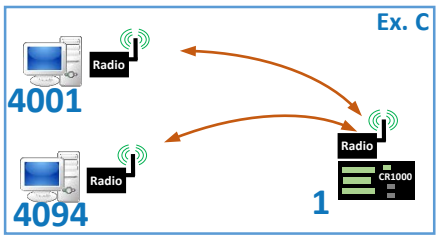
A multi-point network is an advanced data acquisition system network. Dataloggers can talk with other dataloggers. Generally, a single datalogger will have an outside connection to the world (internet) that connects the entire network back to the office computer (*LoggerNet*) through a single Ethernet or cellular connection (Ex. D).

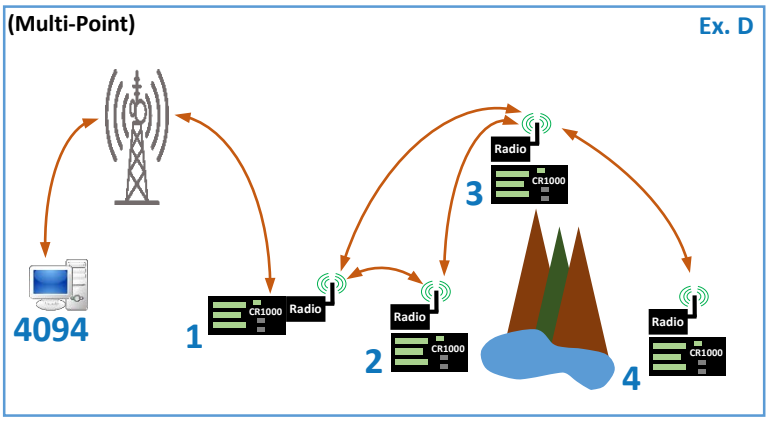
Tips:

- Repeaters work harder than other radios requiring more power (larger solar panel/batteries).
- A datalogger setup as part of a repeater station needs to be a router.









IMPORTANT Field Test Note

The Radio Test Kit tests a single point to point link. You can test a complex radio network by evaluating each point-to-point link.

Summary

Many of the concepts illustrated in the RF407 Network Basics also apply to RF451 networks. RF451 networks behave slightly different than RF407 networks with the introduction of master/slave radios. An RF451 network requires a master radio to coordinate all of the radio traffic. If a radio is not a master radio, it is a slave radio. PakBus™ communications are still used in an RF451 network. Master and slave settings are assigned in *Device Configuration Utility* (*DevConfig*) or *Network Planner* to each radio. Please note, the master radio requires more power. The examples below show PakBus™ addresses in blue, master or slave is also illustrated. our network may be similar or different to the examples below.

Point-to-Point

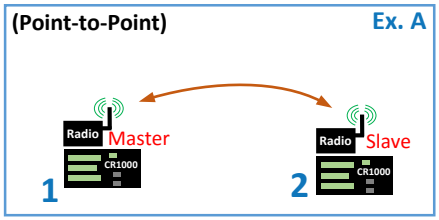
Point-to-point is the simplest design. It is used to communicate between two locations like datalogger to datalogger (Ex. A) or computer to datalogger (Ex. B).

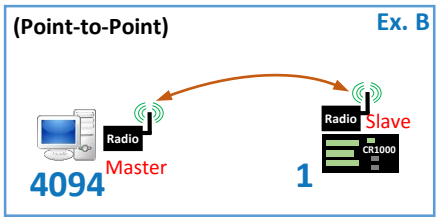
Multi-Point

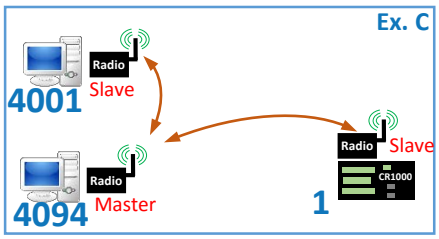
A multi-point network is an advanced data acquisition system network. Dataloggers can talk with other dataloggers. Generally, a single datalogger will have an outside connection to the world (internet) that connects the entire network back to the office computer (*LoggerNet*) through a single Ethernet or cellular connection (Ex. D).

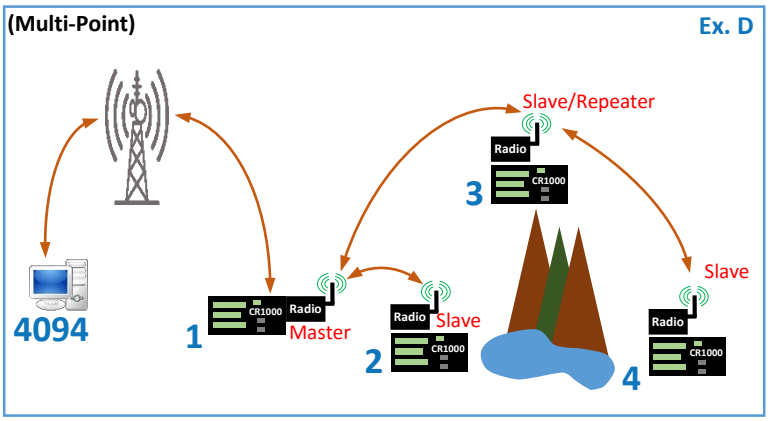
Tips:

- Masters & Repeaters work harder then other radios requiring more power (larger solar panel/batteries).
- There is only one RF451 master in a network. It must be connected to a PakBus™ router. A datalogger can be configured as a router or a PC can be a router with *LoggerNet* or *PC400*.
- The RF451 radio manual (available at www.campbellsci.com is a good resource to better understand various network configurations.
- A slave can only talk to a repeater or master.









Radio History

Campbell Scientific has built radios for 25+ years, we know it is confusing to figure out which radios talk to other radios. Here is a brief history of radio technology w/ notes so you can understand what new radios work with other types of older radios. The radio table below is setup to show that radios in the same color talk with other radios in that color.

Radio :	Status:	Tx Power & Frequency:	Notes:
RF400	*Retired*	**0.1** Watts 910-918 MHz	- Replaced by the RF401 - Used with RF401/RF401A networks when ALL of the RF401/RF401A radios are set to transparent mode - RPSMA antenna connection
RF401 / RF430	*Retired*	**0.1** Watts 910-918 MHz	- Replaced by the RF401A, compatible with RF401A radios - Retired for parts obsolescence - RF430 has USB connection, otherwise the RF401 & RF430 are the same - RPSMA antenna connection
RF401A	Available	**0.25** Watts 910-918 MHz	- Maintain existing RF401 networks, **new networks should use the RF407** - 2.5 times stronger transmit power than RF401 - USB connection on all RF401A radios - Upgradeable to RF407 (upgraded by Campbell Scientific) - RPSMA antenna connection
RF407	Available	**0.25** Watts 902-918 MHz	- ONLY talks with RF407 radios - **Recommended for new networks (instead of RF401A)** - Faster data rates than a RF401A - RPSMA antenna connection
RF450	Retired	**1.0** Watts 902-928 MHz	- Only talks with RF450 & RF451 radios - Replaced by the RF451 - Retired for parts obsolescence - **SMA** antenna connection
RF451	Available	**1.0** Watts 902-928 MHz	- Only talks with RF450 & RF451 radios - **Recommended for new networks (when higher power is needed)** - Maintain existing RF450 networks - Smaller radio (physical size) - **RPSMA** antenna connection

??? RPSMA vs SMA ???

- This is referring to the antenna connection on the radio. For various reasons beyond the scope of this document, the RF450 radios had a different connection. In an effort to standardize antenna connections on the 900 MHz radio family, current and future radios will use the RPSMA antenna connection.
- Confused about which antenna or antenna cable to order with a radio. The Ordering tab lists the available antennas and cables that work with that specific radio.

RPSMA

RPSMA has the pin on the radio

SMA

SMA has NO pin on the radio

Step: 1 Clean and Decontaminate all Equipment

- The equipment arrived clean, it should be returned clean

Step: 2 Package Equipment in Shipping Case

- Repackage similar to how it arrived
- Detailed packing instructions are included in steps 3-5
- Radio Survey sheets can be kept (not the clipboard)
- It is ok if the batteries are low or dead (new batteries are included with each rental)

Step: 3 Pack Radio Boxes and Tripods

- Put foam on bottom of black shipping case
- Place Radio Boxes with handles towards hinge
- Place tripods in the remaining space

Step: 4 Pack Clipboard & Cables

- Put bubble wrap on top of radio boxes and tripods
- Place clipboard/Manual as shown
- Coil antenna cables in bag with small antennas
- DO NOT OVERBEND ANTENNA CABLES

Step: 5 Pack Large Antennas

- Place eggshell foam on top of cables/clipboard
- Wrap each large antenna in bubble wrap
- Place Omni antennas
- Place Yagi antennas
- Place remaining bubble wrap on top
- Close lid. **DO NOT FORCE.** Everything should fit

Step: 5 Mail the Radio Test Kit

- Return Shipment Label is included with each rental
- Apply Return Shipment Label on top of the existing shipping label
- Mail with the carrier specified on the Return Shipping Label

Help

Shipping questions:

- Logistics Coordinator (435) 227-9812

Technical questions:

- Contact your Application Engineer or CSI General Support: (435) 227-9100

Return Shipment Address:

- Campbell Scientific, Inc.
  Attn: Logistics Coordinator
  815 W 1800 N
  Logan, UT 84321

RADIO SURVEY FIELD SHEET

Operator: Project: Page:

Date: Weather:

Radio Survey:

Testing Results					
Attenuator	0	10	20	30	40
PASS	☐	☐	☐	☐	☐
FAIL	☐	☐	☐	☐	☐

Radio Type	
☐ RF407	☐ RF451
Test RSSI:________ *Base RSSI:________*	*(RSSI not available)*

	Location	Latitude	Longitude	Elevation	Antenna
Test Radio					☐ Small Whip ☐ Large Omni ☐ Yagi
Base Radio					☐ Small Whip ☐ Large Omni ☐ Yagi

Notes:

Radio Distance:

GPS Datum: WGS84

Site Map:

North

Radio Survey:

Testing Results					
Attenuator	0	10	20	30	40
PASS	☐	☐	☐	☐	☐
FAIL	☐	☐	☐	☐	☐

Radio Type	
☐ RF407	☐ RF451
Test RSSI:________ *Base RSSI:________*	*(RSSI not available)*

	Location	Latitude	Longitude	Elevation	Antenna
Test Radio					☐ Small Whip ☐ Large Omni ☐ Yagi
Base Radio					☐ Small Whip ☐ Large Omni ☐ Yagi

Notes:

Radio Distance:

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