Troubleshooting tips

Large radio networks
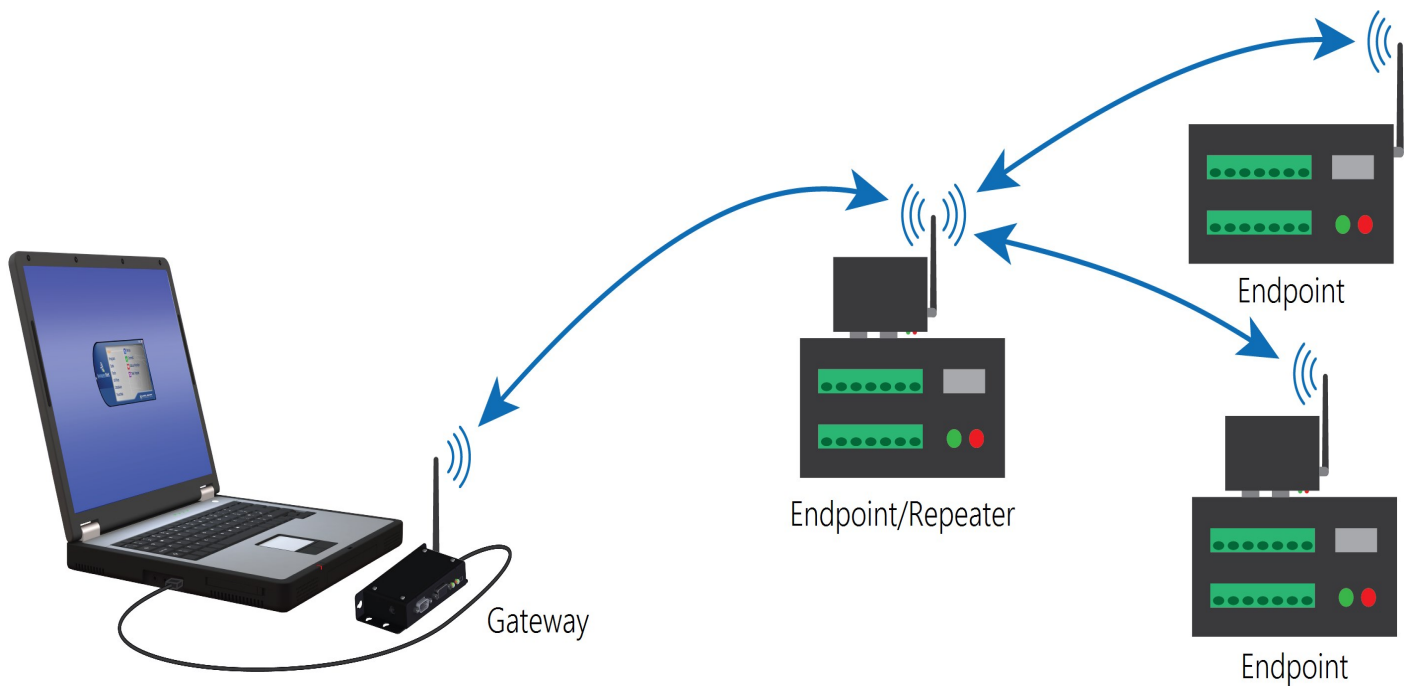
Endpoint

Endpoint/Repeater

Gateway

Endpoint

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1. Introduction

In large networks, it can be challenging to achieve reliable spread-spectrum radio communications. A network with ten or more radios is considered large for the purposes of this paper. Use the following guide to troubleshoot or optimize your Campbell Scientific frequency-hopping spread-spectrum network.

Campbell Scientific frequency-hopping spread-spectrum radios include the following:

- RF401A
- RF407-series (includes RF412, RF422, and RF427)
- RF452, RF451, and RF450

> **NOTE:**
> While RF401A, RF407-series, and RF451/RF452 radios have overlapping frequencies, each radio model communicates with a different protocol and they are not able to communicate with each other. If you are using different radio models, close to one another, expect them to interfere with each other.

2. Perform a physical inspection

Perform a physical inspection if your network has been deployed for an extended period of time and has developed communications problems. Look for the following:

- Water intrusion
- Low battery power
- Physical site changes such as a new building or wall, or matured vegetation. See Verify line-of-sight (p. 2) and Base antenna siting (p. 13).
- Corrosion on an antenna, antenna cable, or CS I/O cable connecting the radio and data logger

3. Verify line-of-sight

Ensure that each radio antenna location provides for line-of-sight with the other radios it will be communicating with. A good way of explaining line-of-sight is that the top of one radio antenna can see the antenna of the other radio (perhaps with binoculars); the view is not obstructed by objects such as hills, trees, or buildings. If you do not have line-of-sight, radio communications will be unreliable. For more information see:https://www.campbellsci.com/blog/line-of-sight-more-than-meets-eye ☑ .

4. Avoid using PakBus nodes

(RF407-series and RF401(A) only)

PakBus nodes are necessary when using the radio, without a data logger, to operate as a PakBus router, similar to a standalone repeater. PakBus nodes are also used when interfacing another peripheral with a PakBus link (such as an NL201 or NL241). If you don't have a specific reason such as these, then ensure radios are not unnecessarily operating as PakBus nodes. Often this creates unnecessary PakBus routing that slows down communications.

Check radio setting in the *Device Configuration Utility* > **Settings Editor** > **Main** > **Protocol**.
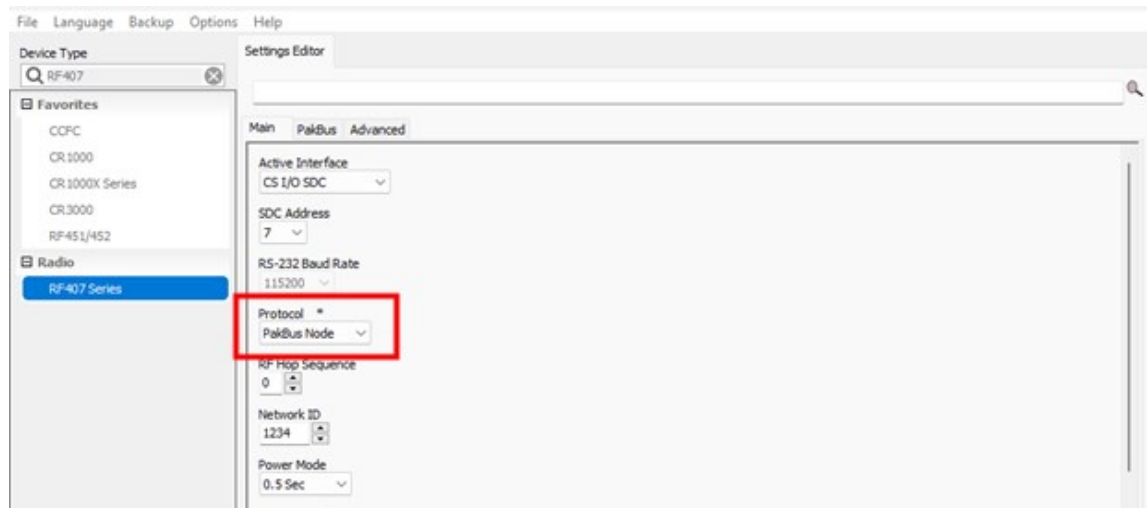
5. Verify consistent repeater settings

(RF450/451/452 only)

If using a repeater in your radio network, turn on the **Repeaters Used** setting in all radios. By default, this setting is turned off. If you make changes to your network and you no longer have repeaters, ensure the setting is turned off in all radios. Find this setting in the *Device Configuration Utility* under the **Deployment** tab > **Repeaters Used**.
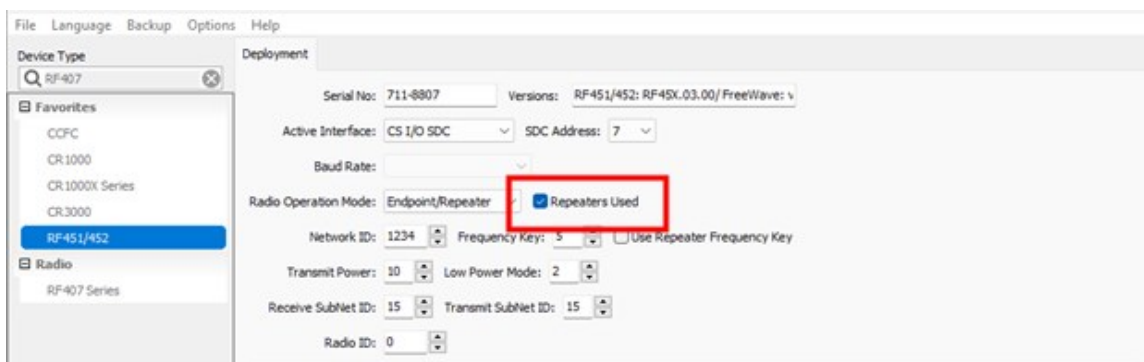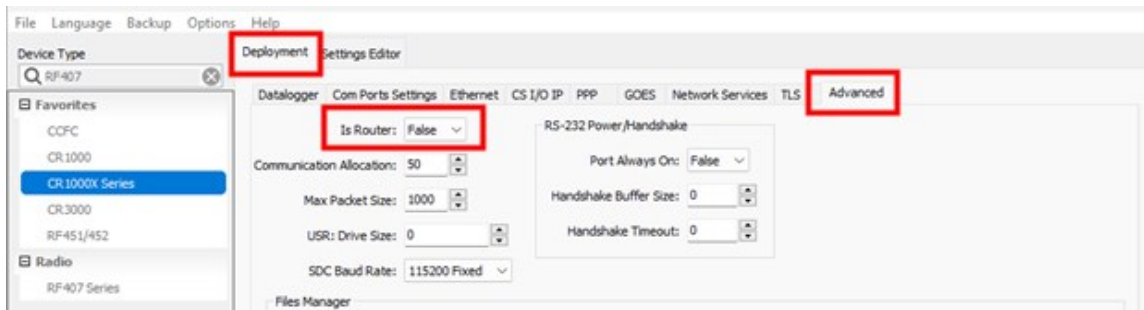

6. Routers

A data logger, when set up as a router, can transmit PakBus packets from one port to another. A data logger configured as a router maintains its own list of neighbors and shares this list with other routers in the PakBus network. It also receives neighbor lists from other routers. Routers keep a routing table, a record of recognized nodes and routes. A router exclusively accepts and transmits packets meant for recognized devices.

6.1 Limit the number of routers

Limit which data loggers operate as PakBus routers. Every device that is set up as a PakBus router communicates with all other routers in the network to exchange the routes to other PakBus devices in the network. When there are a lot of PakBus routers unnecessarily exchanging route information over the same radio network, this exchange can delay normal PakBus data traffic. To determine if a data logger or other PakBus device needs to be a router, ask yourself the question: Does another PakBus device need to route through this device to another PakBus device? If the

answer is no, then turn off the router setting for the device. This data logger setting can be found on your data logger in the *Device Configuration Utility* under **Deployment** > **Advanced** > **Is Router**.

6.2 Designate Central Routers

In networks with several essential PakBus routers, where connections might involve multiple router hops to reach a data logger, the **Central Routers** setting can be used to reduce radio traffic. By default, PakBus routers share their routing tables. This can lead to unnecessary network traffic. To address this, use the **Central Routers** setting on all PakBus routers, excluding the **Central Routers**.

> **NOTE:**
> A PakBus Network can have a maximum of eight **Central Routers**.

When a data logger connects to one or more **Central Routers**, it functions as a *Branch Router*. In this role, it only needs to maintain records of neighbors within its own branch. When configured this way, the data logger disregards neighbor lists from addresses in the **Central Routers** setting. It forwards messages to the nearest default router if it lacks the destination address in its routing table. This significantly reduces unnecessary traffic caused by routing table updates on the network.

This data logger setting can be found on your data logger in the *Device Configuration Utility* under **Settings Editor** > **Advanced** > **Central Routers**.

> **NOTE:**
> Central Routers are not used in smaller PakBus networks where multiple routers are not needed to reach a data logger.

7. Use neighbor lists

Best practice is to use neighbor lists instead of beaconing in most radios. Beaconing is a common form of initiating a hello exchange between PakBus devices. It establishes two devices as PakBus neighbors enabling them to communicate with one another. A beacon happens at a specific time interval, such as every 60 seconds, to keep the communications path available between two neighbor devices. If every device connected to a radio is beaconing at the same time on a large radio network it can create unnecessary congestion between devices. The best practice is to turn off beaconing for devices that don't need it. If two devices are communicating with one another, only one needs to have a neighbor list or beacon for the other to communicate with it.

In practice, if each station can communicate directly with the base station data logger, then only the base station data logger needs to beacon. In this situation, setting the beacon interval for the base station to one hour should be sufficient. If other leaf data loggers must communicate through another data logger to reach the base station, then instead of beaconing they should use a neighbor list to communicate with the data logger (neighbor) next to them. To turn the beacon setting off and use a neighbor list instead, use the *Device Configuration Utility*. Navigate to the **Deployment** tab > **ComPorts Settings** tab > Select the **ComPort** you wish to adjust the setting for > **Beacon Interval** and set the value to **0**.

Next, set up a neighbor list. The allowed neighbor list is set up on the same tab on the right; enter the range of PakBus addresses the data logger will communicate with. On the bottom left of the **Neighbors** section enter the beginning of the range. On the right, enter the end of the PakBus address range. Click the **Add Range** button. Do not include the device's own address in the range. If you need to leave one address out of your range use two ranges such as 2 to 5 and 7 to 9. Only add the neighbor addresses that this device will communicate with through the specified interface (ComPort).
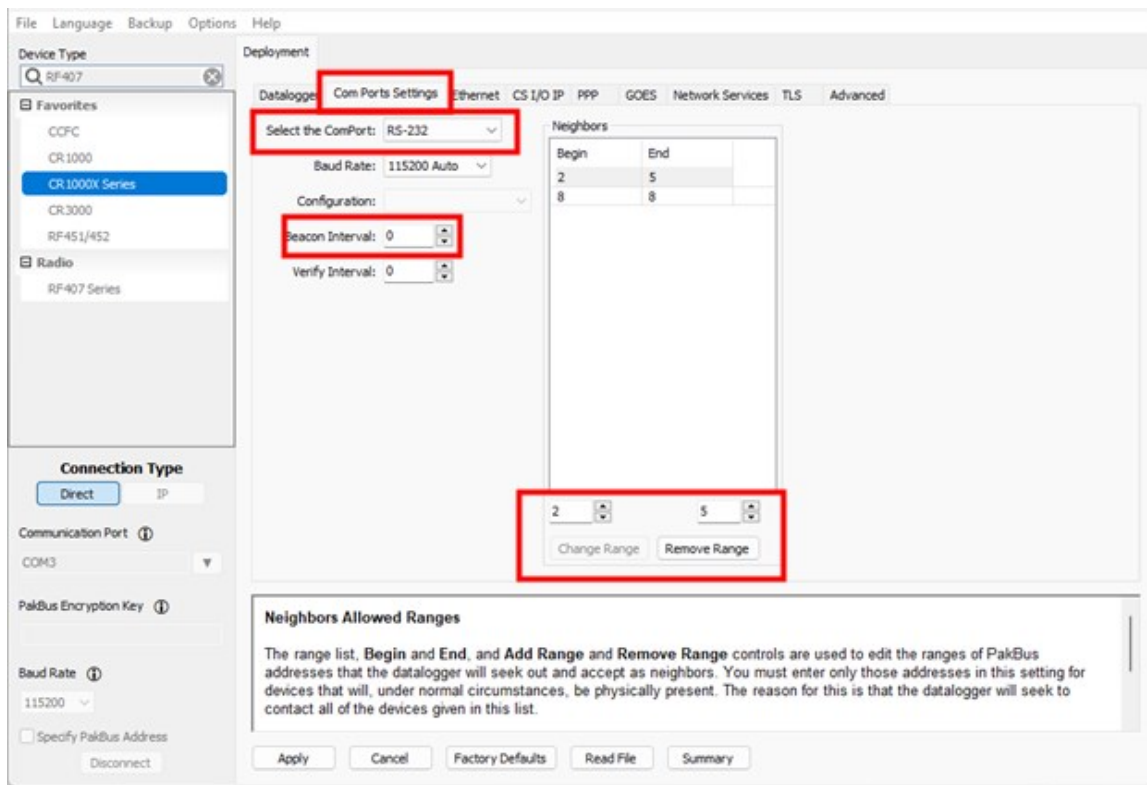
8. Stagger data collection

With large radio networks when data collection for every station is scheduled to take place at the same time, bandwidth limitations could keep multiple stations from communicating simultaneously. To avoid this, stagger data collection among stations.

8.1 LoggerNet scheduled collection

Use the *LoggerNet* **Setup** > **Schedule** > **Time** field to stagger data collection. For example, setting the **Time** to 12:03:00 AM will cause *LoggerNet* to initiate communications to this specific station three minutes after the hour. By setting the next data logger to six minutes after the hour the two are likely to have successful data collection. The actual **Time** you use may be different. Ensure there is enough time to get through the entire network data collection schedule before the first station is contacted again.
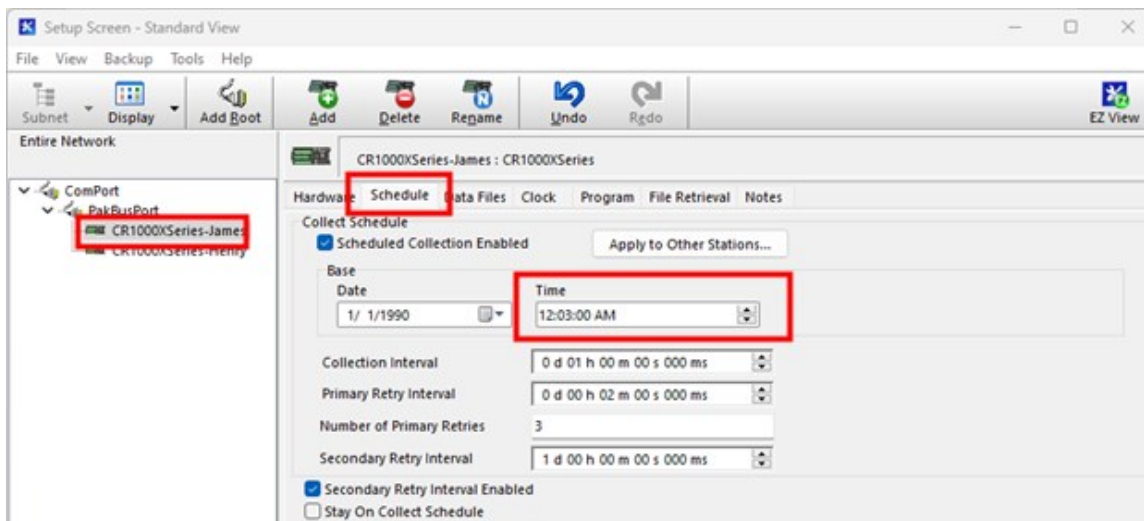
8.2 Callback

Stagger callback times by using `TimeIntoInterval()` to trigger `SendData()` instructions. For more information see: https://www.campbellsci.com/blog/call-back-capability-data-retrieval 🔗.

8.3 Aggregate data

Another alternative is to aggregate data from all stations into one base (centralized) data logger. Use `GetVariables()` or `GetDataRecord()` in the base data logger to pull values from each of the remote stations. Use *LoggerNet* to collect data from the base data logger. This reduces radio network congestion because the base data logger instructions trigger one at a time. When the first completes the second begins, and so on. This reduces radio congestion since all the stations are not trying to send data at once.

9. Reduce PakBus packet size

Reduce the data logger PakBus packet size to less than the radio packet size. PakBus packets larger than the radio packet size are split up, which creates more radio traffic and increases the number of packets that must be retransmitted if a packet is lost. The default RF407-series radio packet size is 256 bytes. Because the 256-byte packet needs to include space for packet header information (imagine putting an envelope inside another envelope to send) 200 is a safe size for the data logger PakBus packets that will go inside the radio packets. The default RF451/RF452 packet size is 234 bytes.

> **TIP:**
> Make the data logger and LoggerNet packet sizes the same.

Use *Device Configuration Utility* to change the PakBus packet size in your data logger. Change the **Max Packet Size** on the **Settings Editor** > **Advanced** tab.
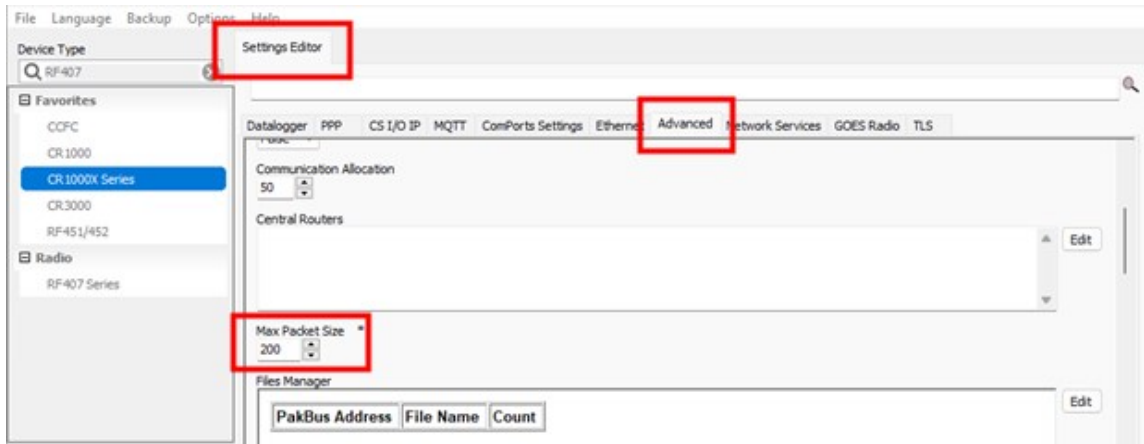
To change the setting in *LoggerNet* select your data logger on the **Setup** screen. On the **Hardware** tab set the **Maximum Packet Size** to **200**.
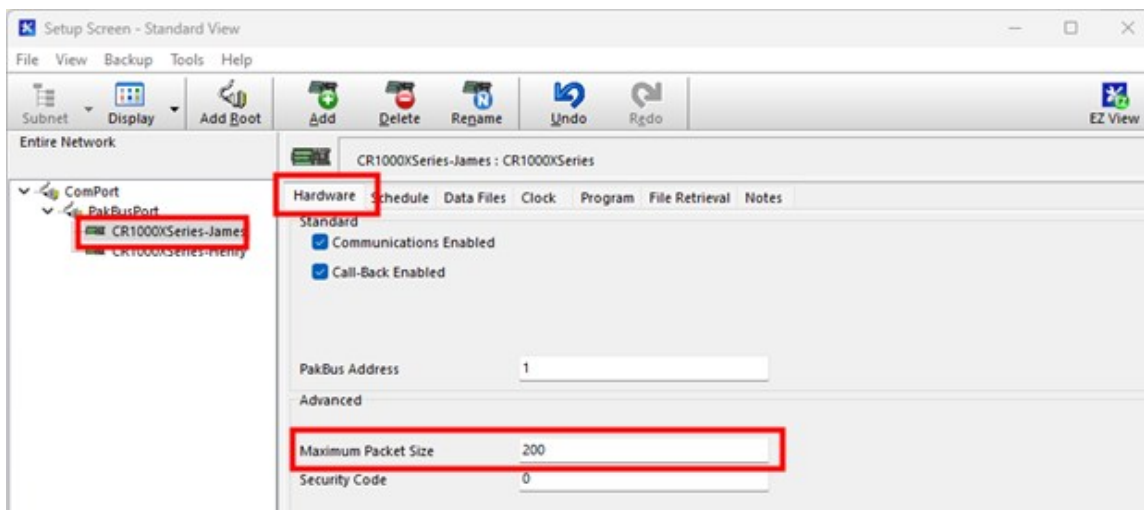
10. Select antenna

Use directional (Yagi) antennas where possible. Generally, base stations use omni-directional antennas since they communicate with stations in multiple directions. Other stations that are only communicating with a base station or with a single neighbor can use directional antennas. Using a directional antenna has two advantages. First, the directional antenna power is focused

allowing it to go greater distances. Second, limiting the direction the antenna transmits helps reduce interference elsewhere.

11. Use different network IDs

If another radio network of the same type is nearby (such as another RF407-series radio network) consider using different **Radio Network IDs** and **RF Hop Sequences**. This will prevent the two networks from joining and minimize interference. In RF451/452 radios the RF Hop Sequence is called the **Frequency Key**.

For RF407-series radios, these are found on the *Device Configuration Utility* **Main** tab.
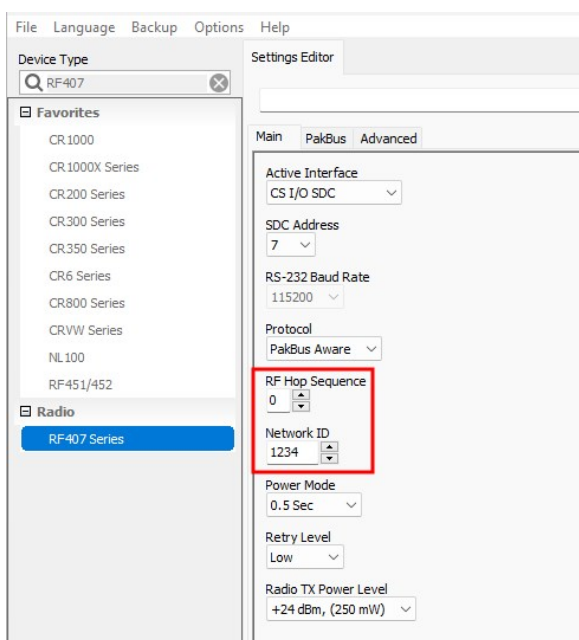
For RF450/451/452 radios, these are found on the *Device Configuration Utility* > **Deployment** tab.
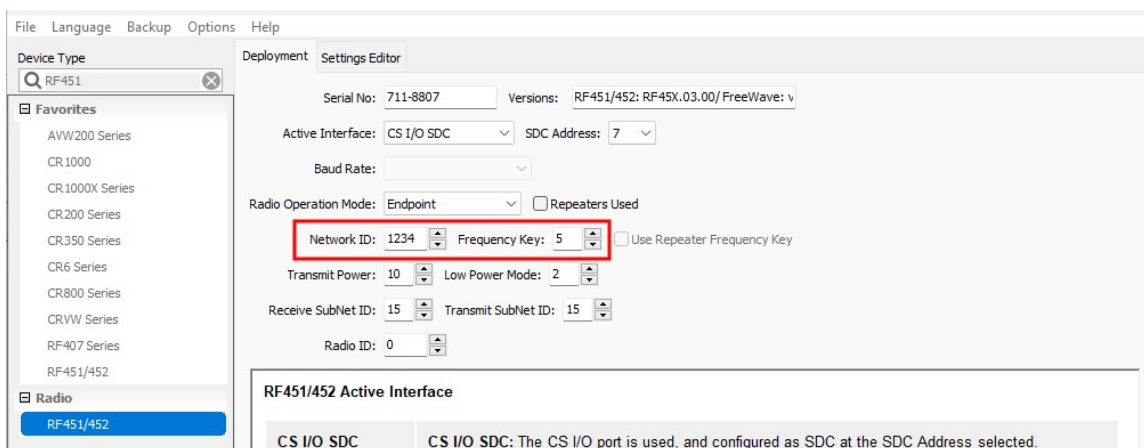
12. Reduce retries

(RF407-series and RF401(A) only)

In large networks where interference or packet loss is high, keep the default **Retry Level** set to **Low**. That reduces retries on the network from interfering with other device communications attempts.

Retry level	Retry count
None	0
Low	2
Medium	4
High	6

13. Avoid interference from other radios

If your radios regularly disconnect from one another and connectivity seems unstable, other spread-spectrum radio interference may be present. Reducing the **Frequency Range** that your radios communicate over may help.
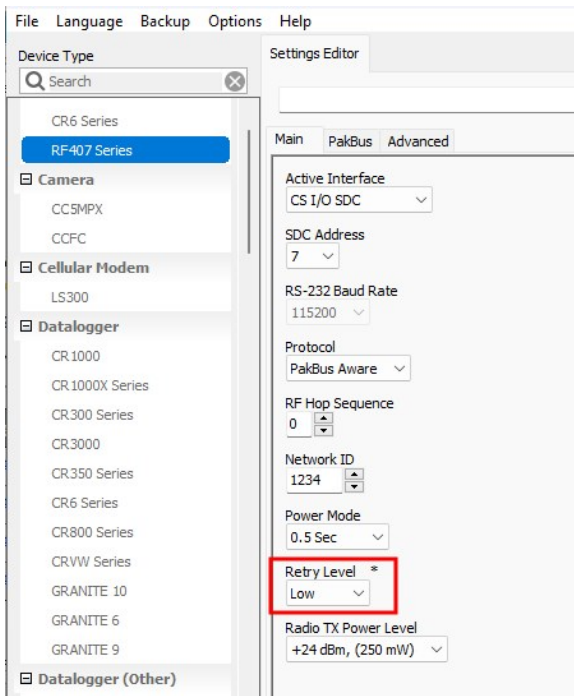
13.1 Reducing the frequency range of RF407-series radios

On the RF407, the frequency is reduced in the *Device Configuration Utility* > **Settings Editor** > **Advanced** > **Radio Channel Mask**.

All devices in the RF407-series radio network must use an identical set of active channels. The 16-digit Hex Radio Channel Mask correlates to the 64 segments of the radio frequency band. Each of the 16 hex values represents four binary values. The lowest frequencies in the band begin on the left and the highest are on the right. Turn off the groups of four by setting the **F** to a **0**. Simply setting the **0** back to an **F** turns the group back on. See the following table for more granular frequency toggling.

Hex value	Effect	Hex value	Effect
0	Turns all 4 channels off	A	Turns on channels 2 and 4
1	Turns on channel 1	B	Turns on channels 1, 2, and 4
2	Turns on channel 2	C	Turns on channels 3 and 4
3	Turns on channel 1 and 2	D	Turns on channels 1, 3, and 4
4	Turns on channel 3	E	Turns on channel 2, 3, and 4
5	Turns on channel 1 and 3	F	Turns on all 4 channels
6	Turns on channel 2 and 3		
7	Turns on channels 1, 2, and 3		
8	Turns on channel 4		
9	Turns on channel 1 and 4		

The following table shows the bit-by-bit frequency breakdown. The first four bits correlate to the first hexadecimal value, the second four bits correlate to the second hexadecimal, and so on.

|	Freq (MHz)		Freq (MHz)		Freq (MHz)		Freq (MHz)
Bit 0	902.4	Bit 16	908.8	Bit 32	915.2	Bit 48	921.6
Bit 1	902.8	Bit 17	909.2	Bit 33	915.6	Bit 49	922
Bit 2	903.2	Bit 18	909.6	Bit 34	916	Bit 50	922.4
Bit 3	903.6	Bit 19	910	Bit 35	916.4	Bit 51	922.8
Bit 4	904	Bit 20	910.4	Bit 36	916.8	Bit 52	923.2
Bit 5	904.4	Bit 21	910.8	Bit 37	917.2	Bit 53	923.6
Bit 6	904.8	Bit 22	911.2	Bit 38	917.6	Bit 54	924
Bit 7	905.2	Bit 23	911.6	Bit 39	918	Bit 55	924.4
Bit 8	905.6	Bit 24	912	Bit 40	918.4	Bit 56	924.8
Bit 9	906	Bit 25	912.4	Bit 41	918.8	Bit 57	925.2
Bit 10	906.4	Bit 26	912.8	Bit 42	919.2	Bit 58	925.6
Bit 11	906.8	Bit 27	913.2	Bit 43	919.6	Bit 59	926
Bit 12	907.2	Bit 28	913.6	Bit 44	920	Bit 60	926.4
Bit 13	907.6	Bit 29	914	Bit 45	920.4	Bit 61	926.8
Bit 14	908	Bit 30	914.4	Bit 46	920.8	Bit 62	927.2
Bit 15	908.4	Bit 31	914.8	Bit 47	921.2	Bit 63	927.6
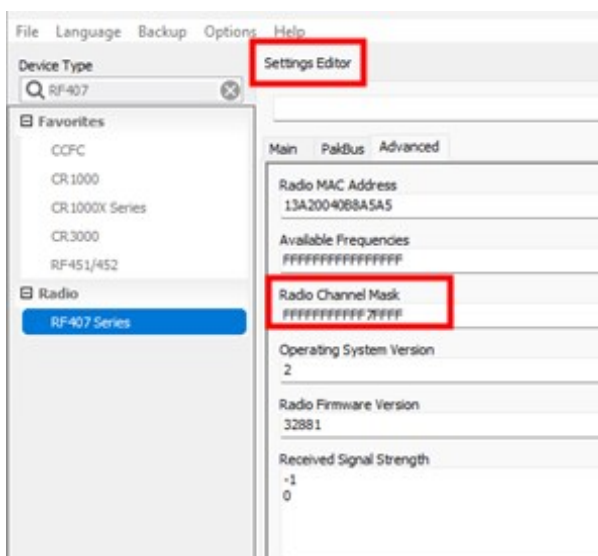
13.2 Reducing the frequency range of RF451/RF452 radios

In the RF450/451/452, the radio frequency range is reduced in the *Device Configuration Utility* from the **Settings Editor** tab. Scroll down and to the **Frequency Zones**. Zones can be toggled off by setting the value for the zone to **0**. Changing the value back to **1** re-enables the zone.
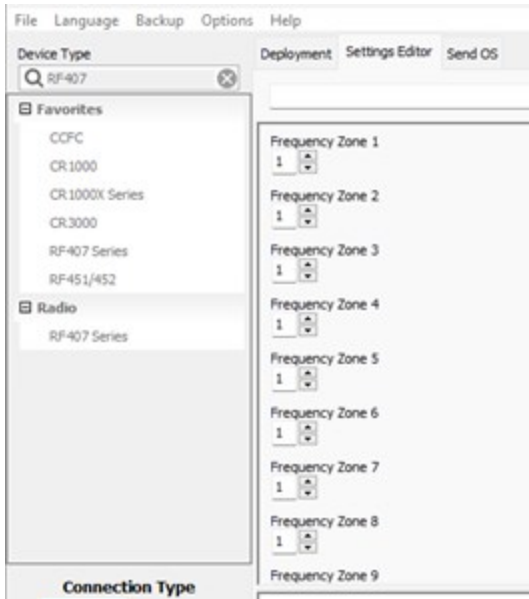
14. Base antenna siting

If you experience frequent disconnects it may be useful to check the location and position of the base station antenna. It could be problematic if it is mounted to a tower where it is close to other antennas. If possible, look for another antenna mounting location. The Radio Test Kit from Campbell Scientific (https://www.campbellsci.com/21107) allows you to setup a temporary base station on a tripod and a remote radio station and move them to find the most suitable location for a tower or station. It can be especially useful during the early phase of a project to verify that the radio equipment being deployed is a good fit for the location.

15. Use a cavity band-pass filter

Use a cavity band-pass filter on your base station radio if the signal consistently goes out during certain times of the day. Install a signal filter to the connection going into the data logger from the antenna. Ensure that the filter is in the range of the radio, generally 902-928 MHz.

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