# LoRa Module Range Testing Report

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## OVERVIEW.

This document describes the range tests performed on the RYLR998 LoRa modules (https://reyax.com/products/RYLR998). These tests were performed in order to verify that these modules meet the range requirements of the IVGM project. Specifically, these tests verified that the modules can successfully communicate between a mailbox located up to 100 feet in front of a house and a hub located just inside of the house.


*Figure 1. RYLR998 LoRa Modem Module.*

## RESULTS.

The RYLR998 LoRa modules easily met the project requirements; in fact, substantially exceeding them. Two range tests were performed:

1. The “hub” was placed in the back of the house. The “tester” was able to communicate with the hub at a distance of over 700 feet outside of the front of the house. Communication was successful over 700 feet of line of sight free air plus about 50 feet through many walls of the house.
2. The “hub” was placed in the front of the house, with only the front wall between the hub and outside free air. The “tester” was able to communicate with the hub at a distance of over 1000 feet outside of the front of the house. Communication was successful over 1000 feet of line of sight free air plus about 2 feet through the front wall of the house. Communication was lost when line of sight to the house was compromised by the street environment. It is possible that communication over

longer distances would have been successful if there was a longer line of sight to the house in the test environment.

Additional, free air – line of sight tests may be conducted in the future.

## TESTING METHODOLOGY.

Two LoRa modules were pre-configured, as described below.


*Figure 2. Range Testing Architecture.*

The module designated for the "tester" was connected to a Particle Photon microcontroller that was programmed to send a short test message via the LoRa module whenever an on-board pushbutton was pressed. The module designated for the "hub" was connected to a Particle Photon microcontroller that was programmed to wait for receipt of a test message from the "tester" and, if a valid message was received, to transmit back a response message to the "tester" via its own LoRa module. After sending out the test message, the "tester" waits three seconds and then reads out its LoRa module received response. If a valid response was received, the Photon microcontroller on the "tester" flashes its D7 LED three times. If no valid response message was received, the "test" flashes its D7 LED once.

These tests were not performed at low power. The "hub" was powered from the AC mains by a USB power supply. Since the tester had to be operated outside, on the street, it was powered by a camping battery/inverter power source; see the figure below.

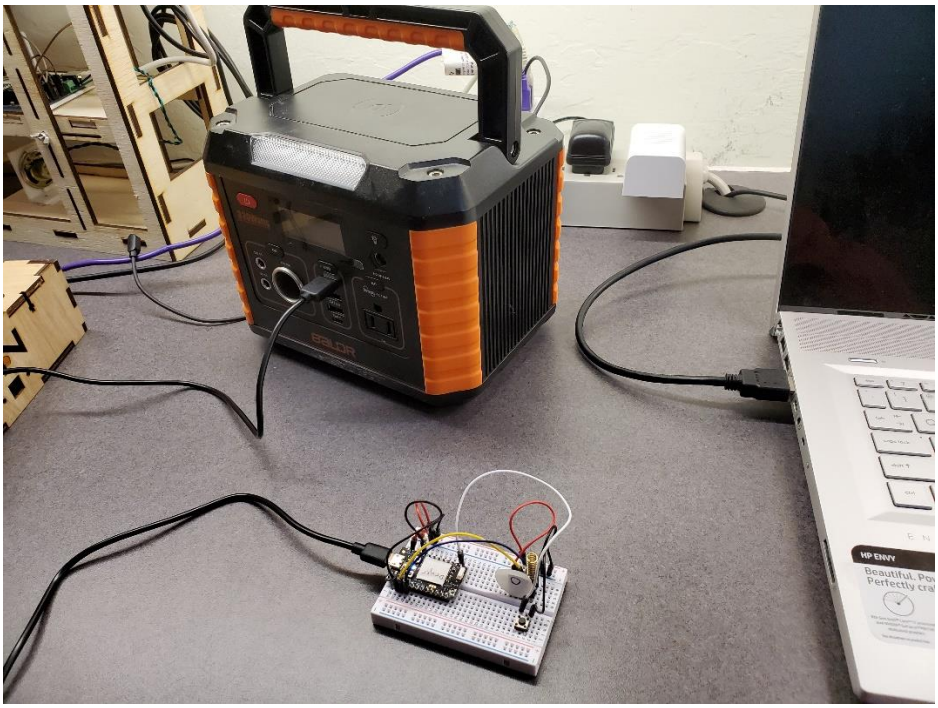

*Figure 3. "Tester" and its portable power source.*

The "hub" was stationary while the "tester" was manually transported to various locations on the street at increasing distances from the house (but trying to keep line of sight to the house). At periodic intervals, the button on the "tester" was pressed and the D7 LED observed after the three second delay. Three flashes indicated successful communication while one flash indicated loss of communication. The point of loss of communication was noted on Google Maps and the Google Map scale was used to determine the distance from the house.

# EQUIPMENT DESCIPTION.

## Parts.

The following parts were used for these tests:

- 2 ea. RYLR998 LoRa Modem Modules. https://www.amazon.com/dp/B099RM1XMG?psc=1&ref=ppx_yo2ov_dt_b_product_details
- 1 ea. USB-Serial ("FTDI") Module. https://www.amazon.com/dp/B00LODGRV8?psc=1&ref=ppx_yo2ov_dt_b_product_details

- 2 ea. Particle Photon modules. https://www.particle.io/. NOTE: The Photon is currently out of production; the Photon 2 may be used instead. The WiFi and BLE capabilities of the Photon/Photon 2 are not used for these tests and any 3.3 volt/USB powered Arduino board may be used.
- 1 ea. Breadboard compatible pushbutton switch.
- 2 ea. Solderless breadboard and male-male jumper wires.
- 1 ea. USB battery power supply.

## Construction.

The figure below shows the “tester”:

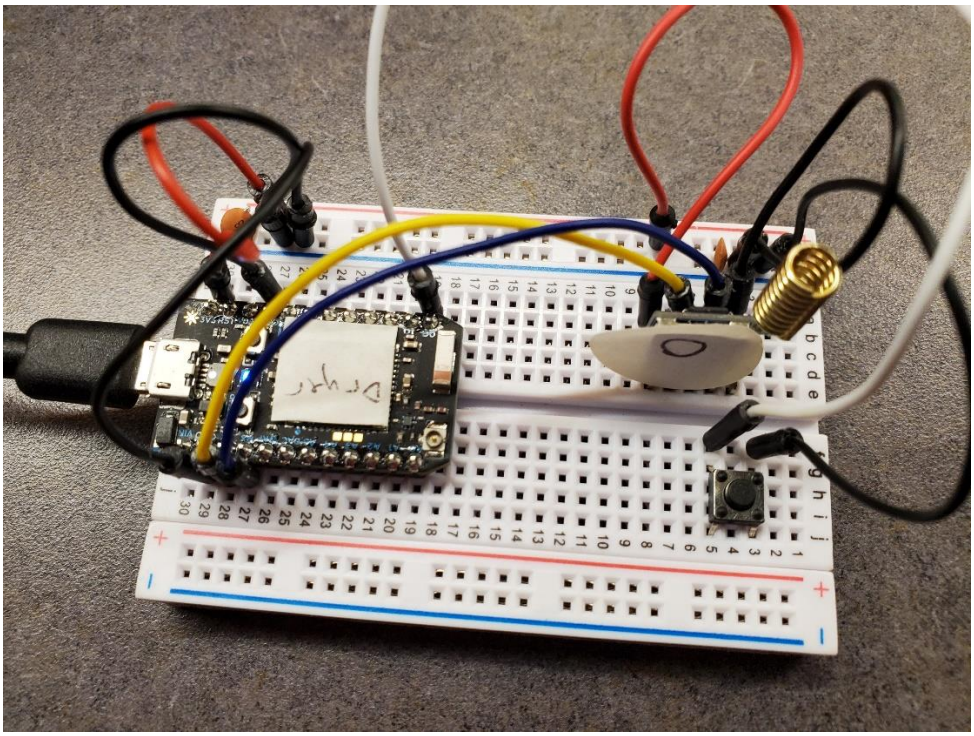

*Figure 4. Photo of the Tester.*

The following figure shows the wiring of the “tester”:

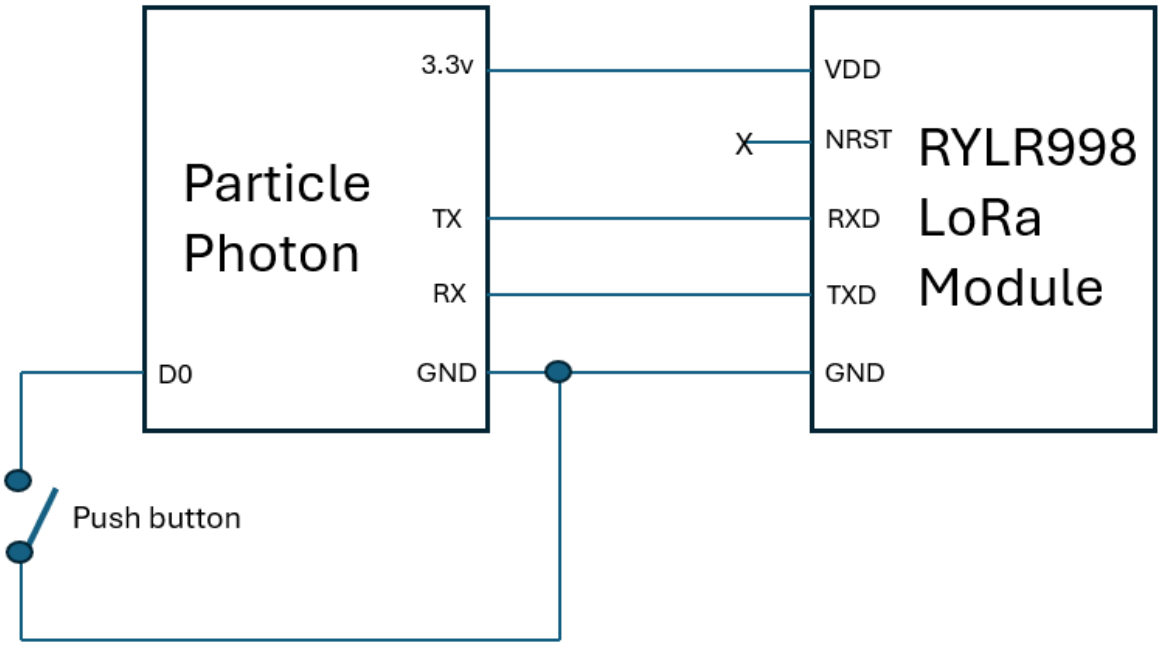


*Figure 5. Tester schematic.*

The Photon is powered through its onboard USB port. The Photon's 3.3 volt output (from its on-board regulator) is used to power the LoRa module. The Photon's TX pin (Serial1 port) is connected to the LoRa module's RXD pin and visa-vera. The LoRa module's NRST (reset) pin is not connected.

The pushbutton switch has one end connected to the Photon D0 pin and the other end connected to ground.

The figure below shows the "hub":

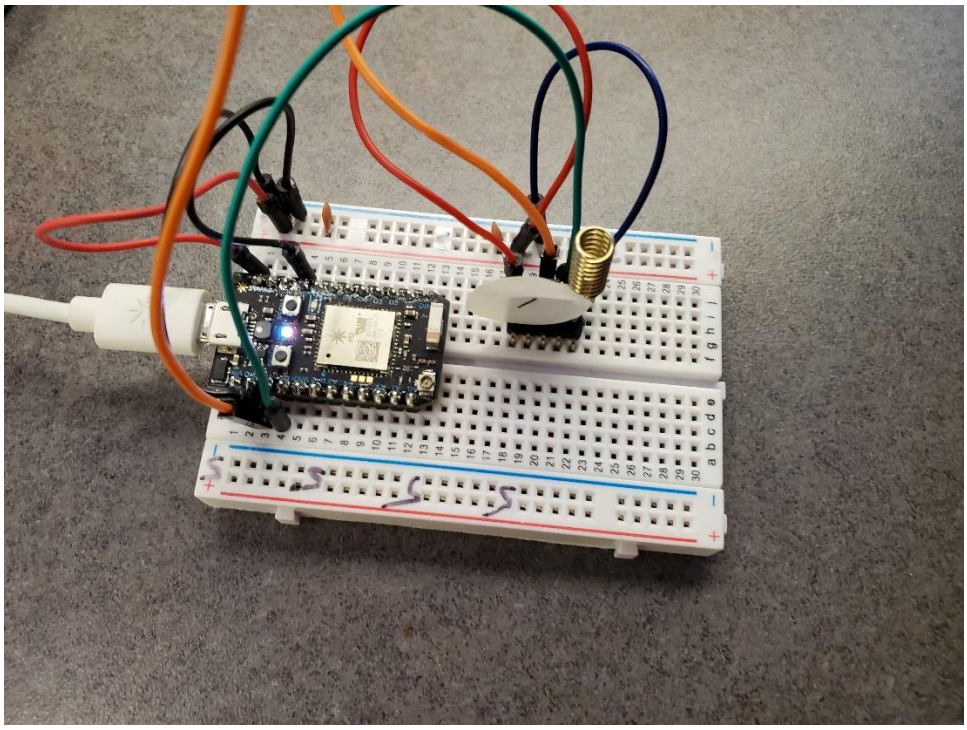

*Figure 6. Photo of the Hub.*

The following figure shows the wiring of the “hub”:

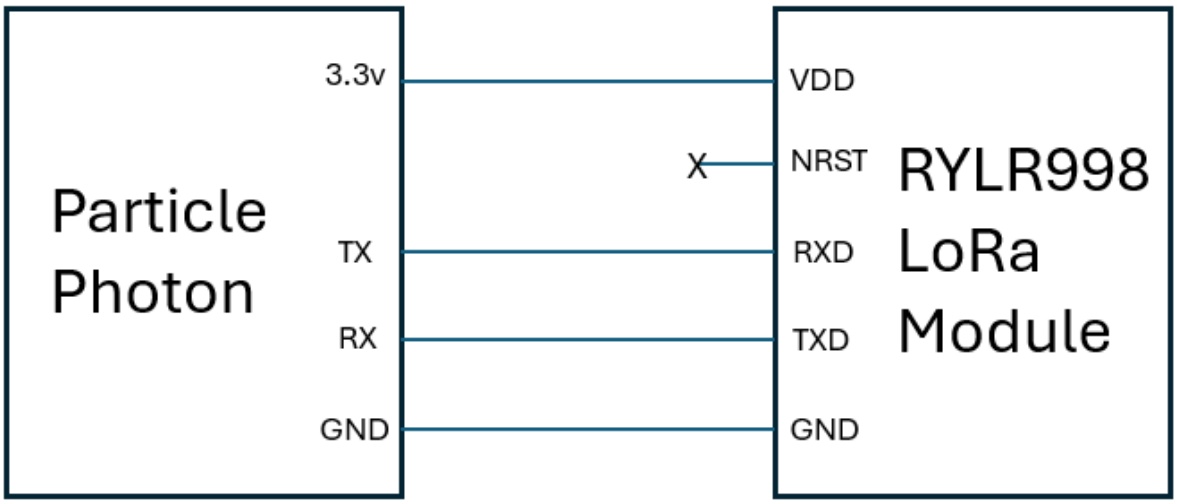


*Figure 7. Hub Schematic.*

Note that the “hub” wiring is identical to the “tester” wiring except that there is no pushbutton switch on the “hub”.

# SETUP AND CONFIGURATION.

The “hub” and “tester” software does not configure the LoRa modules. The modules must be set up using the USB-Serial module (“FTDI” module) and a PC running a terminal program. The terminal program used for these tests was the Arduino serial monitor; however, any terminal program will work.

The LoRa modules come “out-of-the-box” with a number of default settings. In general, the default settings were used for these tests. However, the module number and the network number were changed. The official documentation of the module AT command set can be found at:

https://reyax.com/products/RYLR998

Scroll down to “AT COMMAND MANUAL”.

The default baud rate for these LoRa modules is 115200 baud, and the default end-of-line is CR and LF. In order to communicate with these modules using a terminal program on a PC, this baud rate and end-of-line settings must be used. Here are the settings used for these tests:

## Hub:

- Baud rate: 115200 (default)
- Mode: 0 (default)
- Band (for USA): 915 MHz (default)
- Network ID: 3
- Address: 0 (default)
- Parameters: (all default)
    - Spreading factor: 9
    - Bandwidth: 125 KHz
    - Coding Rate: 1
    - Preamble: 12

## Tester:

- Baud rate: 115200 (default)
- Mode: 0 (default)
- Band (for USA): 915 MHz (default)
- Network ID: 3

- Address: 1
- Parameters: (all default)
    - Spreading factor: 9
    - Bandwidth: 125 KHz
    - Coding Rate: 1
    - Preamble: 12

Note that only the network ID and the module address were changed from the defaults. The two modules must be set to different addresses, but they must both have the same network ID.

# SOFTWARE DESCRIPTION.

The software (firmware) source code for the “hub” and “tester” is included in this repository. The software is well commented; hence only a brief description is given here.

## Tester Software.

The “tester” software must operate independently of whether the “tester” can connect to WiFi. In order to use a Particle Photon, the “semi-automatic” system mode must be declared up front.

The “tester” software sets up things in setup(), including setting up D0 as INPUT_PULLUP, setting the Serial1 (LoRa module) baud rate for 115200, and the Serial (USB) baud rate to 9600 (for debugging using a terminal program), and then enters loop(). In loop(), the software tests for depression of the pushbutton. When the button is depressed, it sends out the “HELLO” message to the hub and sets a flag to expect a response from the hub. The code then waits for 3 seconds, after which the received data is read. The received data contains both the local response from the module’s sending command (“+OK” CR/LF) and any received response message (after 3 seconds). The code tests for “+RCV” in the message buffer to detect receipt of a response message. If a response message was received within 3 seconds, the D7 LED is flashed three times; otherwise it is flashed once.

The code then waits for the pushbutton to be released, after which loop() repeats, waiting for the button to be pressed once again.

## Hub Software.

The “hub” software sets up things in setup(), setting the Serial1 (LoRa module) baud rate for 115200, and the Serial (USB) baud rate to 9600 (for debugging using a terminal program),

and then enters loop(). In loop(), the software tests for data in the Serial1 receive buffer. If there is data in the buffer, is it read out and appended to a string variable to assemble the received message. Each time that data is added to the received message string variable, it is tested to see if the message is the test message from the "tester" ("HELLO"). If the test message has been received, the "hub" sends out the response message back to the "tester" and clears out the message string variable for another test.

# HOW THE LORA MODULES COMMUNICATE.

The LoRa modules communicate using "AT" commands, as specified in the manufacturer's "AT COMMAND MANUAL", which can be found at: https://reyax.com/products/RYLR998

Here is a capture of communication between the "tester" and the "hub".

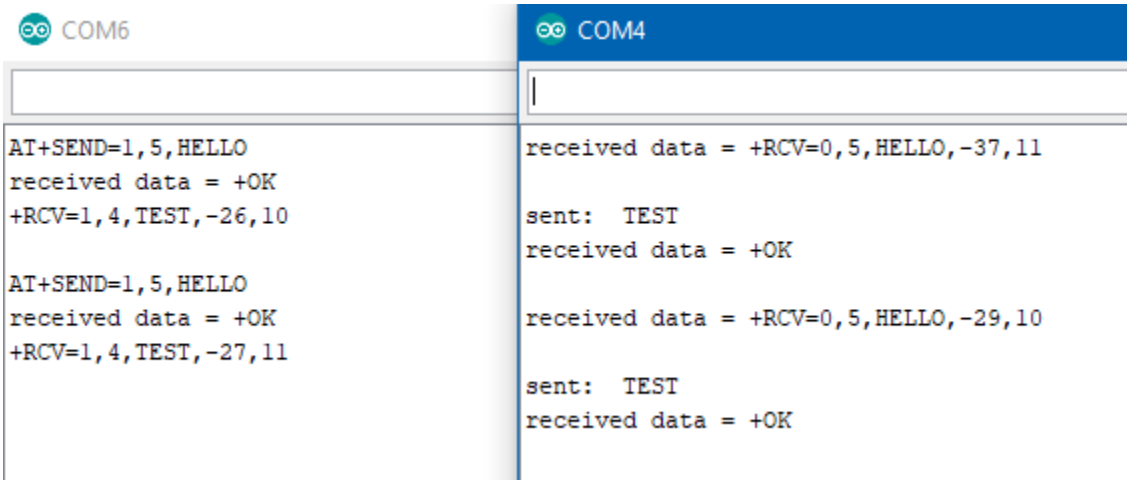


*Figure 8. screen captures of communication.*

Referring to figure 8, "COM 6" is from the "tester" and "COM 4" is from the "hub".

The "tester" sends out its "HELLO" message after the button is pushed. The command to the LoRa module is:

"AT+SEND=1,5,HELLO"

All LoRa modules commands begin with "AT+". The "SEND" command is to transmit data. The "1" parameter is the address of the intended recipient (in this case, 1 is the address set on the "hub" LoRa module). The next parameter is the size of the message. It is "5" because "HELLO" has 5 characters.

The "hub" receives this message, as shown in "COM 4":

"+RCV=0,5,HELLO,-37,11"

“+RCV=” is what the LoRa module uses to designate a received message. “0” is the address of the module that sent the message (in this case, “0” is the address of the “tester”). “5”is the length of the received message and “HELLO” is the received message itself. The remaining two parameters are RSSI and SNR – these relate to the quality of the received signal (see the AT COMMAND MANUAL for details).

Referring to “COM 4”, the “hub”, having received a correct test message, sends out its response message (message data: “TEST”). The “hub” then receives “+OK” – this is a local response from the local LoRa module to the SEND command.

Referring back to “COM 6”:

The received data (after three seconds) contains the following:

“+OK CR/LF +RCV=1,4,TEST,-26,10 CR/LF”

This response is a little complicated. The first part: “+OK CR/LF” is the local response from the local LoRa module to the original “HELLO” message SEND command. This part means that the command was accepted by the LoRa module OK.

(*p.s. – it is currently unclear whether +OK means that the AT string was formatted properly, that the send command was sent to the LoRa chip OK, or whether the LoRa chip transmitted the command in a proper LoRa packet, or even that the message was acknowledged by the receiver. More testing and investigation needs to be done here*).

The remainder of the message string is the message data received from the “hub”:

> “+RCV=” designates that this is a received message.
>
> “1” is the address of the sender of the message (the “hub”, in this case).
>
> “4” is the length (in bytes) if the message (length of “TEST”).
>
> “TEST” is the message itself.
>
> The remaining two parameters are RSSI and SNR – these relate to the quality of the received signal (see the AT COMMAND MANUAL for details).

Figure 8 shows two sets of test message send, receive and respond.