CL024

USER'S GUIDE
VERSION 1.0

global solutions: local support ™

wireless.support@lairdtech.com
www.lairdtech.com/wireless

FCC Notice

WARNING: This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference and (2) This device must accept any interference received, including interference that may cause undesired operation.

RF Exposure/Installation Instructions

WARNING: To satisfy FCC RF exposure requirements for mobile transmitting devices, this equipment must be professionally installed such that the end user is prevented from replacing the antenna with a non-approved antenna. The end user should also be prevented from being within 20cm of the antenna during normal use with the exception of hands, feet, wrists and ankles.

The preceding statement must be included as a CAUTION statement in manuals for OEM products to alert users on FCC RF Exposure compliance.

Caution: Any change or modification not expressly approved by Laird could void the user's authority to operate the equipment.

Revision History

Version	Date	Changes
Version 1.0	8/14/2013	Initial Release

CONTENTS

CL024 RF Transceiver

The CL024 transceiver is a Frequency Hopping Spread Spectrum (FHSS) radio designed for license-free operation in the 2.4 GHz Industrial, Scientific, and Medical (ISM) unlicensed band. The radio sustains a standard asynchronous serial data stream between two or more radios. Housed in a compact and rugged die-cast enclosure, the radio is equipped to replace miles of serial cable with its wireless link. The radio features an RS232 interface for integration into legacy data systems.

Overview

The CL024 uses Frequency Hopping Spread Spectrum technology, where the units "hop" from frequency to frequency many times per second using a specific hop pattern applied to all the transceivers in the same network. A distinct hopping pattern is provided for each Channel Number, thereby allowing multiple networks to co-exist in the same area with limited interference.

CL024 transceivers operate in a Server/Client architecture. The Server radio transmits a beacon at the beginning of every hop which Client radios utilize to synchronize their hopping. Communication between devices cannot occur until both devices are synchronized. While an unlimited number of clients can synchronize to the server's beacon, communication between devices is limited to the chosen RF rate (either 500kbps or 230kbps). The CL024 radios come with options for enabling Full Duplex communication to reserve slots for server and client transmissions and with Random-Backoff settings to ensure retransmissions don't collide.

CL024 radios implement a proprietary communication protocol to provide secure data transmissions. FHSS technology ensures data reliability over long distances. The license-free frequency bands ensure that the units are ready for use with no further certification requirements.

The CL024 transceivers use the 2.4 GHz ISM license free frequency band, which requires no additional certifications when designing into a new or legacy data system.

Each unit is small and easily portable for use in mobile and temporary settings as well as fixed installations. The CL024 configuration software enables custom configurations based on unique application requirements.

This document contains information about the hardware and software interface between a Laird CL024 transceiver and an OEM host. Information includes the theory of operation, specifications, serial interface definition, security information and mechanical drawings. The OEM is responsible for ensuring the final product meets all appropriate regulatory agency requirements listed herein before selling any product.

Note: CL024 modules are referred to as the "radio" or "transceiver". Individual naming differentiates product -specific features. The host (PC, Microcontroller or any connected device) is "OEM host."

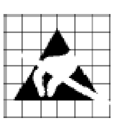
Features

- Server/Client architecture, with an unlimited number of Clients in a network
- API commands to control packet routing and acknowledgement on a packet-by-packet basis
- Durable industrial-grade enclosure
- Transparent operation; supports any legacy system
- Transmits around corners and through walls
- Reliable communication with serial UART speeds up to 460.8 Kbps
- Point-to-Point and Point-to-Multipoint configurations

Detailed Specifications

Table 1: CL024-1000 Specifications

INTERFACE	
Serial Interface Connector	DB-9 Male (RS232)
RF Connector	RPSMA Jack
Serial Interface Data Rate	Serial UART to OEM host: Up to 460.8 Kbps
Power Consumption	400 mA @ 12 VDC
Channels	US/Canada: 43 or 79 channels
Supported Network Topologies	Point-to-Point, Point-to-Multipoint
OPERATIONAL	
Frequency Band	2400 – 2483.5 MHz (US/Canada)
RF Data Rate	280 kbps or 500 kbps selectable
Host Data Throughput	115 Kbps maximum
RF Technology	Frequency Hopping Spread Spectrum (FHSS)
EEPROM write cycles	1000 Write/Erase Cycles
Hop Period	13.2 ms
Output Power	Conducted (no antenna) / EIRP (3dBi gain antenna) CL024-100: 125 mW typical / 250 mW typical
Supply Voltage	CL024-1000: 7-18VDC; 400 mA
Receiver Sensitivity	-100dBm typical @ 76.8 kbps RF Data Rate
Range, Line of Sight (based on 3dBi gain antenna)	Max. 1300 feet (400 m) indoors; Max. 2.5 miles (km) line-of-sight
ENVIRONMENTAL	
Temperature (Operational)	-40° C to +85° C
Temperature (Storage)	-50° C to +85° C
Humidity (Non-Condensing)	10% to 90%
PHYSICAL	
Dimensions	4.4 x 2.7 x 1.4 inches
Weight	6 oz. (170 g)
CERTIFICATIONS	
FCC Part 15.247	CL024-100: KQL-RM024
Industry Canada (IC)	CL024-100: 2268C-RM024



Caution! ESD Sensitive Component. Use proper ESD precautions when handling this device to prevent permanent damage.

External ESD protection is required to protect this device from damage as required to pass IEC 61000-4-2 or ISO 10605 based on end system application.

Status LEDs

CL024

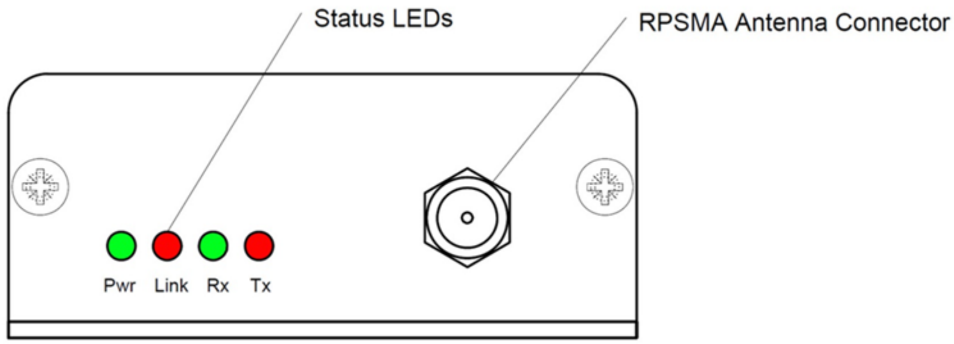


Figure 1: CL024 Status LEDs

Table 2 describes each of the CL024 Status LEDs.

Table 2: CL024 Status LEDs

LED	COLOR	DESCRIPTION
Pwr	Green	On. Indicates the unit is powered up.
Link	Red	On. Indicates the CL024 is synchronized. Note for a Server the Link will always be on
RXD	Green	When flashing, indicates the CL024 is receiving data.
TXD	Red	When flashing, indicates the CL024 is transmitting data.

Serial Interface

- CL024 Serial Interface
- Hardware Flow Control

The CL024 supports the following protocols:

- RS232

CL024 Serial Interface

RS232

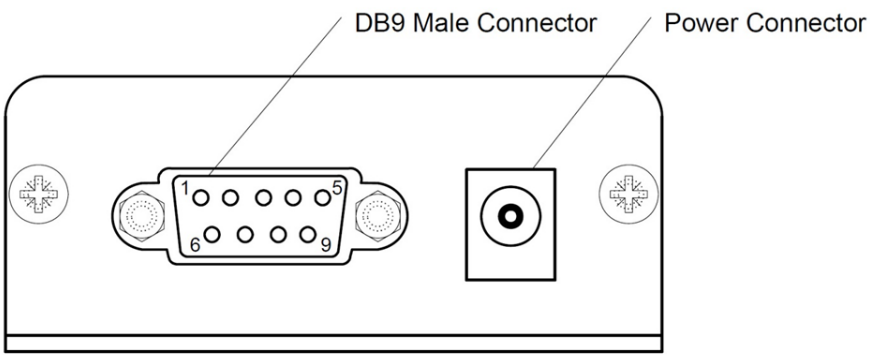
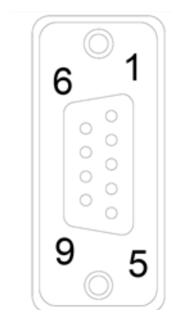


Figure 2: CL024-RS232

RS232 is a single-ended data transmission protocol. The RS232 signals are represented by voltage levels with respect to a system common (power/logic ground). The "idle" state (MARK) has the signal level negative with respect to common, and the "active" state (SPACE) has the signal level positive with respect to common.

Table 3: CL024 DB9 Male Connector Pinout

DB9 Pin	Signal Name	Description	Direction
1	DCD	Data Carrier Detect	Out
2	TXD (RXD with respect to DTE)	Transmit Data	Data Out to Host
3	RXD (TXD with respect to DTE)	Receive Data	Data In to CL024
4	DTR	Data Terminal Ready	In
5	GND	Ground	-
6	DSR	Data Set Ready	Out
7	RTS	Request to Send	In
8	CTS	Clear to Send	Out
9	RI	Ring Indicator	Out



Interfacing to Other RS232 Equipment

The CL024 is a DCE (Data Communications Equipment) device. Typically, devices like PCs are considered DTE (Data Terminal Equipment) devices while peripheral devices are classified as DCE. A DCE device can interface to a DTE device using a straight-through serial cable (Figure 3). When interfacing two DCE (or two DTE) devices together, a null modem cable (or crossover cable) is required to swap the pins and convert the signals accordingly (Figure 4).

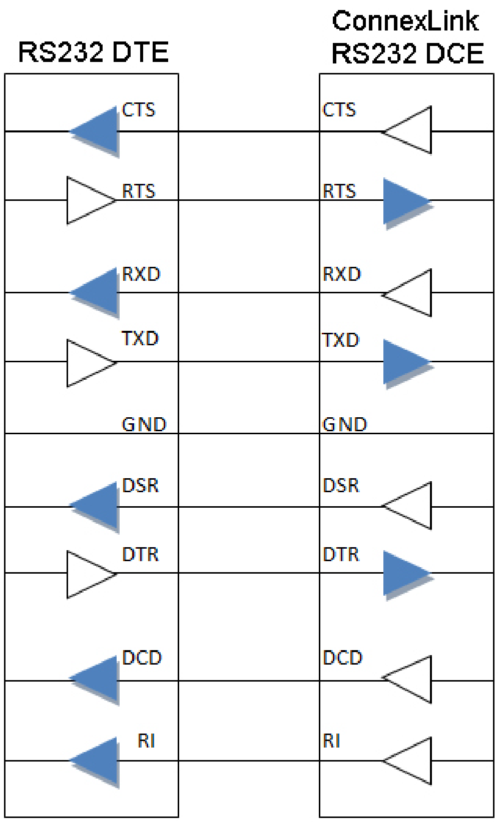


Figure 3: DTE to DCE interface (all signals with respect to DTE)

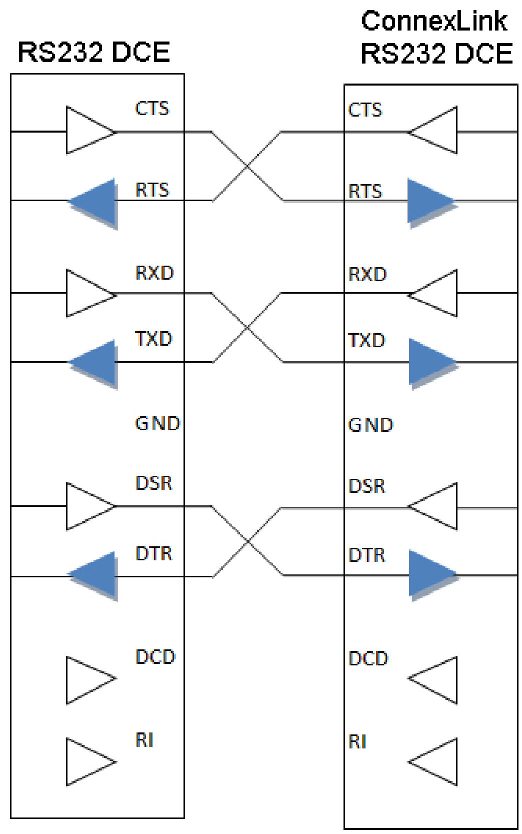


Figure 4: DCE to DCE interface (all signals with respect to DTE)

Note: If you previously used a straight-through cable to connect your PC to your device, you'll need to use a null modem cable or adapter to connect the CL024 to that device. Please refer to www.lairdtech.com/wireless for more information.

Hardware Flow Control

Flow control refers to the control of data flow between the host and the CL024. It is the means of handling data in the transmit/receive buffer of the CL024 interface and it determines the throttling of data flow between the host and the CL024. Often in serial communication, one device is capable of sending data much faster than the other can receive. Flow control allows the slower device to tell the faster device to pause and resume data transmission. Because flow control signals CTS and RTS are used by the CL024 and its host *locally* (rather than over the air), one CL024 cannot tell the other CL024 to slow down or speed up.

The CL024 controls the Clear to Send (CTS) output to the OEM host. The state of the CTS pin is based on the amount of data in the interface buffer. If the buffer is below the maximum limit, the transceiver holds CTS logic Low to signal to the OEM host that data can be accepted over the serial interface safely. If the buffer is full, then CTS transitions logic High to signal to the OEM host that additional data sent over the serial bus has the potential to be lost due to buffer overflow.

Ready to Send (RTS) is an input to the CL024 from the OEM host. When the RTS Enable option is selected in the software configuration of the CL024, the transceiver checks the status of RTS before attempting to send received RF data to the OEM host. If RTS is logic Low, the transceiver sends data to the OEM host. If RTS is logic High, the CL024 does not send data to the host.

Note: CTS is always enabled by default.

RTS is high by default on the CL024. If RTS Enable is enabled, the CL024 does not transmit data out the serial interface unless the RTS line is driven low by the OEM host.

Tip

Can I implement a design using just Txd, Rxd and Gnd (Three-wire Interface)?

Yes. However, Laird strongly recommends that your hardware monitor the CTS pin of the radio. The radio signals CTS logic High when its interface buffer is nearly full. Your hardware should stop sending data over the serial interface at this point to avoid a buffer overrun (and subsequent loss of data).

You can perform a successful design without monitoring CTS. However, you must take into account the amount of latency the radio adds to the system, any additional latency caused by Transmit Retries or Broadcast Attempts, how often you send data, non-delivery network timeouts, and interface data rate. Polled type networks, where a centralized host requests data from the surrounding hosts and the surrounding hosts respond, are good candidates for avoiding the use of CTS. This is because no one transceiver can monopolize the RF link. Asynchronous type networks, where any radio can send to another radio at any point in time, are much more difficult to implement without the use of CTS.

Theory of Operation

Network Topologies

Topology refers to the shape of a network, or the network's layout. The way different nodes in a network connect to each other and how they communicate is determined by the network's topology. The CL024s have a Server/Client communication protocol, which supports Point-to-Point and Point-to-Multipoint topologies. All clients must be in range of the server to maintain network synchronization and all communicating devices must be in range of each other. Communication between out-of-range devices is also possible using repeaters or Host systems that can direct the data through a Daisy Chain type topology.

See the RM024 Embedded Module User Manual for more detailed information about setting up different topologies using the advanced API features in the RM024 family of radios.

Modes of Operation

The CL024 has three different operating modes:

- Transmit/Receive Mode
- Command Mode

If the transceiver is not communicating with another radio, it is in Receive mode actively listening for packet from another transceiver. A transceiver enters Transmit or Command mode when the OEM host sends data over the serial interface. The contents of the data on the serial interface determine which of the two modes the radio enters.

Transmit/Receive Mode

All packets sent over the RF are either Addressed or Broadcast packets. You may dynamically control Broadcast and Addressed delivery with the API Control byte, which can be modified during operation with On-the-Fly commands (for more information on APIs and on-the-fly commands, see the RM024 Embedded Module User Manual). To prohibit transceivers from receiving broadcast packets, Unicast only can be enabled.

When a radio has data to transmit, it will transmit it at the next available data slot.

Addressed Packets	When sending an addressed packet, the RF packet sends only to the receiver specified in the destination address. To increase the odds of successful delivery, Transmit Retries are utilized. Transparent to the OEM host, the sending radio sends the RF packet to the intended receiver. If the receiver receives the packet free of errors, it returns an RF acknowledge within the same 13.2 ms hop. If a receive acknowledgement is not received, the radio uses a transmit retry to resend the packet. The radio continues sending the packets until either (1) it receives an acknowledgement, or (2) it has used all transmit retries. The received packet only sends to the OEM host if and when it is received free of errors.
Broadcast Packets	When sending a broadcast packet, the RF packet sends out to every eligible transceiver on the network. To increase the odds of successful delivery, Broadcast Attempts are utilized. Transparent to the OEM host, the sending radio sends the RF packet to the intended receiver(s). Unlike Transmit Retries, all Broadcast Attempts are used regardless of when the RF packet is actually received and without RF acknowledgements. If the packet is received on the first attempt, the receiver ignores the remaining broadcast attempts. The received packet is only sent to the OEM host if and when it is received free of errors.

Command Mode

A radio enters Command mode when data is received over the serial interface from the OEM host and contains the "AT+++" (Enter AT Command mode) command. Once in Command mode, all data received by the radio is interpreted as command data. Command Data may exist as either EEPROM Configuration or On-The-Fly commands. For more information on EEPROM Configuration and On-the-Fly commands, download the RM024 Embedded Module User Manual).

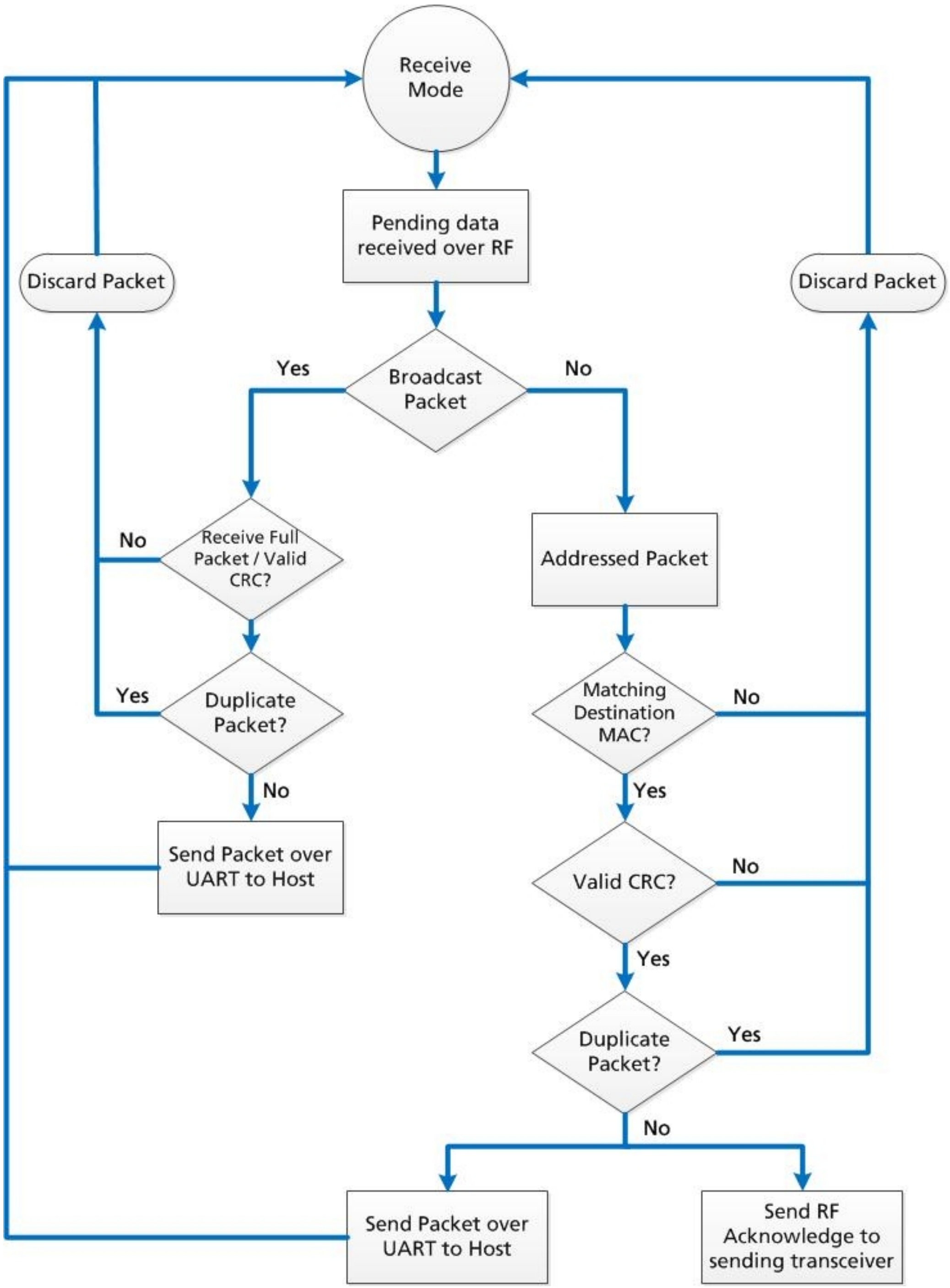


Figure 5: Pending RF data received over RF

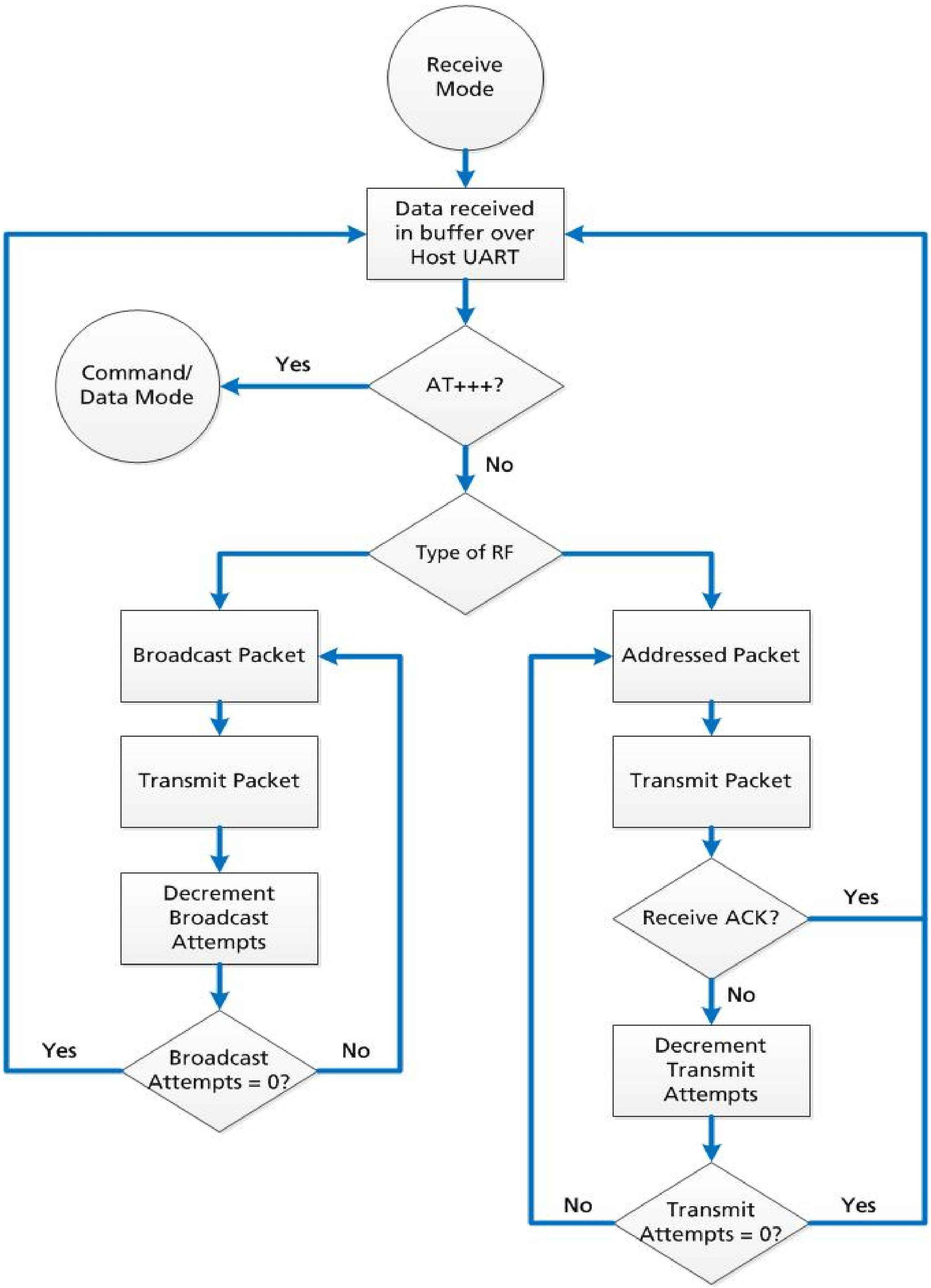


Figure 6: Pending RF data in buffer flow

Spread Spectrum History

Spread Spectrum, or SS, dates back to World War II, when actress Hedy Lamarr and composer George Antheil were granted a U.S. patent on a simple frequency hopping continuous wave (CW) system. These early research and development efforts tried to provide countermeasures for radar, navigation beacons, and communications.

How Spread Spectrum Works

SS radio communication has long been a favourite technology of the military because it resists jamming and is hard for an enemy to intercept. And now, this very same technology is widely used in the commercial, industrial and even consumer markets. The reason: SS signals distribute over a wide range of frequencies and then collect onto their original frequency at the receiver, making them so inconspicuous they are almost transparent. Just as they are difficult to intercept by a military opponent, so are they unlikely to interfere with other signals intended for business and consumer users – even ones transmitted on the same frequencies.

Spread signals are intentionally made to have a much wider band than the information they are carrying and use special pseudo noise codes to make them more noise-like. It is this very characteristic that makes SS signals difficult to detect, intercept, and demodulate. SS signals are hard to detect on narrowband equipment because the signal's energy spreads over a much wider bandwidth. Further, SS signals are harder to jam (interfere with) than narrowband signals and have a much lower probability of being intercepted, which is why the military has used SS for so many years.

The spread of energy over a wide band makes SS signals less likely to interfere with narrowband communications. Narrowband communications, conversely, cause little to no interference to SS systems because the receiver effectively integrates the signal over a wide bandwidth to recover it.

Besides being hard to intercept and jam, spread spectrum signals are also difficult to exploit or imitate. Signal exploitation is the ability of a non-network member to listen to a network and use information from the network without being a valid network member or participant. Imitation is the act of falsely or maliciously introducing false traffic or messages into a network. SS signals also are naturally more secure than narrowband radio communications. Thus SS signals can have any degree of message privacy that is desired. Messages can also be encrypted to any level of secrecy desired. The very nature of SS allows military or intelligence levels of privacy and security with minimal complexity. While these characteristics may not be very important to everyday business or consumer needs, these features are important to understand.

Frequency Hopping Spread Spectrum

An FHSS radio does just what its name implies – that is, it "hops" from frequency to frequency over a wide band. The specific order in which it occupies frequencies is a function of a code sequence, and the rate of hopping from one frequency to another is a function of the information rate.

CL024 Security Features

In addition to FHSS technology, Laird has implemented two levels of security in the CL024. All levels associate with their own EEPROM parameter that you may program for permanent operation or change during system operation in volatile memory using On-the-Fly commands (see the RM024 Embedded Module User Manual). The two levels of security configure and establish a network of transceivers and are defined as the RF Channel Number and System ID.

The RF Channel Number represents a specific hopping sequence and provides physical separation between collocated networks. Thus, all transceivers in a network must use the same RF Channel Number. There are a total of 43 or 79 Channel Numbers depending on the RF Rate chosen

System ID is similar to a password character or network number and makes network eavesdropping more difficult. A receiving radio will not go in session (communicate) with another radio on a different System ID. There are a total of 256 System ID values.

PROGRAMMING THE CL024

Laird provides the easy-to-use CL024 Configuration Utility software for programming the CL024. The GUI based software does not require any hardware configuration and works by itself. The software is compatible with Microsoft® Windows. CL024s are plug-and-play devices that work with minimal or no configuration.

This section provides instructions for quick and simple setup of CL024 networks. The Laird Configuration Utility User Manual provides a full description of the software tool's functionality and features.

CL024 customers who need advanced features and functionality like Transmit/Receive API can unlock these and other features in the Laird Configuration Utility software (see Enabling the Security Pane). The Info Center located on the Configure tab of the Laird Configuration Utility provides a quick explanation of all CL024 features. Detailed descriptions for all available RM024 features are found in the RM024 Embedded Module User Manual.

To program the CL024, follow these steps:

1. Start the Laird Configuration Utility. Click here to download.
2. Connect a CL024 unit to the serial port on the PC (refer to the Serial Interface section).
3. Attach the antenna to the CL024 unit; make sure the connection is secure.
4. Connect the power supply to the CL024 unit. Make sure the Pwr LED is on.
5. In the PC Settings tab in the Configuration Utility, select **Connex024** from the Product drop-down.
6. Click **Find Port**.
7. From the Port drop-down menu, select the COM port that is connected to the CL024.
8. Select the **Baud Rate** from the drop-down menu.

Note: All CL024 units ship with a default baud rate of 115200 (unless units have been pre-configured to match specific serial settings). If the Interface Baud Rate of the CL024 unit is changed, the PC Setting baud rate must match the device baud rate to allow proper programming of the units.

9. Click **Open Port** and verify that the Port (1/2) status bar at the bottom of the window shows the correct COM number, is OPEN, and CTS is Low.
10. Go to the Configure tab and click **Read Radio**.
11. Change settings based on the type of network needed.

Note: The Laird Configuration Utility automatically programs the mode (point-to-point or point-to-multipoint) based on the radio's current settings:
☐ If the Destination Address field is set to any value other than *FF FF FF FF FF FF*, the radio sends data only to the radio whose MAC matches that specified in the Destination Address field (point-to-point).

☐ If the Destination Address field is set to *FF FF FF FF FF FF*, it is set to Broadcast mode and transmits to all transceivers in range with the same System ID and RF Channel (point-to-multipoint).

For more information on settings, see the Info Center in the Laird Configuration Utility or the RM024 Embedded Module User Manual.

Note: The *Show Defaults* button can display sample Radio Settings. These settings *may not* reflect the current default settings of the radio.

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12. After all changes are made, click **Write Radio** to save the changes.

HARDWARE

Mechanical Drawing

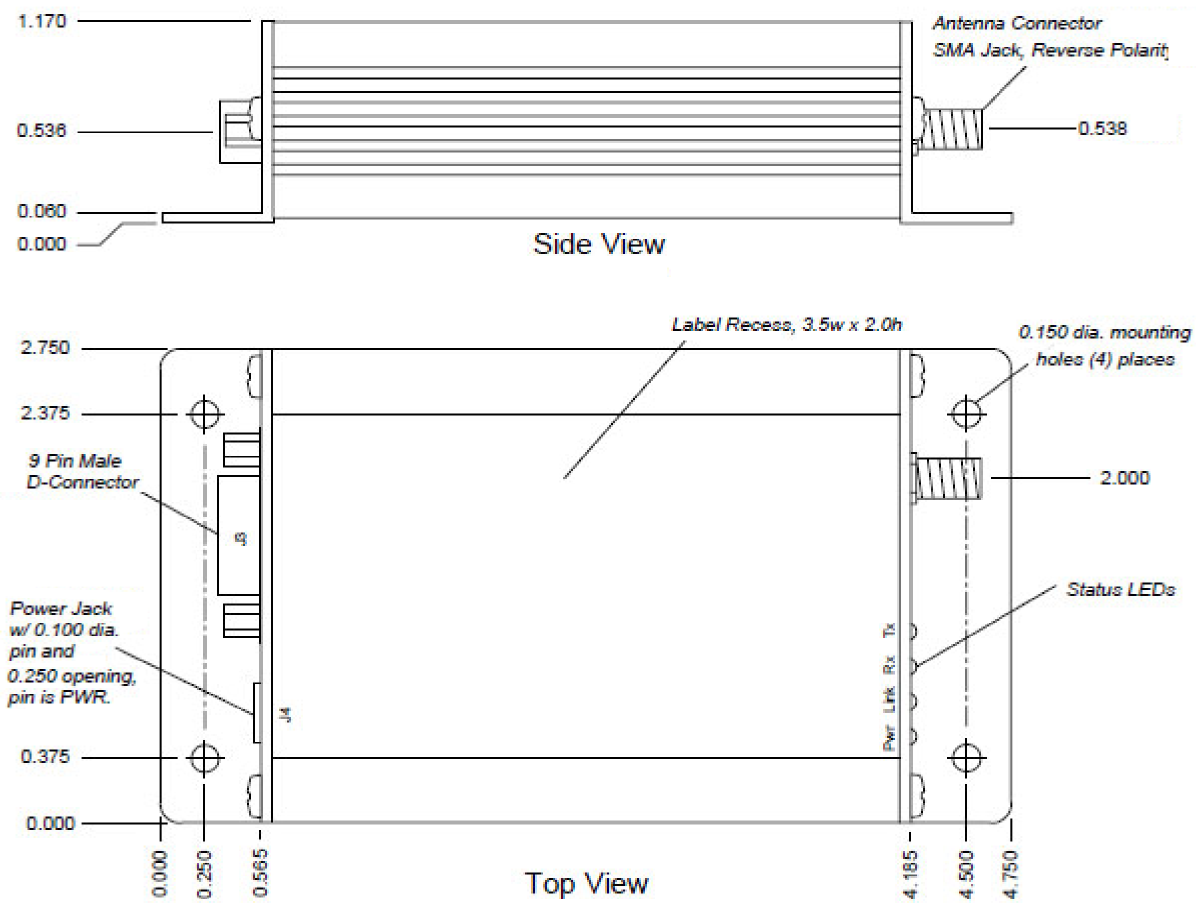

Figure 7: Mechanical Drawing

Approved Antenna List

Table 4: CL024 approved antennas

Item	Part Number	Mfg.	Type	Gain (dBi)
1	ID2450-RS36	Laird Technologies	Panel	9
2	IG2450-RS36	Laird Technologies	Omni	6
3	S151-6-PX-2450S	Nearson	Dipole	5

1. *Strictly requires professional installation*

Note: You may use different antenna manufacturers as long as the antenna is of like type and equal or lesser gain to one of the antennas listed in the table above.

Appendix I: Troubleshooting

Problem	Solution
Read Radio displays error message: "Radio not responding."	Make sure the PC Settings are correct and that the CL024 unit uses the right serial cable. Refer to RS232. If any other program using the same COM port as CL024 is open, close that program and try to read the radio again. Reset the radio by cycling power after each unsuccessful read.
Write Radio displays error: "Radio not responding."	Cycle radio power. Read the radio, make changes and click **Write Radio**.
Garbled Data received.	Check Data Encryption Standard settings.
Client Link LED won't light.	Make sure the unit is connected to power. Cycle power to the radio.
Link LED is on, but data does not get transmitted or received.	Make sure the CL024 unit or units connect to the correct COM port. Check the COM port settings for correct baud, parity, and either Hardware or No Flow Control. May be caused by Flow Control set to Xon/Xoff. Try increasing the Maximum Transmit Attempts (clients) and/or Broadcast Attempts (servers) in small increments until communication is established. Connect a Null Modem adapter between the client and its host device. Check the Destination Address setting.

If these tips do not resolve the problem, please call our toll free number at (800) 492-2320, option 2 for technical support. Hours are Monday through Friday, 8:00 am to 5:00 pm Central Standard Time.

Force 9600 Baud Recovery

To force the serial interface to a known value, perform the following steps (this also sets the RF Packet Size and Interface Timeout to default values):

1. Remove power from the radio.
2. Remove the screws on the case and slide the radio out.
3. Reapply power to the radio.
4. Press and hold both pushbuttons S1 and S2.
5. Release pushbutton S2 while still holding down pushbutton S1.
6. Wait 5 seconds, then release pushbutton S1.
7. Connect the radio to the PC via a straight through cable.
8. On the PC Settings tab, click **Find Ports.**
9. Select the appropriate port from the drop-down list.
10. Set the rest of the settings to:
    - Baud Rate: 9600
    - Parity: None
    - Handshaking: Hardware
    - Data Bits: 8
    - Stop Bits: 1
11. Under Options, ensure the *Read/Write with AT Commands* check box is selected.
12. Ensure the *Port Status* is open.
13. On the Configure tab, click **Read Radio**.
14. Set the *Interface Baud Rate* to the appropriate value and click **Write Radio**.
15. Power off the radio.
16. Remove the jumper.
17. Power on the radio.
18. Set the *Baud Rate* on the PC Settings tab to the baud rate you configured on the radio.
19. On the Configure tab, click **Read Radio**.