LT2510 User Manual

version 1.0.8

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This material is preliminary

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Revision History

Revision	Description
Version 1.0	7/21/08 - Initial Release Version
Version 1.0.1	8/25/08- Updated name to LT2510
Version 1.0.2	10/8/08- Changed Modulation and RF Data Rate
Version 1.0.3	11/17/08- Added TX API and Adjustable RF Data Rate
Version 1.0.4	12/4/08- Engineering Updates
Version 1.0.5	1/27/09- Updated FCC/IC IDs and Antenna information
Version 1.0.6	2/11/09- Updated Read ADC, Write PWM and FCC Warnings, Added Bin Analyzer and Change Server/Client Mode Commands
Version 1.0.7	2/23/2009- Updated Antenna requirements for FCC approval
Version 1.0.8	3/10/09- Portable and Mobile qualifications for FCC approval

Contents

LT2510 TRANSCEIVER MODULE

The LT2510 Frequency Hopping Spread Spectrum Transceiver Module from Laird Technology is the latest in robust and easy to use radio modules. Supporting both high data rates and long ranges, the LT2510 is a great fit for any number of machine-to-machine applications. The LT2510 features an easy to use serial UART with hardware flow control for fast integration into an existing serial infrastructure.

LT2510 KEY FEATURES

- Retries and Acknowledgements
- Programmable Network Parameters
- Multiple generic I/O
- 280 kbps or 500kbps RF data stream
- Receive Average current draw of 12mA
- Software selectable interface baud rates from 1200 bps to 230.4 kbps
- Low cost, low power and small size ideal for high volume, portable and battery powered applications
- All modules are qualified for Industrial temperatures (-40°C to 85°C)
- Advanced configuration available using AT commands
- Easy to use Configuration & Test Utility software

OVERVIEW

This document contains information about the hardware and software interface between a Laird Technologies LT2510 transceiver and an OEM Host. Information includes the theory of operation, specifications, interface definitions, configuration information and mechanical drawings.

Note: Unless mentioned specifically by name, the LT2510 modules will be referred to as **"radio"** or **"transceiver"**. Individual naming is used to differentiate product specific features. The host (PC/Microcontroller/Any device to which the LT2510 module is connected) will be referred to as "OEM Host" or "Host."

SPECIFICATIONS

DETAILED SPECIFICATIONS

Table 1 list the detailed parameters for the operation of the LT2510 transceiver.

Table 1: LT2510 Detailed Specifications

General	
Form Factor	Surface Mount
Antenna	Chip antenna or U.FL connector
Serial Interface Data Rate	Baud rates from 1200 bps to 230,400 bps. Non-standard baud rates are also supported.
Serial Buffer	768 Byte RX Serial Buffer, 5120 Byte TX Serial Buffer
Channels	42 or 78 Channels
Security	Channelization and System ID
Transceiver	
Frequency Band	2400 - 2483.5 MHz
Hop Bin Spacing	280kbps RF Data Rate: 900kHz 500kbps RF Data Rate: 1500kHz
RF Data Rate (Raw)	280 kbps or 500kbps
RF Technology	Frequency Hopping Spread Spectrum
Modulation	MSK
Output Power EIRP (conducted)	PRM110/111: +2dBm to +18dBm PRM310/311: +5dBm to +21dBm
Supply Voltage	3.3 - 3.6V, ±50mV ripple
Current Draw	100% TX / 100% RX / Receive Avg / Deep Sleep PRM110/111: 85mA / 40mA / 12 mA / 50uA PRM310/311: 190mA / 40mA / 12 mA / 50uA
Sensitivity (1% PER)	280kbps RF Data Rate: -99 dBm typical 500kbps RF Data Rate: -94 dBm typical
Range, Line of Site (based on 3dBi gain antenna)	280kbps RF Data Rate: 4 miles (6.4klm) 500kbps RF Data Rate: 2 miles (3.2km)
Environmental	
Temperature (Operating)	-40°C to 85°C
Temperature (Storage)	-50°C to +85°C
Physical	
Dimensions	1.13" x 1.75" x 0.165" (28,7 x 44.5 x 4.2 mm)

Table 1: LT2510 Detailed Specifications

Certifications	
FCC Part 15.247	KQL-2510100
Industry Canada (IC)	2268C-2510100
CE	Pending

PIN DEFINITIONS

The LT2510 has a simple interface that allows OEM Host communications with the transceiver. Table 2 below shows the connector pin numbers and associated functions.

Table 2: Pin Definitions for the LT2510 transceiver

SMT Pin	Type	Signal Name	Function
1	O	GO_0	Generic Output
2	O	GO_1	Generic Output
3		DNC	Do not connect.
4			Reserved for future use
5	O	PWM_Output	PWM Digital to Analog Output
6	I	RXD	Asynchronous serial data input to transceiver
7	O	TXD	Asynchronous serial data output from transceiver
8	GND	GND	Signal Ground
9	PWR	VCC	3.3 - 3.6 V ±50mV ripple **(must be connected)**
10	PWR	VPA	3.3 - 3.6 V ±50mV ripple **(must be connected)**
11	GND	GND	Signal Ground
12	I	$\overline{\text{Test}}$	Test Mode – When pulled logic Low and then applying power or resetting, the transceiver's serial interface is forced to a 9600, 8-N-1 rate. To exit Test mode, the transceiver must be reset or power-cycled with Test Mode pulled logic High or left floating/disconnected. **Note:** Because this mode disables some modes of operation, it should not be permanently pulled Low during normal operation.
13		Reserved	Reserved for future use
14	I	$\overline{\text{UP\_Reset}}$	RESET – Controlled by the LT2510 for power-on reset if left unconnected. After a stable power-on reset, a logic Low pulse will reset the transceiver.
15	I	$\overline{\text{CMD}}$/Data	When logic Low, the transceiver interprets OEM Host data as command data. When logic High, the transceiver interprets OEM Host data as transmit data.

Table 2: Pin Definitions for the LT2510 transceiver

SMT Pin	Type	Signal Name	Function
16	O	In Range	When logic low, the client is in range and synchronized with a server. This will always be low on a Server.
17	I	RTS	Request to Send. Floats high if left unconnected, be careful when using enable RTS in the configuration.
18	O	CTS	Clear to Send - Active Low when the transceiver is ready to accept data for transmission.
19		Reserved	Reserved for future usu. Do not connect.
20		Reserved	Reserved for future use. Do not connect.
21		Reserved	Reserved for future use. Do not connect.
22	I	AD_In	Analog to Digital Input

ENGINEER'S TIP

Design Notes:
- All I/O is 3.3V TTL.
- All inputs are weakly pulled High via a 20kOhm pull-up resistor and may be left floating during normal operation
- Minimum Connections: VCC, VPA, GND, TXD, & RXD
- Signal direction is with respect to the transceiver
- Unused pins should be left disconnected

ELECTRICAL SPECIFICATIONS

Table 3: Input Characteristics

Signal Name	High Min	High Max	Low Min	Low Max	Unit
RXD	2.31	3.3	0	.99	V
$\overline{\text{Test}}$	2.31	3.3	0	.99	V
$\overline{\text{UP\_Reset}}$	0.8	3.3	0	0.6	V
$\overline{\text{CMD/Data}}$	2.31	3.3	0	.99	V
$\overline{\text{RTS}}$	2.31	3.3	0	.99	V
AD/_In	N/A	3.3	0	N/A	V
GI_0	2.31	3.3	0	.99	V
GI_1	2.31	3.3	0	.99	V

Table 4: Output Characteristics

Signal Name	High Min	Hiigh Max	Low Min	Low Max	Units
GO_0	2.5	3.3	0	0.4	V
GO_1	2.5	3.3	0	0.4	V
PWM_Output	N/A	3.3	0	N/A	V
TXD	2.5	3.3	0	0.4	V
In_Range	2.5	3.3	0	0.4	V
CTS	2.5	3.3	0	0.4	V

BLOCK DIAGRAM

Figure 1 includes a functional Block Diagram of the transceiver module.

PWM

GPIO

ADC

InRange

Test

CMD/Data

UpReset

AC2510

Antenna

RTS

CTS

Serial UART

TXD

RXD

Output Buffer 512 Bytes

Input Buffer 768 Bytes

CPU

EEPROM

Transmitter

PA

LNA
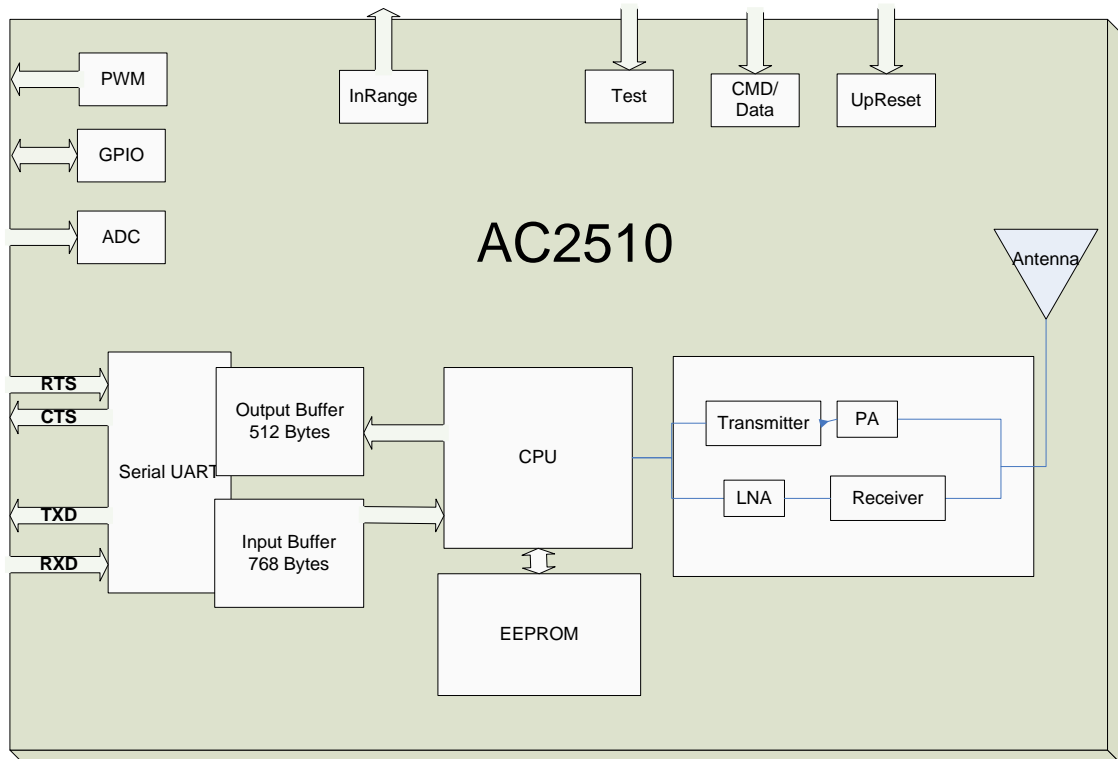
Receiver

HARDWARE INTERFACE

PIN DESCRIPTIONS

RXD and TXD

The LT2510 accepts 3.3 VDC TTL level asynchronous serial data from the OEM Host via the RXD pin. Data is sent from the transceiver, at 3.3V levels, to the OEM Host via the TXD pin.

Test

Test Mode - When pulled logic Low before applying power or resetting, the transceiver's serial interface is forced to 9600, 8-N-1 (8 data bits, No parity, 1 stop bit): regardless of actual EEPROM setting. The interface timeout is also set to 3 ms and the RF packet size is set to the default size for the selected RF Data Rate. To exit, the transceiver must be reset or power-cycled with $\overline{\text{Test}}$ pin logic High or disconnected.

Note: Because this pin disables some modes of operation, it should <u>not</u> be permanently pulled Low during normal operation.

UP_Reset

UP_Reset provides a direct connection to the reset pin on the LT2510 microprocessor and is used to force a hard reset. For a valid reset, reset must be asserted Low for an absolute minimum of 250 ns.

$\overline{\text{Command}/\text{Data}}$

When logic High, the transceiver interprets incoming serial data as transmit data to be sent to other transceivers. When logic Low, the transceiver interprets incoming serial data as command data. When logic Low, data packets from the radio will <u>not</u> be transmitted over the RF interface however incoming packets from other radios will still be received. RX Data Received can be disabled by enabling CMD/Data RX Disable in the EEPROM.

In Range

The In Range pin will be driven low when a client radio is synchronized with a server. In Range will always be driven low on a server.

$\overline{\text{RTS}}$ Handshaking

With RTS mode disabled, the transceiver will send any received data to the OEM Host as soon as it is received. However, some OEM Hosts are not able to accept data from the transceiver all of the time. With RTS enabled, the OEM Host can prevent the transceiver from sending it data by de-asserting $\overline{\text{RTS}}$ (High). Once $\overline{\text{RTS}}$ is re-asserted (Low), the transceiver will send packets to the OEM Host as they are received.

Note: Leaving $\overline{\text{RTS}}$ de-asserted for too long can cause data loss once the transceiver's receive buffer reaches capacity.

$\overline{\text{CTS}}$ Handshaking

If the transceiver buffer fills up and more bytes are sent to it before the buffer can be emptied, data loss will occur. The transceiver prevents this loss by deasserting $\overline{\text{CTS}}$ High as the buffer fills up and asserting $\overline{\text{CTS}}$ Low as the buffer is emptied. $\overline{\text{CTS}}$ should be monitored by the Host device and data flow to the radio should be stopped when $\overline{\text{CTS}}$ is High.

THEORY OF OPERATION

SERVER/CLIENT ARCHITECTURE

The LT2510 utilizes a server-client network architecture to synchronize the frequency hopping. Each network must have one radio configured as a Server and all other radios configured as Clients. When a radio is configured as a Server, it will transmit a beacon at the beginning of each hop. Radios configured as Clients will default to a receive mode where they are scanning the available frequencies listening for a beacon from a Server in their network. When a Client detects the Server's beacon, the client will synchronize to it and transition the InRange pin low. When the Server and the Client are synchronized they can begin transferring data.

Each network consists of one, and only one, Server. Multiple networks can exist in the same area, provided the networks are configured on different Channels. The LT2510 utilizes an intelligent Frequency Hopping algorithm which ensures minimal interference between two networks. There is no need to synchronize the communications between the networks. The possible interference between two networks is given by the equation.

Maximum number of interfering bins = #of collocated Servers -1

The LT2510 radio can be configured to hop over 43 or 79 bins, so with two Servers present they will interfere with each other once every 43 or 79 hops. With 10 collocated Servers, they will interfere a maximum of 9 out of 43 or 79 hops (presuming they are also transmitting data during each hop).

ADJUSTABLE RF DATA RATE

The LT2510's RF data rate can be adjusted to provide a trade-off between throughput and range.

Table 5: RF Data Rate

Product Model	RF Data Rate	Number of hops	Receiver Sensitivity	Throughput[1]
100mW, 200mW, 1W	280kbps	79	-99dB	120kbps
100mW, 200mW	500kbps	43	-94dB	250kbps

1. Throughput is ideal, one direction, with no retransmissions. All practical RF applications should include the need to retransmit data due to interference or less than ideal RF conditions

Deciding which RF Data Rate to choose depends on the individual application. The fast RF Data Rate will deliver much faster throughput, but will have much less range. In addition, because the lower data rate solution uses more hops, it is better situated for collocated networks.

A rule of thumb for RF systems is every 6dB of gain doubles the effective distance.   The 5dB gain on the Receive Sensitivity for the lower data rate solution means it will be able to transmit almost twice as far as the higher data rate solution.

MODES OF OPERATION

The LT2510 has three different types of interface modes:

- Transparent Mode
- API Mode
- Command Mode

The first two modes are used to transmit data across the RF, the third mode is used to configure the radio.

Transparent Mode

When operating in Transparent Mode, the LT2510 can act as a direct serial cable replacement in which received RF data is forwarded over the serial interface and vice versa. In transparent mode, the radio needs to be programmed with the MAC Address of the desired recipient. The destination address can be programmed permanently or on-the-fly.

When Transparent Mode is used, data is stored in the TX buffer until one of the following occurs:

- The RF packet size is reached (EEPROM address 0x5A)
- An Interface Timeout occurs (EEPROM address 0x58)

Any parameters can be configured by entering Command Mode using either AT commands or by toggling the Command/Data pin on the transceiver.

API Mode

API Mode is an alternative to the default Transparent operation of the LT2510 and provides dynamic packet routing and packet accounting abilities to the OEM Host without requiring extensive programming by the OEM Host. API Mode utilizes specific frame-based packet formats; specifying various vital parameters used to control radio settings and packet routing on a packet-by-packet basis. The API features can be used in any combination that suits the OEM's application specific needs.

API Mode provides an alternative method of configuring modules and message routing at the OEM Host level; without requiring the use of Command Mode. The LT2510 has three API functions:

- Transmit API
- Receive API
- API Send Data Complete

Command Mode

Command Mode is used to configure and poll for status of the transceiver.   Command mode can be entered by issuing the Enter AT Command string or by setting the CMD/Data pin low.   Details of using Command Mode to configure the LT2510 are detailed in Section 5.

SERIAL INTERFACE BAUD RATE

In order for the OEM Host and a transceiver to communicate over the serial interface they need to have the same serial data rate. This value determines the baud rate used for communicating over the serial interface to a transceiver.   For a baud rate to be valid, the calculated baud rate must be within ±3% of the OEM Host baud rate

Table 6: Baud Rate / Interface Timeout

Desired Baud Rate	Baud (0x42)	Minimum Interface Timeout[1] (0x58)
230,400	0x0A	0x02
115,200[2]	0x09	0x02
57,600	0x08	0x02
38,400[3]	0x07	0x02
28800	0x06	0x03
19,200	0x05	0x05
14400	0x04	0x07
9,600	0x03	0x10
4,800	0x02	0x15
2,400	0x01	0x2A
1,200	0x00	0x53
Non-standard	0xE3	Use equations below

1. Interface timeout = 200us per increment, this is set automatically with the Auto Config option
2. Default baud rate
3.

For baud rates other than those shown in Table 6 the following equations can be used:

$$\text{Baud Rate} = \frac{(256 + \text{BAUD\_M}) \times \left(2^{\text{BAUD\_E}}\right) \times \text{FREQUENCY}}{2^{28}}$$

Where:

FREQUENCY = 26 MHz
BAUD_M = EEPROM Address 0x43
BAUD_E = EEPROM Address 0x44

$$\text{MinimumInterfaceTimeout} = \frac{100000}{\text{Baud Rate}}$$

INTERFACE TIMEOUT / RF PACKET SIZE

Interface Timeout – Interface Timeout specifies a maximum byte gap between consecutive bytes. When that byte gap is exceeded, the bytes in the transmit buffer are processed as a complete packet. Interface Timeout (EEPROM address 0x58), in conjunction with the RF Packet Size, determines when a buffer of data will be sent out over the RF as a complete RF packet, based on whichever condition occurs first. Interface Timeout is adjustable in 200us increments and should be equal to or greater than two full bytes times. The minimum Interface Timeout is 0x02.

RF Packet Size - RF Packet Size is used in conjunction with Interface Timeout to determine when to delineate incoming data as an entire packet based on whichever condition is met first. When the transceiver receives the number of bytes specified by RF Packet Size (EEPROM address 0x5A) without experiencing a byte gap equal to Interface Timeout, that block of data is processed as a complete packet. Every packet the transceiver sends over the RF contains extra header bytes not counted in the RF Packet Size. Therefore, it is much more efficient to send a few large packets than to send many short packets. The maximum RF Packet Size is 239 bytes, or 0xEF, at 500kkbps RF Data Rate and 96 bytes, or 0x60, at 280kbps RF Data Rate.

FLOW CONTROL

Although flow control is not required for transceiver operation, it is <u>recommended</u> to achieve optimum system performance and to avoid overrunning the LT2510's serial buffers. The LT2510 uses separate buffers for incoming and outgoing data.

RXD Data Buffer and $\overline{CTS}$

As data is sent from the OEM Host to the radio over the serial interface, it is stored in the LT2510's buffer until the radio is ready to transmit the data packet. The radio waits to transmit the data until one of the following conditions occur (whichever occurs first):

- The RF packet size is reached (EEPROM address 0x5A)
- An Interface Timeout occurs (EEPROM address 0x58)

The data continues to be stored in the buffer until the radio receives an RF Acknowledgement (ACK) from the receiving radio (addressed mode), or all transmit retries/broadcast attempts have been utilized. Once an ACK has been received or all retries/attempts have been exhausted, the current data packet is removed from the buffer and the radio will begin processing the next data packet in the buffer.

To prevent the radio's RXD buffer from being overrun, it is strongly <u>recommended</u> that the OEM Host monitor the radio's $\overline{CTS}$ output. When the number of bytes in the RXD buffer reaches the value specified by CTS_ON (EEPROM address 0x5C - 0x5D), the radio de-asserts (High) $\overline{CTS}$ to signal to the OEM Host to stop sending data over the serial interface. $\overline{CTS}$ is re-asserted after

the number of bytes in the RXD buffer is reduced to the value specified by CTS_OFF (EEPROM addresses 0x5E- 0x5F); signalling to the OEM Host that it may resume sending data to the transceiver.

Note: It is recommended that the OEM Host cease all data transmission to the radio while $\overline{\text{CTS}}$ is de-asserted (High); otherwise potential data loss may occur.

TXD Data Buffer and $\overline{\text{RTS}}$

As data to be forwarded to the OEM Host accumulates, it is stored in the LT2510's outgoing buffer until the radio is ready to begin sending the data to the OEM Host. Once the data packet has been sent to the Host over the serial interface, it will be removed from the buffer and the radio will begin processing the next data packet in the buffer.

With RTS Mode disabled, the transceiver will send any data to the OEM Host as soon as it has data to send. However, some OEM Hosts are not able to accept data from the transceiver all of the time. With RTS Mode Enabled, the OEM Host can prevent the transceiver from sending it data by de-asserting $\overline{\text{RTS}}$ (High), causing the transceiver to store the data in its buffer. Upon asserting RTS up to two additional bytes can be received over the serial interface before the flow is stopped. Once $\overline{\text{RTS}}$ is re-asserted (Low), the transceiver will continue sending data to the OEM Host, beginning with any data stored in its buffer.

Note: Leaving $\overline{\text{RTS}}$ de-asserted for too long can cause data loss once the radio's TXD buffer reaches capacity.

ENGINEER'S TIP

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

Yes. However, it is strongly recommended that your hardware monitor the $\overline{\text{CTS}}$ pin of the radio. $\overline{\text{CTS}}$ is taken High by the radio when its interface buffer is getting full. Your hardware should stop sending at this point to avoid a buffer overrun (and subsequent loss of data).

You can perform a successful design without monitoring $\overline{\text{CTS}}$. However, you need to take into account the amount of latency the radio adds to the system, any additional latency caused by Transmit Retries, how often you send data, non-delivery network timeouts and interface data rate.

Larid Technologies can assist in determining whether $\overline{\text{CTS}}$ is required for your application.

CONFIGURING THE LT2510

The LT2510 can be configured using AT Configuration Commands. These commands can be issued only in Command Mode. Command Mode can be entered by setting pin 15 of a transceiver asserted low or by entering AT Command Mode before issuing the Enter AT Command.

AT COMMANDS

The AT Command mode implemented in the LT2510 creates a virtual version of the Command/Data pin. The "Enter AT Command Mode" Command asserts this virtual pin Low (to signify Command Mode) and the "Exit AT Command Mode" Command asserts this virtual pin High (to signify Data). Once this pin has been asserted Low, all AT Commands documented in the manual are supported.

There are four types of AT Commands supported by the LT2510.   On-the-Fly commands for dynamic reprogramming of running memory, EEPROM commands for configuring the EEPROM, Utility commands for dealing with Command Mode and Status Commands for polling the radio for information.

While in Command mode, the incoming RF interface of the transceiver is active and packets sent from other transceivers will still be received; however no outgoing RF packets will be sent. The transceiver uses Interface Timeout/RF Packet Size to determine when an AT Command is complete. Therefore, there should be no delay between each character as it is sent from the OEM Host to the transceiver or the transceiver will not recognize the command.

When an invalid command is sent, the radio discards the data and no response is sent to the OEM Host. Table 7 below shows a quick summary of the basic configuration & diagnostic commands available on the LT2510. For detailed command information, please refer to the command descriptions immediately following the Quick Reference Table

Utility Commands

Utility Commands are used to enter and exit AT Command Mode and to reset the radio.

On-the-Fly Control Commands

The LT2510 transceiver contains memory that holds many of the parameters that control the transceiver operation. Using the On-the-Fly command set allows many of these parameters to be viewed and changed during system operation. Because the memory these commands affect is dynamic, when the transceiver is reset, these parameters will revert back to the settings stored in the EEPROM.

Status Commands

Status Commands are used to poll the radio for information. Status commands can be used to poll GPIOs, ADCs or to retrieve information about the state of the network.   Status commands do not affect the operation of the transceiver aside from being in Command Mode.

EEPROM Configuration Commands

Two Commands are available to read and write the EEPROM of the radio. These commands are very powerful as they can control the entire configuration of the radio. They should be used with caution as overwriting reserved areas of memory can adversely affect the operation of the radio. The radio must be reset for any changes to the EEPROM to take affect.

COMMAND QUICK REFERENCE

Table 4 provides an at-a-glance view of all available AT commands.

.

Table 7: Command Quick Reference

Command Name	Command (All bytes in Hex)	Return (All bytes in Hex)
Utility Commands		
Enter AT Command Mode	<0x41> <0x54> <0x2B> <0x2B> <0x2B> <0x0D>	<0xCC> <0x43> <0x4F> <0x4D>
Exit AT Command Mode	<0xCC> <0x41> <0x54> <0x4F> <0x0D>	<0xCC> <0x44> <0x41> <0x54>
Enter Deep Sleep	<0xCC> <0x86> <0x03>	None
Soft Reset	<0xCC> <0xFF>	None
Status Commands		
Status Request	<0xCC> <0x00> <0x00>	<0xCC> <Firmware Version> <Status>
Read Temperature	<0xCC> <0xA4>	<0xCC> <Temperature>
On-the-Fly Commands		
Change Channel	<0xCC> <0x02> <Channel>	<0xCC> <Channel>
Change Server/Client Mode	<0xCC> <0x03> <Data>	<0xCC> <Firmware Version> <Status>
Set Broadcast Mode	<0xCC> <0x08> <Data>	<0xCC> <Data>
Write Destination Address	<0xCC> <0x10> <Dest Address last thee bytes>	<0xCC> <Dest Addr>
Read Destination Address	<0xCC> <0x11>	<0xCC> <Dest Addr>
Auto Destination/Channel	<0xCC> <0x15> <Data>	<0xCC> <Data>
Read API Control	<0xCC> <0x16>	<0xCC> <API Control>
Write API Control	<0xCC> <0x17> <API Control>	<0xCC> <API Control>
Read Digital Input	<0xCC> <0x20>	<0xCC> <Data>
Read ADC	<0xCC> <0x21> <Data>	<0xCC> <ADC Hi> <ADC Lo>
Write PWM Output	<0xCC> <0x24> <Data>	<0xCC> <0x24>
Write Digital Outputs	<0xCC> <0x23> <Data>	<0xCC> <0x23>
Set Power Control	<0xCC> <0x25> <Power>	<0xCC> <Power>
EEPROM Commands		
EEPROM Byte Read	<0xCC> <0xC0> <Start> <Length>	<0xCC> <Start> <Length> <Data [n-0]>
EEPROM Byte Write	<0xCC> <0xC1> <Start> <Length> <Data>	<Start> <Length> <Last byte written>

Table 7: Command Quick Reference

Command Name	Command (All bytes in Hex)	Return (All bytes in Hex)
	Advanced Networking Commands	
Bin Analyzer	<0xCC> <0x8F> <Data>	<0xCC> <0x8F>

COMMAND DESCRIPTIONS

Enter AT Command Mode

Prior to sending this command, the OEM Host must ensure that the transceiver's RF transmit buffer is empty. This can be accomplished by waiting up to one second between the last packet and the AT command. If the buffer is not empty, the radio will interpret the command as data and it will be sent over the RF.

Command: <0x41> <0x54> <0x2B> <0x2B> <0x2B> <0x0D>

Number of Bytes Returned: 4

Response: <0xCC> <0x43> <0x4F> <0x4D>

Exit AT Command Mode

The OEM Host should send this command to exit AT Command mode and resume normal operation.

Command: <0xCC> <0x41> <0x54> <0x4F> <0x0D>

Number of Bytes Returned: 4

Response: <0xCC> <0x44> <0x41> <0x54>

Enter Deep Sleep

The OEM Host issues this command to put the module into a Deep Sleep state to minimize current draw. In this state a Server will not send out a beacon, a Client will not remain In Range and no commands sent over the Serial UART will be processed. To awake from Deep Sleep the OEM must toggle the Up_Reset pin.

Command: <0xCC> <0x86> <0x03>

Number of Bytes Returned: None

Response: None

Reset

The OEM Host issues this command to perform a soft reset of the transceiver. Any transceiver settings modified by CC commands will revert to the values stored in the EEPROM.

Command: <0xCC> <0xFF>

Number of Bytes Returned: None

Response: None

Status Version Request

The OEM Host issues this command to request the firmware and link status of the transceiver.

Command: <0xCC> <0x00> <0x00>

Number of bytes returned: 3

Response: <0xCC> <Firmware Version> <Status>

Parameter Range:
<Firmware> = Radio Firmware version
<Status> = 0x02: Server
0x03: Clients In Range
0x01: Client not In Range

Read Temperature

The OEM Host issues this command to read the onboard temperature sensor.

Note: The temperature sensor is uncalibrated and has a tolerance of +/- 3C. For calibration instructions, contact Laird Technology's technical support.

Command: <0xCC> <0xA4>

Number of bytes returned: 2

Response: 0xCC <Temp.>

Parameter Range:
<Temp.>   =   Temperature (Celsius) in Two's compliment format

Change Channel

The OEM Host issues this command to change the channel of the transceiver.

Command: <0xCC> <0x02> <Channel>

Number of Bytes Returned: 2

Response: <0xCC> <Channel> <ChMask>

Parameter Range:
<Channel>   =   0x00 - 0x4E RF Channel to use

Change Server/Client Mode

The OEM Host issues this command to change the transievers mode from Server to Client or vice-versa.
The OEM can use Bit 1 to force the status of the transiever.

Command: <0xCC> <0x03> <Data>

Number of Bytes Returned: 3

Response: <0xCC> <Firmware Version> <Status>

Parameter Range:
<Data>   =   Bit0::
                          0= Server
                          1= Client
                          Bit1::
                          0= Force InRange
                          1= Force Out of Range
<Firmware>   =   Radio Firmware version
<Status>   =   0x02: Server
                          0x03: Clients In Range
                          0x01: Client not In Range

Set Broadcast Mode

The Host issues this command to set the addressing mode in the radio.

Command: <0xCC> <0x08> <Data>

Number of Bytes Returned: 2

Response: <0xCC> <Data>

Parameter Range:
<Data>   =   0x00 Disable Broadcast Mode
                          0x01 Enable Broadcast Mode

Write Destination Address

The OEM Host issues this command to the transceiver to change the Destination Address.

Command: <0xCC> <0x10> <MAC1> <MAC2> <MAC3>

Number of bytes returned: 4

Response: <0xCC> <MAC1> <MAC2i> <MAC3>

Parameter Range:
0x00 - 0xFF corresponding to the 3 LSBs of the destination MAC Address

Read Destination Address

The OEM Host issues this command to the transceiver to read the Destination Address.

Command: <0xCC> <0x11>

Number of bytes returned: 4

Response: <0xCC> <MAC1> <MAC2> <MAC3>

Parameter Range:
0x00 - 0xFF corresponding to the 3 LSBs of the destination MAC Address

Auto Destination/Channel

The Host issues this command to change the Auto Destination setting. When issuing this command, the Auto Destination setting will only be changed if the corresponding enable bit is set. Otherwise, the command performs a read of Auto Destination.

Command: <0xCC> <0x15> <Data>

Number of Bytes Returned: 2

Response: <0xCC> <Auto Dest>

Parameter Range:
<Auto Dest>   =   bit 7: Ignored
                          bit 6: Ignored
                          bit 5: Enable Modification of Auto Channel
                          bit 4: Enable Modification of Auto Destination
                          bit 3: Ignored
                          bit 2: Ignored
                          bit 1: Auto Channel
                          bit 0: Auto Destination

Read API Control

The OEM Host issues this command to read the API Control byte.

Command: <0xCC> <0x16>

Number of Bytes Returned: 2

Response: <0xCC> <API Control>

Parameter Range:
<API Control>=   bits 7-3: 0
                          bit-2: Send Data Complete
                          bit-1: Transmit API
                          bit-0: Receive API

Write API Control

The OEM Host issues this command to write the API Control byte to enable or disable the API features.

Command: <0xCC> <0x17> <API Control>

Number of Bytes Returned: 2

Response: <0xCC> <API Control>

Parameter Range:
<API Control>=   bits 7-3: Ignored
                          bit-2: Send Data Complete
                          bit-1: Transmit API
                          bit-0: Receive API

Read Digital Outputs

The OEM Host issues this command to read the state of both digital output lines.

Command: <0xCC> <0x20>

Number of Bytes Returned: 2

Response: 0xCC <Digital Out>

Parameter Range:
<Digital Out> =   bit-1: GO1
                   bit-0: GO0

Read ADC

The OEM host issues this command to read the analog to digital converters at up to 12-bit resolution.   Higher resolutions can cause slower responses from the command. The time required for a conversion is

Tconv = (decimation rate + 16) * .23uS.

In the most common forms this will be used to measure the input voltage (to detect reduced battery power) with Vdd/3, the temperature sensor or the Analog input on Pin 22. For the most accurate results the 1.25V internal reference should be chosen, though this would limit the OEM to a maximum AD/In of 1.25 v [Vdd/3 and Temperature Sensor should always be below 1.25v]

The ADC result is represented in a two's complement form.   The result is the difference between ground and the selected channel and will be a value between -2048 and 2047 with 2047 representing the maximum value where the ADC result equals the reference voltage and -2048 equals the negative of the reference voltage. The ADC cannot measure a voltage higher than the reference voltage.

Command: <0xCC> <0x21> <Data>

Number of Bytes Returned: 3

Response: 0xCC <Hi ADC> <Lo ADC>

Parameter Range:
<Data bits 6-7>=   <Reference Voltage>
                   00: Internal 1.25V reference
                   10: Vdd on AVdd pin
<Data bits 4-5>=   <Resolution>
                   00: 64 decimation rate (7 bits resolution)
                   01: 128 decimation rate (9 bits resolution)
                   10: 256 decimation rate (10 bits resolution)
                   11: 512 decimation rate (12 bits resolution)
<Data bits 0-3>=   <Channel>
                   0000: AD/In PIn 22
                   1100: GND
                   1101: Positive Voltage Reference
                   1110: Temperature Sensor
                   1111: Vdd/3
<Hi ADC>   =   MSB or requested 12-bit ADC value
<Lo ADC>   =   LSB of reequested 12-bit ADC value

Write PWM Outputs

The OEM Host issues this command to set the PWM_Output.   The PWM output is a repeating 630.1uS period. The PWM ratio is the ratio of the high pulse time to the low pulse time.   A value of 0x00 will output a continuous low signal. A ratio of 0xFF will output a continuous high signal. A ratio of 0x80 will put out a repeating pulse of 315.05uS high and 315.05uS low.

Command: <0xCC> <0x24> <PWM Ratio>

Number of Bytes Returned: 2

Response: 0xCC <0x24>

Parameter Range:
<PWM Ratio> =   0x00 -0xFF, the ratio of the high pulse versus the low pulse for a single period.

Write Digital Outputs

The OEM Host issues this command to write both digital output lines to particular states.

Command: <0xCC> <0x23> <Digital Out>

Number of Bytes Returned: 2

Response: 0xCC <0x23>

Parameter Range:
<Digital Out> =   bit-1: GO1
                   bit-0: GO0

Set Max Power

The OEM Host issues this command to adjust the maximum output power.

Command: <0xCC> <0x25> <Max Pwr>	
Number of Bytes Returned: 2	
Response: 0xCC <Max Pwr>	

Parameter Range:
<Max Pwr>   =   <u>Power</u>
            0x00: 21 dBm
            0x01: 15 dBm
            0x02: 9 dBm
            0x03: 3 dBm	

EEPROM Byte Read

Upon receiving this command, a transceiver will respond with the desired data from the addresses requested by the OEM Host.

Command: <0xCC> <0xC0> <Start> <Length>
Number of Bytes Returned: 4+
Response: <0xCC> <Start> <Length> <Data>
Parameter Range: <Start>   =   EEPROM address to begin reading at <Length>   =   Length of data to be read <Data>   =   Requested data

EEPROM Byte Write

Upon receiving this command, a transceiver will write the data byte to the specified address but will not echo it back to the OEM Host until the EEPROM write cycle is complete.

Note: The maximum length of data that can be written in a single write process is 0x50. If writing the entire 256-byte EEPROM, it is convenient to perform 64 byte (0x40) writes.

Command: <0xCC> <0xC1> <Start> <Length> <Data>
Number of Bytes Returned: 3
Response: <Start> <Length> <Last byte>
Parameter Range: <Start>   =   EEPROM address to begin writing at <Length>   =   Length of data to be written (Max = 0x50) <Data>   =   Data to be written <Last byte> =   Value of last byte written

Bin Analyzer

The Bin Analyzer is a powerful command for understanding the link conditions between two radios over the entire frequency hopping spectrum. The Bin Analyzer will cause the local radio to send a special Bin Analyzer packet to the radio in the Desitnation field. The remote radio will respond with RSSI information and this is then streamed to the OEM through the Serial UART.

Due to the random frequency hopping sequence of the radios, it is not possible to associate a specific bin # with a specific frequency, though the OEM can use the Bin Analyzer response to identify any possible interferers and to provide a quantitative analysis of the total number of good versus bad bins.

The Bin Analyzer command will stream data results back for each hop until the command is turned off or the number of runs is met.

The Bin Analyzer command must be issued from Command Mode, but it will continue to stream results back even after the OEM has exited Command Mode. The Bin Analyzer packet is sent as part of the RF Packet Header and does not affect the throughput of data between two radios.

Command: <0xCC> <0x8F> <Control> <NumRuns>
Number of Bytes Returned: 2
Response: <0xCC> <0x8F>
Bin Response Stream: <0xCC> <Bin#> <RSSI_1> <RSSI_2>

Parameter Range:
<Control>   =   0x00= Turn Bin Analyzer Off
                     0x01= Turn Bin Analyzer On
<NumRuns>   =
                     0x00= Continous
                     0x01- 0xFF= Number of runs [bins]
<Bin#>   =   Bin# from 0-79 or 0-53 depending on the RF Data Rate
<RSSI_1>   =   RSSI the remote radio heard the local radio's bin request
<RSSI_2>   =   RSSI the local radio heard the remote radio's response

EEPROM PARAMETERS

The OEM Host can program various parameters that are stored in EEPROM and become active after a power-on reset. The table below gives the locations and descriptions of the parameters that can be read/written by the OEM Host. Factory default values are also shown. Do not write to any EEPROM addresses other than those listed below. Do not copy one transceiver's EEPROM to another transceiver as doing so may cause the transceiver to malfunction.

Table 8: EEPROM Parameters

Parameter	EEPROM Address	Length (Bytes)	Range	Default	Description
Product ID	0x00	40			Product identifier string. Includes revision information for software and hardware.
Range Refresh	0x3D	1	0x01-0xFF	0x18	Specifies the maximum amount of time a transceiver will report In Range without having heard a Server's beacon. Equal to hop period * value, do not set to 0x00.
Channel Number	0x40	1	0x00 - 0x4F	0x00	RF Channel Number, used to determine the hopping sequence.
Baud Rate	0x42	1	0x00 - 0x0A	0x09	Baud Rate, see serial interface section for details. Default represents 115,200kbps.
Transmit Retries	0x4C	1	0x01 - 0xFF	0x03	Maximum number of times a packet is transmitted when Addressed packets are selected. **Note**: Do not set to 0.
Broadcast Attempts	0x4D	1	0x01 - 0xFF	0x03	Number of times each packet is transmitted when Broadcast packets are selected. **Note**: Do not set to 0.
Control 1	0x56	1	0x00 - 0xFF	0x40	Settings are: bit-7: Reserved bit-6: Reserved bit-5: Reserved bit-4: Auto Destination 0 = Use destination address 1 = Use auto destination bit-3: Client Auto Channel 0 = Disable Auto Channel 1 = Enable Auto Channel bit-2: Reserved bit-1: Duplex 0 = Half Duplex 1 = Full Duplex bit-0: Reserved
Interface Timeout	0x58	1	0x02 - 0xFF	0x02	Specifies a byte gap timeout, used in conjunction with RF Packet Size to determine when a packet coming over the interface is complete (200us per increment).

Table 8: EEPROM Parameters

Parameter	EEPROM Address	Length (Bytes)	Range	Default	Description
RF Packet Size	0x5A	1	0x01 - 0xEF	0xEF	Used in conjunction with Interface Timeout; specifies the maximum size of an RF packet. **Note**: Must be set to a minimum of 6 in order to send the Enter AT command.
$\overline{CTS}$ On	0x5C	2	0x0000 - 0x02C0	0x0280	$\overline{CTS}$ will be de-asserted (High) when the transmit buffer contains at least this many characters.
$\overline{CTS}$ Off	0x5E	2	0x0000 - 0x02C0	0x0200	Once $\overline{CTS}$ has been de-asserted, $\overline{CTS}$ will be reasserted (Low) when the transmit buffer is contains this many or less characters.
Max Power	0x63	1	0x00 - 0x03	0x00	Used to increase/decrease the output power. 0x00 21dBm 0x001 10dBm 0x02 4dBm 0x03 0dBm **Note**: The transceivers are shipped at maximum allowable power.
Destination MAC Address	0x70	6	0x00 - 0xFF	0xFF	Specifies destination for RF packets
System ID	0x76	1	0x00 - 0xFF	0x01	Similar to network password. Radios must have the same system ID to communicate with each other.
Control 2	0xC1	1	0x01 - 0xFF	0x00	Settings are: bit-7: Broadcast Mode 0 = Disable 1 = Enable bit-6: Reserved bit-5: Reserved bit-4: Reserved bit-3: Unicast Only 0 = Disable 1 = Enable bit-2: Send Data Complete API 0 = Disable 1 = Enable bit-1: Transmit API 0 = Disable 1 = Enable bit-0: Receive API 0 = Disable 1 = Enable
D.O.B.	0xE0	4			Provides factory calibration and test date.

API OPERATION

API Operation is a powerful alternative to the default Transparent operation of the LT2510 and provides dynamic packet accounting abilities to the OEM Host without requiring extensive programming by the OEM Host. API operation utilizes specific packet formats. The API features can be used in any combination that suits the OEM's specific needs and can be different between radios operating on the same network.
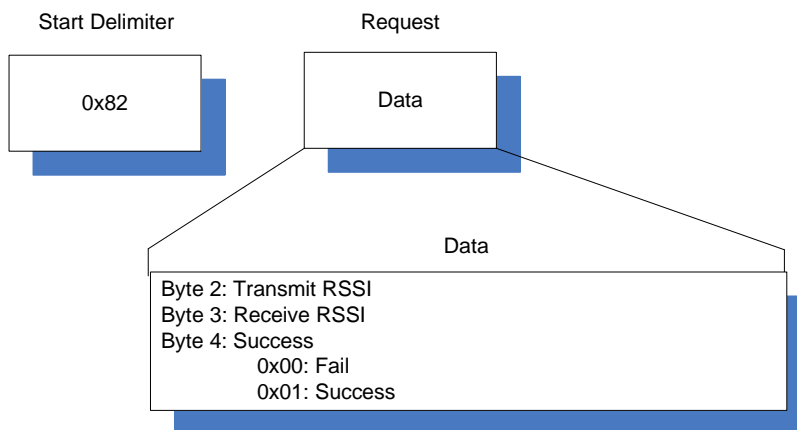
API SEND DATA COMPLETE

API Send Data complete can be used as a software acknowledgement indicator. When a radio sends an addressed packet, it will look for a received acknowledgement (transparent to the OEM Host). If an acknowledgement is not received, the packet will be retransmitted until one is received or all retries have been exhausted.

For applications where data loss is not an option, the OEM Host may wish to monitor the acknowledgement process using the API Send Data Complete. If an acknowledgement is not received (Failure), the OEM Host can send the packet to the transceiver once again.

API Send Data Complete is enabled when bit-2 of the Control 2 (Address 0xC1) byte is enabled. The transceiver sends the OEM Host the data shown in Figure 1 upon receiving an RF acknowledge or exhausting all attempts.

Figure 1: Send Data Complete packet format

Start Delimiter

0x82

Request

Data

Data

Byte 2: Transmit RSSI
Byte 3: Receive RSSI
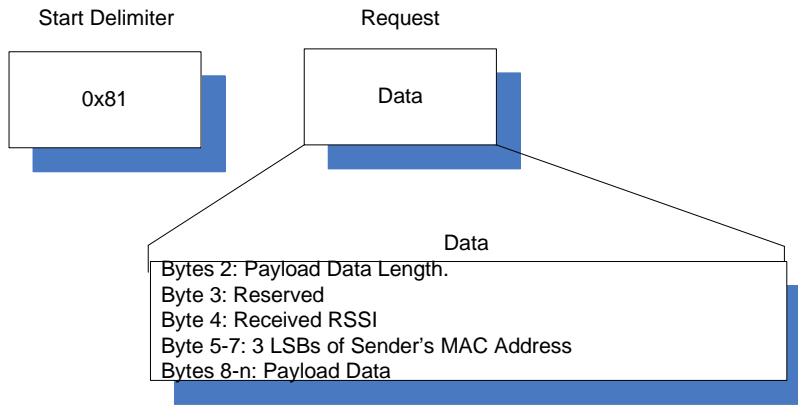Byte 4: Success
      0x00: Fail
      0x01: Success

API RECEIVE PACKET

By default, the source MAC is not included in the received data string sent to the OEM Host. For applications where multiple radios are sending data, it may be necessary to determine the origin of a specific data packet. When API Receive Packet is enabled, all packets received by the transceiver will include the MAC address of the source radio as well as an RSSI indicator which can be used to determine the link quality between the two.

API Receive Packet is enabled when bit-0 of the Control 2 (Address 0xC1) byte is enabled. Upon receiving a RF packet, the radio sends its OEM Host the data as shown in Figure 2 below.

Figure 2: Receive API packet format

Start Delimiter

0x81

Request

Data

Data
Bytes 2: Payload Data Length.
Byte 3: Reserved
Byte 4: Received RSSI
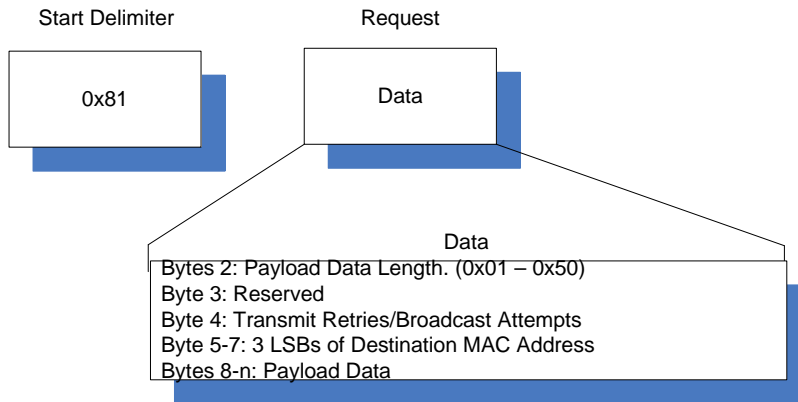Byte 5-7: 3 LSBs of Sender's MAC Address
Bytes 8-n: Payload Data

API TRANSMIT PACKET

API Transmit Packet is a powerful API Mode that allows the OEM Host to send data to a single or multiple (via Broadcast) transceivers on a packet-by-packet basis.   This can be useful for many applications; including polling networks and mesh networks.

API Transmit Packet is enabled when bit-1 of the Control 2 (address 0xC1) byte is enabled.   The OEM should pre-pend each packet of data with the following header information.

Figure 3: Transmit API packet format[1]

Start Delimiter

0x81

Request

Data

Data
Bytes 2: Payload Data Length. (0x01 – 0x50)
Byte 3: Reserved
Byte 4: Transmit Retries/Broadcast Attempts
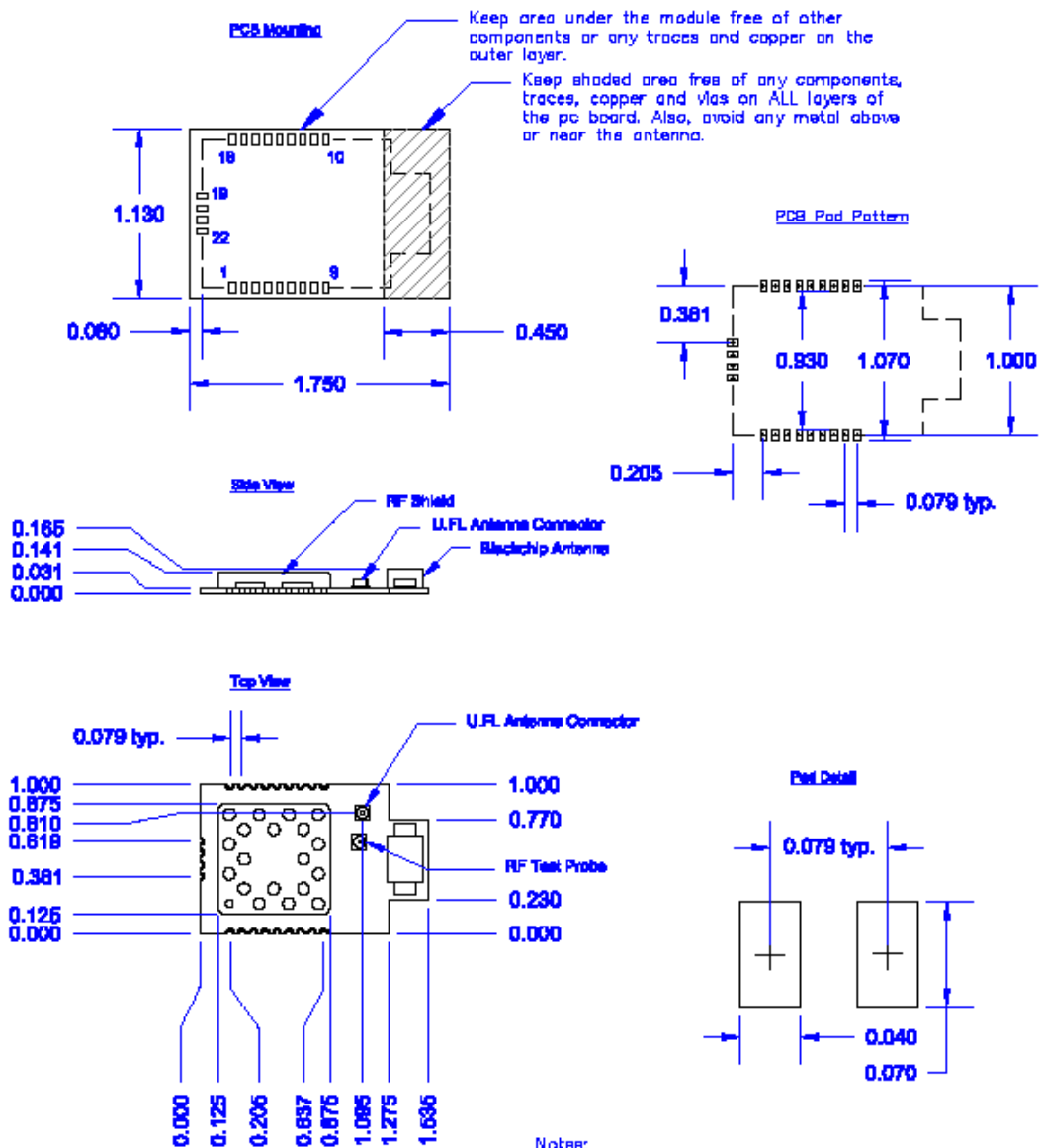Byte 5-7: 3 LSBs of Destination MAC Address
Bytes 8-n: Payload Data

1.Setting the Destination Address to 0xFF 0xFF 0xFF will broadcast the packet to all available transceivers in the network.

DIMENSIONS

MECHANICAL DRAWING

Figure 4: Mechanical Drawing

Notes:
— All dimensions are +/− .005 inches
— PC Board Material is 0.031 thick FR4
— Board edge connections are 0.031 plated holes
— Not to exceed 260 degrees C during soldering

ORDERING INFORMATION

<div style="text-align:right">9</div>

PRODUCT PART NUMBERS

Table 9: LT2510 Part Numbers

Part Number	Description
PRM110	100W, Chip Antenna
PRM111	100mW, U.FL
PRM121	100mW with U.FL mounted on AC4424 compatible board

Table 10: LT2510 Development Kit Part Numbers

Part Number	Description
DVK-PRM110	Full Development kit with two radios with Chip Antennas and accessories
EVB-PRM112	One 100mW radio with Chip antenna on USB eval board
EVB-PRM113	One 100mW radio with Chip antenna on RS-232 eval board
DVK-PRM111	Full Development kit with two radios with U.FL connectors and accessories
EVB-PRM114	One 100mW radio with U.FL connectors on USB eval board
EVB-PRM115	One 100mW radio with U.FL Connectors on RS-232 eval board

COMPLIANCY INFORMATION

AGENCY IDENTIFICATION NUMBERS

Table 11: Agency Identification Numbers

Part Number	US/FCC	CANADA/IC	ETSI
LT2510	KQL-2510100	2268C-2510100	Pending

APPROVED ANTENNA LIST

The following antennas are approved for operation with the LT2510 as identified. .

This device has been designed to operate with the antennas listed below, and having a maximum gain of 6dB when hopping over 43 hop bins and 9dB when hopping over 79 hop bins.. Antennas not included in this list or having a gain greater than the maximum allowed are strictly prohibited for use with this device. The required antenna impedance is 50 Ohms.

Table 12: LT2510 Approved Antenna List[1]

Laird Technology Part Number	Manufacturer Part Number	Manufacturer	Type	Gain (dBi)
	WIC2450-A	Laird	Chip	2
	IG2450-RS36	Laird Technologies	Omni	6
	ID2450-RS36[2]	Laird Technologies	Panel	9
	S151FC-L-(132)PX-2450S	Nearson	Dipole	5

1. The OEM is free to choose another vendor's antenna of like type and equal or lesser gain as an antenna appearing in the table and still maintain compliance
2. To comply with the power requirements of 15.247(b)(1) and 15.247(b)(4), the module cannot be used with the 9dBi antenna if using the 43 channel hop sequence and full power.   The module must either hop over the full 79 channels or the power setting must be turned down to 0x01 or lower.

FCC / IC REQUIREMENTS FOR MODULAR APPROVAL

In general, there are two agency classifications of wireless applications; portable and mobile.

Portable - Portable is a classification of equipment where the user, in general, will be within 20 cm of the transmitting antenna. Portable equipment is further broken down into two classes; within 2.5 cm of human contact and beyond 2.5 cm. The LT2510 is not agency approved for portable applications. The OEM is required to have additional testing performed to receive this classification. Contact Laird Technology for more details.

Mobile - Mobile defines equipment where the user will be 20 cm or greater from the transmitting equipment. The antenna must be

mounted in such a way that it cannot be moved closer to the user with respect to the equipment, although the equipment may be moved.

This equipment has been approved for mobile applications where the equipment should be used at distances greater than 20cm from the human body. Operation at distances of less than 20cm would require additional RF exposure evaluation, including SAR requirement according to FCC RF exporsure guideline.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

OEM EQUIPMENT LABELING REQUIREMENTS

WARNING: The OEM must ensure that FCC labeling requirements are met. This includes a clearly visible label on the outside of the OEM enclosure specifying the appropriate Laird Technology FCC identifier for this product as well as the FCC notice below. The FCC identifiers are listed above.

> **Contains FCC ID: KQL-2510100**
> **The enclosed 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.**

Label and text information should be in a size of type large enough to be readily legible, consistent with the dimensions of the equipment and the label. However, the type size for the text is not required to be larger than eight point.

ANTENNA REQUIREMENTS

To reduce potential radio interference to other users, the antenna type and gain should be chosen so that the equivalent isotropically radiated power (e.i.r.p.) is not more than that permitted for successful communication.

WARNING: This device has been tested with a U.FL connector with the above listed antennas. When integrated into the OEM's product, these fixed antennas require professional installation preventing end-users from replacing them with non-approved antennas. Any antenna not listed in the above table must be tested to comply with FCC Section 15.203 for unique antenna connectors and Section 15.247 for emissions. Contact Laird Technology for assistance.

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

WARNINGS REQUIRED IN OEM MANUALS

WARNING: This equipment has been approved for mobile applications where the equipment should be used at distances greater than 20cm from the human body. Operation at distances of less than 20cm is strictly prohibited and requires additional SAR testing.