FCC ID: O9P-E2-455C92

ELPRO Technologies

User Manual for E2-455 Licensed Radio

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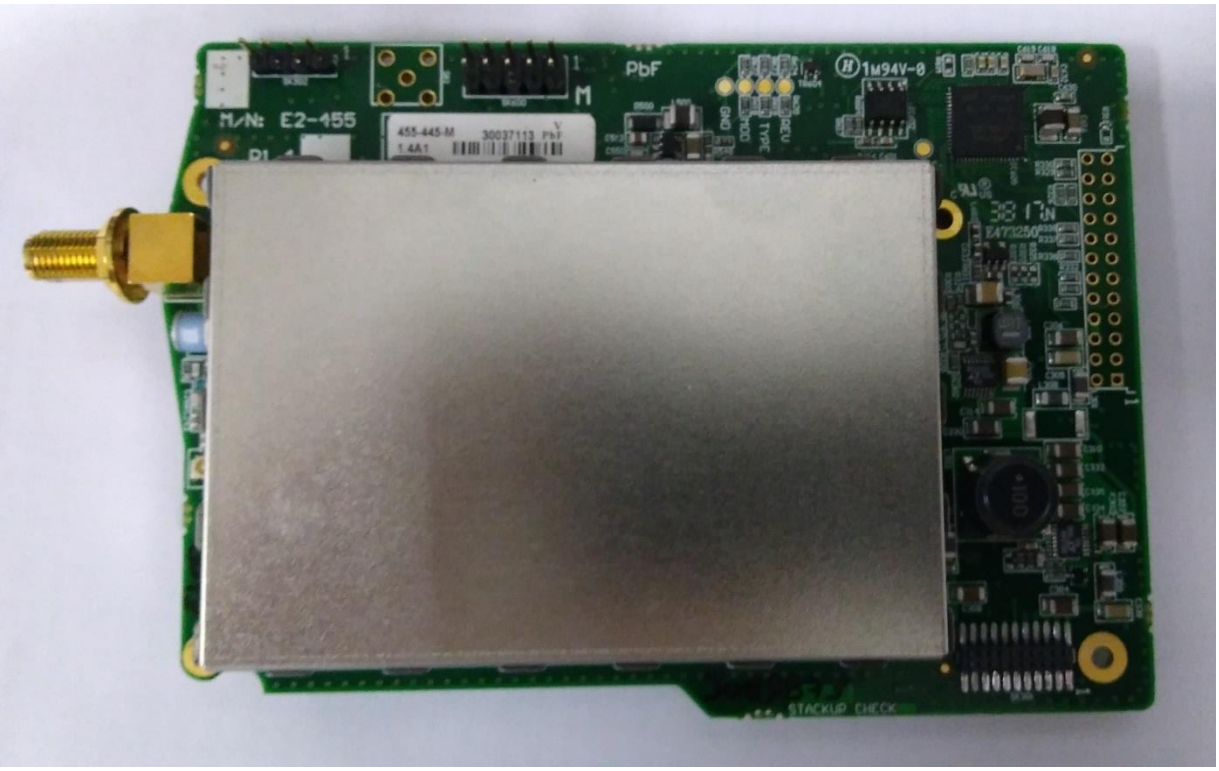


E2-455 Radio Module
OEM/Integrators Installation Manual

ATTENTION!

Incorrect termination of the supply wires may cause internal damage. Before turning the power on double-check ALL connections by referring to this User Manual.

CAUTION

To comply with FCC RF Exposure requirements in section 1.1310 of the FCC Rules, antennas used with this device must be installed to provide a separation distance from all persons as described in section “Safety Notices” below to satisfy RF exposure compliance.

DO NOT

- Operate the transmitter when anyone is within a distance from the antenna less than the minimum safe distances described in section “Safety Notices” below.
- Operate the transmitter unless all RF connectors are secure and any open connectors are properly terminated.
- Operate the equipment near electrical blasting caps or in an explosive atmosphere.

All equipment must be properly grounded for safe operations. All equipment should be serviced only by a qualified ELPRO staff only.

FCC Notice:

- Part 15 – This device has been tested and found to comply with the limits for a Class B digital device, pursuant to Part15 of the FCC rules (Code of Federal Regulations 47CFR Part 15). Operation is subject to the condition that this device does not cause harmful interference.
- Part 90 – This device has been type accepted for operation by the FCC in accordance with Part90 of the FCC rules (47CFR Part 90). See the label on the unit for the specific FCC ID and any other certification designations.
- Part 101 – The C92 model complies with the limits defined in 47 CFR Part 101 and 47 CFR Part 2 when tested in-accordance with the test methods described in 47 CFR Part 2, ANSI C63.25 – 2015 and ANSI / TIA-603-E -2016.

⚠ **Note: This device should only be connected to Devices that are covered by either a FCC DoC or are FCC certified.**

Antenna Models:

Manufacturer	Model Number	Coax Kit	Net
C1 Band			
ELPRO	UDP150-C	none	2dB Gain
ELPRO	BU-3/150	none	5dB Gain
ELPRO	BU-3/150	CC3	4.5dB Gain
ELPRO	YU3/150	none	6dB Gain
ELPRO	YU3/150	CC3	5.5dB Gain
ELPRO	YU6/150	None	9dB Gain
ELPRO	YU6/150	CC3	8.5dB Gain
C3, C4, C5 bands			
ELPRO	UDP400-3	Includes 3m Cellfoil	1dB Gain
ELPRO	UDP400-5	Includes 5m Cellfoil	Unity Gain
ELPRO	BU-3/400	CC10/450	2.5dB Gain
ELPRO	BU-6/400	CC10/450	5.5dB Gain
ELPRO	YU3/400	CC10/450	3.5dB Loss
ELPRO	YU6/400	CC10/450	6.5dB Gain

ELPRO	YU9/400	CC20/450	5dB Gain
ELPRO	YU16/400	CC20/450	10dB Gain

Safety Notices:

FCC (USA)

Exposure to RF energy is an important safety consideration. The FCC has adopted a safety standard for human exposure to radio frequency electromagnetic energy emitted by FCC regulated equipment as a result of its actions in Docket 93-62 and OET Publication KDB 447498 D01. Depending on antenna type, ensure the following minimum separation distances from antennas for (A) Occupational and (B) General Population.

Model Number	Minimum Distance (cm)	
(Antenna + Coax Kit)	Occupational / Controlled Exposure	General Population / Uncontrolled Exposure
UDP150-C	113	252
BU-3/150 + CC3	150	335
BU-3/150	159	355
YU3/150 + CC3	169	376
YU3/150	178	398
YU6/150 + CC3	238	531
YU6/150	252	563
UDP400-3	9	20
UDP400-5	8	18
BU-3/400 + CC10/450	11	24
BU-6/400 + CC10/450	15	33
YU3/400 + CC10/450	12	26
YU6/400 + CC10/450	17	37
YU9/400 + CC20/450	14	31
YU16/400 + CC20/450	25	55

ISED (Canada)

Exposure to RF energy is an important safety consideration. Innovation, Science, and Economic Development Canada (ISED) has adopted a safety standard for human exposure to radio frequency electromagnetic energy emitted by ISED regulated equipment as standard RSS 102 Issue 5. Depending on antenna type, ensure the following minimum separation distances from antennas for (A) Occupational and (B) General Population.

Model Number	Minimum Distance (m)	
(Antenna + Coax Kit)	Occupational / Controlled Exposure	General Population / Uncontrolled Exposure
UDP150-C	0.39	0.99
BU-3/150 + CC3	0.52	1.32
BU-3/150	0.55	1.40
YU3/150 + CC3	0.58	1.48
YU3/150	0.61	1.57
YU6/150 + CC3	0.82	2.09
YU6/150	0.87	2.22

UDP400-3	0.28	0.8
UDP400-5	0.25	0.72
BU-3/400 + CC10/450	0.34	0.95
BU-6/400 + CC10/450	0.47	1.35
YU3/400 + CC10/450	0.38	1.07
YU6/400 + CC10/450	0.53	1.51
YU9/400 + CC20/450	0.45	1.27
YU16/400 + CC20/450	0.79	2.26

Limitations and Condition of Use:

ELPRO E2-455 radio module is designed as a reusable module for use with future development of ELPRO products. The module is limited for use by ELPRO only. This module is not to be made available for third party use or in any OEM arrangements.

The following requirements apply to any product which incorporates the E2-455 radio module:

The product incorporating the ELPRO E2-455 radio must not include any instructions to remove or install the E2-455 radio module.

The product incorporating the ELPRO E2-455 radio must be limited to installation in mobile or fixed application.

A separate approval is required for all other operating configurations, including portable configurations with respect to Part 2.1093 and different antenna.

Any product incorporating the ELPRO E2-455 radio must include a label on the final product that indicates the certification numbers for the E2-455 radio. The following must appear on the final product label:

C1 band

Contains:
FCC ID : O9P-E2-455C1
IC : 3957A-E2455C1

C4 band

Contains:
FCC ID : O9P-E2-455C4
IC : 3957A-E2455C4

C92 band

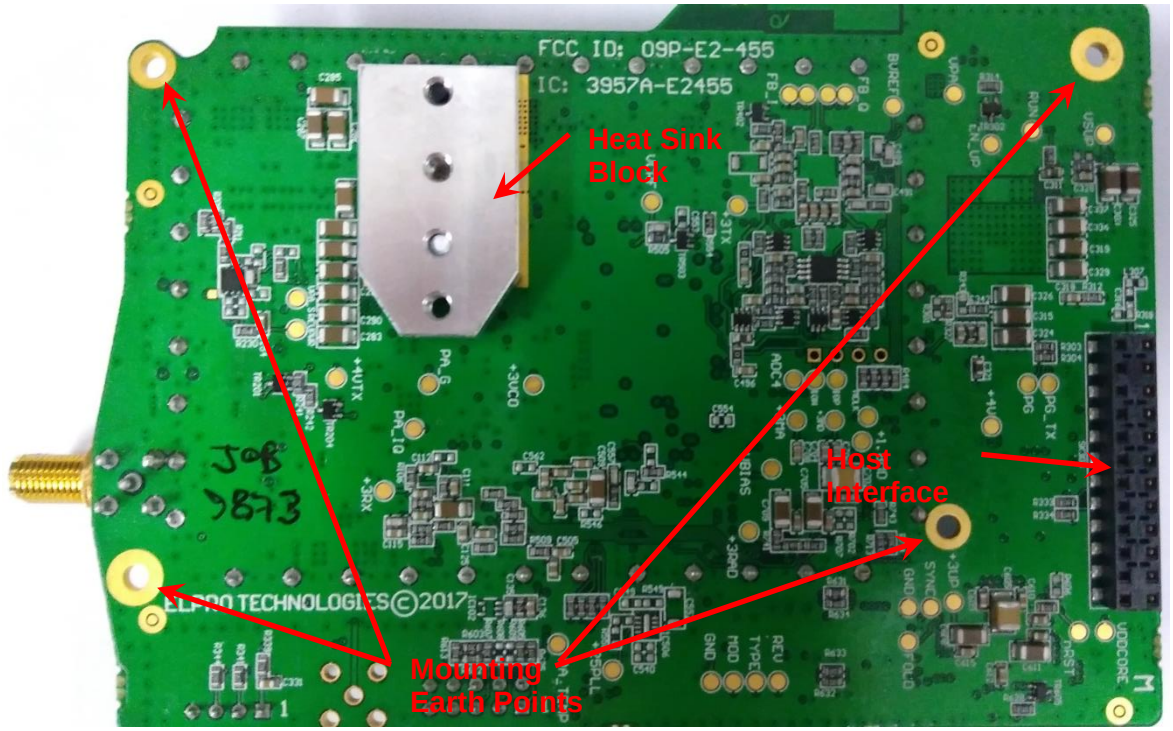
Contains:
FCC ID : O9P-E2-455C92
IC : 3957A-E2455C92

1 Introduction

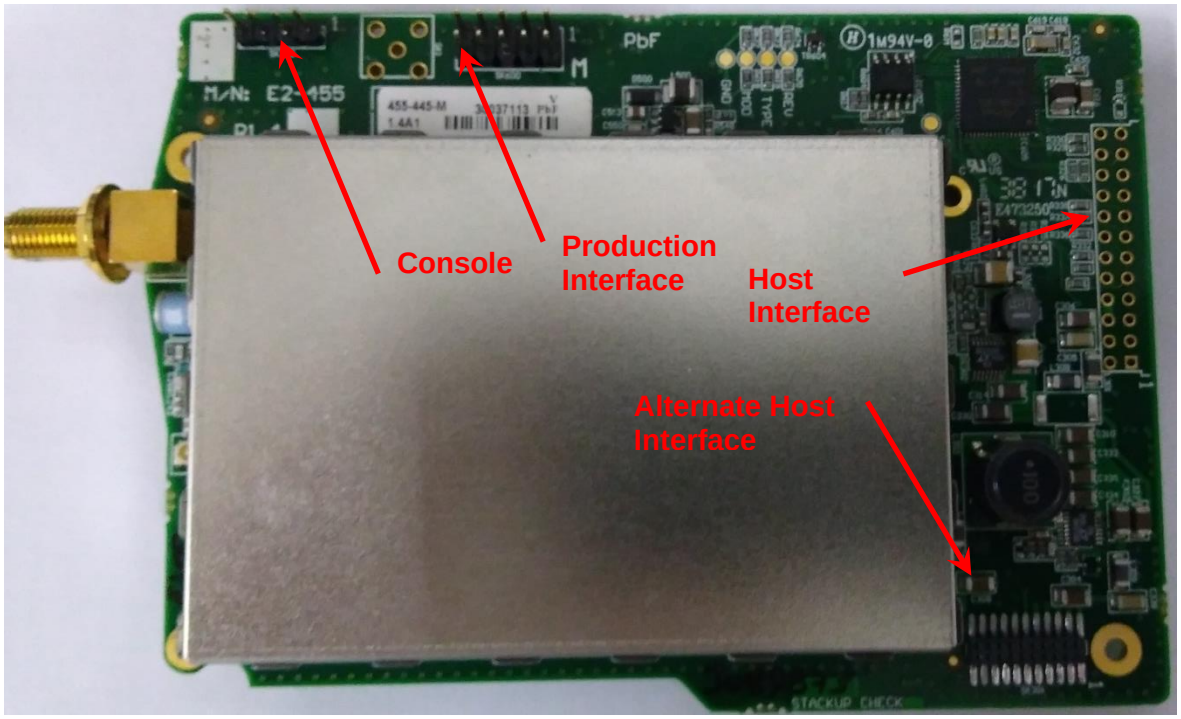
The E2-455 is a radio modem module used as a base radio for a number of Elpro wireless products, with additional products to be added in the future. It operates as a wireless network adapter for transfer of 802.11 format data frames over lower speed wireless links. The E2-455 consists of a host microcontroller, an RF transceiver section, and a power supply section.

2 Module Description

Under Side View



Top Side View



2.1 Mounting Points

Four mounting points are provided for 2.5mm Mounting screws.

2.2 Heat-Sink Block

A Heat-Sink should be connected to the device's Heat-Sink block to prevent the power amplifier overheating. The interface to the Heat-Sink block uses two M3 screws separated by 15mm, with engagement depth between 3mm-4mm. Use heat-paste or other heat-conducting material to provide an effective heat conduction path from the heat-sink block to the supplied heat-sink.

2.3 Main Host Interface

The main host interface is implemented through a 24-pin socket, allowing connection to standard 0.1" pitch headers. This interface supplies power to the module as well as the high speed serial connection providing communication to the host device.

2.4 Alternate Host Interface

The alternate host interface provides the same functionality as the Main host interface, in a more compact form-factor for use with products requiring a more compact interface.

2.5 Production Interface

Production interface consists of a JTAG port for programming and developer debug of the device.

2.6 Console Interface

The Console interface allows connection of a serial terminal to the device for diagnostic operation and testing.

3 Locale

The E2-455 design is capable of supporting frequencies through manufacture of different variants:

- C1 band supports frequency range 148-174MHz.
- C3 band supports frequency range 340-400MHz.
- C4 band supports frequency range 400-480MHz.
- C5 band supports frequency range 470-520MHz.
- C92 band supports frequency range 928-960MHz.

The host software shall implement Locale settings to restrict the range of frequencies, bandwidths and power relevant to the regulations of the specified locale.

The user manual of the product shall state that the unit is to be installed by professional personnel.

3.1 United States Locale

The following restrictions on each of the bands apply when US Locale is selected:

Locale	Frequency Band	Supported Channel Bandwidth
FCC_Part90	150.8 MHz - 152.855 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90	152.855 MHz - 154.0 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90	154.0 MHz - 156.2475 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90	157.1875 MHz - 157.45 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90	157.45 MHz - 161.575 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90	161.775 MHz - 161.9625 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90	162.0375 MHz - 173.2 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90	173.2 MHz - 173.4 MHz	6.25kHz, 12.5kHz, 25kHz
FCC_Part90_B1	421.000MHz – 454.000MHz	6.25kHz, 12.5kHz
FCC_Part90_B2	456.000MHz – 462.375MHz	6.25kHz, 12.5kHz
FCC_Part90_B3	462.7375MHz – 467.5375MHz	6.25kHz, 12.5kHz

FCC_Part90_B4	467.7375MHz – 480.000MHz	6.25kHz, 12.5kHz
FCC_Part90	928.0 – 930.0MHz	12.5kHz, 25kHz
FCC_Part90	935.0 – 940.0MHz	12.5kHz, 25kHz
FCC_Part101	928.0 – 929.0MHz	12.5kHz, 25kHz
FCC_Part101	932.5 – 935.0MHz	12.5kHz, 25kHz
FCC_Part101	941.0 – 960.0MHz	12.5kHz, 25kHz

3.2 Canada Locale

The following restrictions on each of the bands apply when Canadian Locale is selected:

Locale	Frequency Band	Supported Channel Bandwidth
RSS-119	148.000MHz -149.900MHz	6.25kHz, 12.5kHz, 25kHz
RSS-119	150.050MHz – 174.000MHz	6.25kHz, 12.5kHz, 25kHz
RSS-119_B1	421.000MHz – 430.000MHz	6.25kHz, 12.5kHz
RSS-119_B2	450.000MHz – 470.000MHz	6.25kHz, 12.5kHz

4 Operation

The host system communicates with the E2-455 module via the serial interface provided by either the main or alternate host interface. The serial interface is a standard TTL UART interface in full duplex asynchronous connection. The baud rate is 1.0Mbps. RTS and CTS lines are used to provide flow control between the host and radio processors.

The serial protocol is a proprietary message structure.

In addition, a secondary diagnostic interface is provided over the Console interface. This provides the interface for testing the device. It operates at a rate of 115,200 baud.

4.1 Diagnostic Interface Command Reference

4.1.1 Radio Commands – General

- Set to QAM Mode (Note: par rate command must be re-issued)

```
> cfg mod qam
  0:15:44.891 RAD: CMX7164: Function image 4112                [  OK  ]
  0:15:45.603 RAD: CMX7164 Rx DC calibration                   [  OK  ]
    [1]                      Modulation =       QAM

  0:15:45.662 RAD: CMX7164 Tx DC calibration                   [  OK  ]
```

- Set to FSK Mode (Note: par rate command must be re-issued)

```
> cfg mod fsk
  0:16:35.955 RAD: CMX7164: Function image 2035                [  OK  ]
  0:16:36.910 RAD: CMX7164 Rx DC calibration                   [  OK  ]
    [1]                      Modulation =       FSK

  0:16:36.970 RAD: CMX7164 Tx DC calibration                   [  OK  ]
```

(Note: par rate command must be re-issued after every Mode change)

- Set radio transmit modulation format

```
> par rate 4qam (options 4qam, 16qam, 64qam, 2fsk, 4fsk)
    [1]               Radio frame rate =   4QAM
```

- Set radio transmit FEC (only in QAM mode) to FEC or RAW

```
> par fec fec
    [1]                Radio frame FEC =    FEC
> par fec raw
    [1]                Radio frame FEC =    RAW
```

- Set Radio Channel Bandwidth (6.25kHz, 12.5kHz, 25kHz)

```
> cfg bw 12500  (Options 6250(QAM only), 12500, 25000)
```

```
  0:35:03.651 RAD: CMX7164 Rx DC calibration                    [  OK  ]
    [1]             Frequency bandwidth =  12500 Hz

  0:35:03.694 RAD: CMX7164 Tx DC calibration                    [  OK  ]
```

- Set Radio Tx and Rx Frequency (in Hz).

```
> cfg freq_tx 442012500
    [1]              Transmit frequency = 442012500 Hz

> cfg freq_rx 442006250
    [1]               Receive frequency = 442006250 Hz
```

- Save Configuration (save all cfg and par items except for rate).

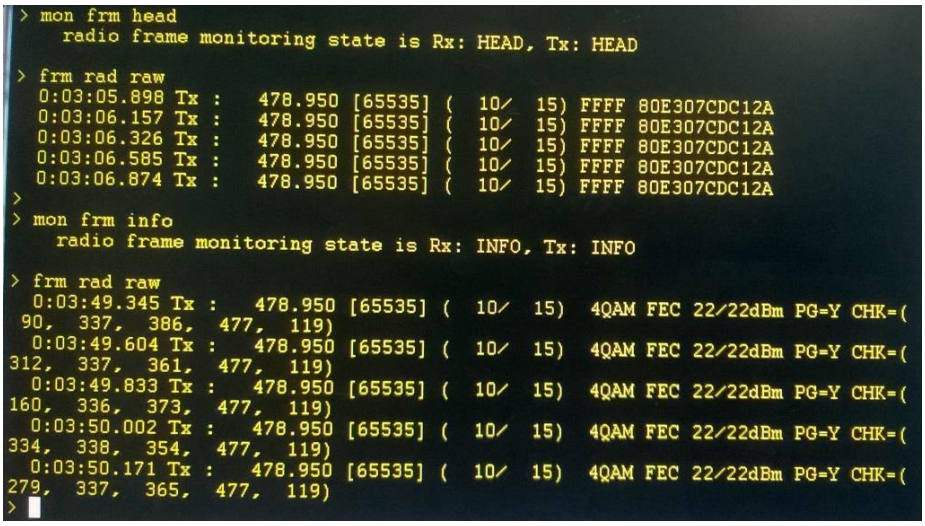
```
> cfg save
```

- Reset unit.

```
> reset
```

- To change rx/tx monitor).

```
> mon frm info                                  Shows more information
> mon frm head                                  Shows less information
```



4.1.2 Radio Transmit Commands

- Set Transmit Power for Test commands.

```
> par txpwr 27
    [1]                  Transmit power =     27 dBm
```

Note: Maximum power is limited according to supply voltage and modulation selected. Power drops by 3dB at approximately 12V supply.

- Transmit Repeating 511 bit PRBS

```
> rad prbs
  [1] Radio mode = PRBS, MAC state = TONE, PHY state = TONE, modem state = TONE
```

- Transmit unmodulated carrier (only available in FSK mode)

```
> rad tone
  [1] Radio mode = TONE, MAC state = TONE, PHY state = TONE, modem state = TONE
```

- To stop transmit sequence, start receiving:

```
> rad auto
  [1] Radio mode = AUTO, MAC state = EMPTY, PHY state = FS, modem state = FS
```

4.1.3 Frame Transmit Commands

- To Transmit a single message frame (Default repeat is 2, Default Length is 60)

```
> par repeat 1
    [1]        Radio frame repeat count =      1
> par len 10
    [1]              Radio frame length =     10
> frm rad raw
 20:13:38.777 Tx :   440.000 [65535] (  10/  15) FFFF 80E307CDC12A
```

- To check Frame Receive statistics at receiver

```
> stat frm clr                              Clear frame Statistics counters
> stat frm
    [1]     RX_ERR_PREAM =        3         Received Preamble, no Frame Sync
    [1]  RX_ERR_PLCP_HDR =        0         Corrupted Message Header block
    [1]       RX_ERR_CRC =        0         Received with corrupted Message body
    [1]       RX_RTS_OTH =        0         Number of Received frames of different types
    [1]        RX_RTS_ME =        0         RTS to other / Me
    [1]       RX_CTS_OTH =        0
    [1]        RX_CTS_ME =        0         CTS to other / Me
    [1]       RX_ACK_OTH =        0
    [1]        RX_ACK_ME =        0         ACK to other / Me
    [1]        RX_UNSPRT =        0         Unsupported Frame Type
    [1]         RX_MULTI =        0         Multicast Frame
    [1]       RX_UNI_OTH =        0
    [1]        RX_UNI_ME =        0         Unicast message to other / Me
```

To count the number of received frames, add RX_RTS, RX_CTS, RX_ACK, RX_UNSPRT, RX_MULTI and RX_UNI types. When testing with command “frm rad raw”, all received frame should be RX_UNSPRT.

- To Transmit BER Test frames (Default repeat is 8). BER frame length must be > 31 bytes to allow valid testing.

```
> par len 131                    (e.g. for 100 bytes of BER data for each test frame)
> par ber_num 3
    [1]          Radio BER frame number =      3


> frm rad ber
  0:05:40.050 Tx : B 440.000 [65535] (  60/  52) D000 FFFFFFFFFFFF 0012AF000000
  0:05:40.337 Tx : B 440.000 [65535] (  60/  52) D000 FFFFFFFFFFFF 0012AF000000
  0:05:40.654 Tx : B 440.000 [65535] (  60/  52) D000 FFFFFFFFFFFF 0012AF000000
```

- To check BER at receiver (Over successfully received BER frames).

```
> stat ber clr                                  Clear BER Statistics counters
> stat ber
    [1]           Frame number =        0       Number of Received BER frames
    [1] Accumulated error bits =        0       Total over all received BER frames
    [1]             Total bits =        0       Total over all received BER frames
    [1]           Average RSSI =        0 dB    Average over all received BER frames
    [1]            Average LQI =        0       Average over all received BER frames
```

4.2 Host Interface Message Framing

Message framing is based on PPP Byte stuffing. The special characters 0x7F, 0x7D and 0xFF are the beginning of a frame, data link escape and end of frame characters respectively.

Each message begins with the transmission of the start of frame character. This is followed by the message data payload for the message end of the message is indicated by the end of frame character.

Occurrence of the characters for start of frame, end of frame, or the data link escape character within the data packet is indicated by stuffing an additional data link escape character into the data stream before the special character and then setting bit 5 of the control character to 0.

Whenever the start flag character is detected, the framer state is reset to receiving the first data payload byte. (Start flag should never occur in the data payload due to the escaping scheme above.)

The end of frame character ensures that the transmitter and receiver are synchronised at the beginning of the next data frame. If they are not correctly synchronised, the 0xFF will result in the additional “ones” being detected as a long stop condition at the receiver and subsequent characters being correctly synchronised.

4.3 Host Interface Message Format

4.3.1 Endian

All multi-byte fields are transmitted in little endian format.

4.3.2 General Message Format

Table 1 describes the general format of the messages including the start and end flags.

START_FLAG	1 byte	Start of message identifier (0x7E)
Service_code	2 bytes	Service code to identify message type and message ID
Payload Data	0-n bytes	Message payload data. Interpreted according to Service code
END_FLAG	1 byte	End of message identifier (0xFF)

Table 1

4.3.3 Service code encoding

Table 2 describes the encoding of the Service code field from the Service Type and Service ID

b15 - b14	**Service Type** 00: request 01: indicate 10: confirm 11: unused
b13 - b0	**Service ID** 0x41: Transmit 0x42: Flush 0x43: Receive 0x44: Local_Management 0x45: Extended Transmit 0x46: Extended Flush 0x47: Extended Receive

Table 2

4.3.4 Service types

Table 3 describes the service types and their interactions

Request (0b00)	Request messages are used where a message acknowledgement is required. A confirm message is expected to be sent from the other party. Matching of request and confirm messages depends on the message ID. Messages may include a unique handle to that can used to match request to confirm, or the process transmitting the message can ensure that only one message of that type is outstanding at any time.
Indicate (0b01)	Used when acknowledgement of the message is not required. Indicate messages do not have any matching confirm message.
Confirm (0b10)	Confirm messages are returned to the process that initiated a Request message to acknowledge receipt of the request message (and possible acknowledge processing of the request message is complete). Generation of the Confirm message and the details of any payload data depend on the Service ID for the message. The Service ID for the confirm must match the service ID for the original request message.

Table 3

For more detailed information about the protocol, refer to ELPRO document; spec_E2-Radio-io-protocol

5 Host Interface Hardware Description

This section describes the interface to the host, including the two alternate power/data interfaces and the earthing connections.

5.1 Alternate Host Interface Pin Description

Pin	Signal	Description	Direction
1	VSupply	9-30V Supply from host	Input to module
2	VSupply	9-30V Supply from host	
3	VSupply	9-30V Supply from host	Input to module
4	GND	Ground	
5	VSupply	9-30V Supply from host	Input to module
6	GND	Ground	
7	NO_CON	No Connection	
8	GND	Ground	
9	NO_CON	No Connection	
10	GND	Ground	
11	NO_CON	No Connection	
12	PG	Power Good Indication	Output from module
13	NO_CON	No Connection	
14	nEN_RADIO_PWR	Radio Power Enable	Input to module
15	NO_CON	No Connection	
16	RXD0_7	Data Receive	Output from module
17	TXD0_7	Data Transmit	Input to module
18	CTS0_7	Clear to Send (When toggled, it indicates that the host should wake up.)	Output from module
19	RTS0_7	Ready to Send (When toggled, it indicates that the radio processor should wake up.)	Input to module
20	Test Point	Not used	
21	Test Point	Not used	
22	Test Point	Not used	

5.2 Main Host Interface Pin Description

Pin	Signal	Description	Direction
1	NC	No Connection	
2	NC	No Connection	
3	NC	No Connection	
4	NC	No Connection	
5	GND	Ground	
6	VSUP_CON	Main DC input power supply rail of the host (9-30V)	Input to module
7	GND	Ground	
8	VSUP_CON	Main DC input power supply rail of the host (9-30V)	Input to module

9	MB_CSF	Future Use – Do Not Connect	Output from module
10	CTS0_7	Clear to send (When toggled, it indicates that the host should wake up.)	Output from module
11	MBIRQ	Future Use – Do Not Connect	Input to module
12	RTS0_7	Ready to Send (When toggled, it indicates that the radio processor should wake up.)	Input to module
13	BRX	Future Use – Do Not Connect	Input to module
14	TXD0_7	Data Transmit	Input to module
15	BTX	Future Use – Do Not Connect	Output from module
16	RXD0_7	Data Receive	Output from module
17	_SHDN	Radio Shutdown	Input to module
18	USBH	Future Use – Do Not Connect	Input to module
19	nR_OC	Over Current	Output from module
20	GND	Ground	
21	USBCX	Future Use – Do Not Connect	Input to module
22	USBDN	Future Use – Do Not Connect	Input to module
23	USBDP	Future Use – Do Not Connect	Input to module
24	NC	No Connection	

5.3 Protective Earthing Point

There are four mounting screw points around the cage which are connected to the ground plane of the module. These should be screwed on with metallic screws to the metallic casing or ground points on the host system.

6 Specifications

Environmental					
	Operating Temperature		-40°C to +70°C (-40 to +120°F)		
	Humidity		0-95% Non-Condensing		
	Altitude		0-2000m / 6500ft		
Radio					
General	Half Duplex UHF radio supports operation on Licensed and Unlicensed bands.				
RF Bands	Channel Spacing		6.25kHz, 7.5kHz, 12.5 kHz, 20kHz, 25 kHz		
	Supported Frequency Bands		148-174MHz 340-400MHz 400-480MHz 470-520MHz 928-960MHz		
Antenna	Single SMA Connector for Receive and Transmit.				
	Impedance		50Ω		
Transmitter	Power Range		10mW - 10 Watt (+10 to +40 dBm)		
	Maximum Power Levels with QAM (Power reduction due to Modulation Peak-Average ratio)		Encoding	Max Power	PAPR
			4-QPSK	4W	0.4
			16-QAM	2.5W	0.25
			64-QAM	2.5W	0.25
Data Rates	Data Encoding and Data rates	Channel / Encoding	6.25kHz	12.5kHz	25kHz
		4-QPSK-FEC	4kpbs	8kbps	16kbps
		4-QPSK	8kpbs	16kbps	32kbps
		16-QAM	16kbps	32kbps	64kbps
		64-QAM	24kbps	48kbps	96kbps
	Data Encoding (DFSK Mode for E2-450 compatibility)	Channel / Encoding	12.5kHz	25kHz	
		2-FSK	4.8kbps	9.6kbps	
		4-FSK	9.6kbps	19.2kbps	
Receiver	Receiver Sensitivity 6.25/12.5/25kHz channel spacing (BER=1x10^{-5})		Encoding	Sensitivity	
			4-QPSK-FEC	-116dBm	
			4-QPSK	-110dBm	
			16-QAM	-102dBm	
			64-QAM	-94dBm	
	Receiver Sensitivity DFSK Mode 6.25/12.5/25kHz channel spacing (BER=1 x 10^{-5})		2-FSK	-110dBm	
			4-FSK	-102dBm	

7 REVISION HISTORY

Issue No.	Date	Details of Amendment
1.0	24/10/2017	Initial Issue – From E2-450 User Manual
1.1	04/02/18	Update Safe distance limits
1.2	08/03/18	Update Safety notices to include Canada (ISED) specific RF exposure limits.
1.4	22/03/18	Update after CB Review. Notes re OEM installation, application notes. Note on Antenna connectors. Update FCC Exposure table.
1.5	08/05/18	Updates after CB review. Added Canada Locale details.
1.6	22/10/2019	Add C1, C3, C5 bands.
1.7	18/11/2019	For C1 band: Added antennas, cables, FCC and IC safe distance, markings, band, channel spacing.
1.8	25/01/2022	Add C9 band.