1421 Research Park Drive Suite 2A
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O-79 Imaging Radar
Device Manual

FCC ID = 2ATMB-O79V3, IC = 26683-O79V3

Revision History

Release Version	Date	Authors	Notes
0.1	June 22nd, 2020	Nick Rotella Dave Ochs	Initial version for first delivered Rev 1.0 units
1.0	July 16th, 2020	Nick Rotella Dave Ochs	Updated version for firmware version 2.0.0
1.1	July 31st, 2020	Dave Ochs	Added supported CAN command and feedback messages
1.2	August 12, 2020	Bennett Haase-Divine	Added reconfigurable network parameters
1.3	August 25, 2020	Nick Rotella	Added UDP message documentation
1.4	August 27, 2020	Bennett Haase-Divine	Added reconfigurable device Identifiers
1.5	September 8th, 2020	Nick Rotella	Updated message documentation, added section on conventions
1.6	September 17th, 2020	Nick Rotella	Added Cartesian filter parameter and message documentation
1.7	November 4th, 2020	Dave Ochs	Added Advanced Configuration and ROS GUI tabs' documentation
1.8	November 13th, 2020	Dave Ochs Nick Rotella	Added units (dB) to SNR and SNR description
1.9	December 2nd, 2020	Nick Rotella	Updated message formats and scale factors for firmware 4.0.0
1.10	January 11th, 2021	Dave Ochs	Updated message formats for firmware 5.0.0
1.11	January 21, 2021	Dave Ochs	Consolidated Header message/frame information in a new subsection. Corrected UDP message format tables
1.12	February 2, 2021	Bennett Haase-Divine and Dave Ochs	Updated for firmware 5.2.0; add documentation for AWRx243 monitor data over CAN
1.13	February 11, 2021	Dave Ochs	Updated for firmware and GUI version 6.0.0; remove references to

			K-79
1.14	April 15, 2021	Dave Ochs	Added documentation for ground targets and target state machine; firmware and GUI version 6.4.0
1.15	April 27, 2021	Bennett Haase-Divine	Updated monitoring message documentation
1.16	June 18, 2021	Dave Ochs	Replace SNR with signal power
1.17	August 17, 2021	Colten Becker	Add support for non-default camera device and resolution for ROS
1.18	August 18, 2021	Dave Ochs	Add raw point message with 16-bit signal power
1.19	September 15, 2021	Dave Ochs	Add more monitors to the monitor alarm CAN message table
1.20	October 7, 2021	Dave Ochs	Update Configuration App section; reorganize Tracking Filter settings
1.21	January 31, 2022	Dave Ochs	Add responses to CAN reset network and reset MAC commands
1.22	February 9, 2022	Dave Ochs	Updated photos and instructions for Rev. 2 units
1.23	February 16, 2022	Andy Borders	Updated Advanced Configuration section
1.24	April 27, 2022	Mason Hayes	Update O-79 Configuration App section
1.25	May 13, 2022	Bennett Haase-Divine	Remove footnote about the CAN SA being reset by the Reset Network Parameters CAN command
1.26	June 13, 2022	Dave Ochs	Add new messages for raw and filtered point cloud data
1.27	June 17, 2022	Dave Ochs	Add description of how large objects are communicated
1.28	June 16, 2022	Mason Hayes	Move O-79 Configuration App portions related to Advanced Config to an appendix, replace with new regular Configuration settings

1.29	July 12, 2022	Bennett Haase-Divine Dave Ochs	Add low-resolution CAN message format. Add J1939-76 CAN header messages.
1.30	August 2, 2022	Mason Hayes	Update screenshots
1.31	December 8, 2022	Chris Chung	Add CAN message to set a temporary CAN source address
1.32	December 8, 2022	Dave Ochs	Add Base/Pro distinctions; add Installation section; add Appendix for radar parameters
1.33	September 21, 2023	Eric Shumaker	Update photos for ext V3 radar. Add FCC id placeholder to title page. Statement about how far away a person would be.
1.34	October 9, 2023	Eric Shumaker	FCC application version. Added appendix A - RF Exposure Requirements, Limits and Warnings
1.35	October 18, 2023	Eric Shumaker	Removed confidential from the footer per the fcc.

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Overview

This guide details the basic hardware requirements, initial setup, testing, and integration of O-79 for object detection and tracking applications.

There are two versions of the O-79 Imaging Radar: Base and Pro. The Pro version includes Ethernet connectivity. The contents of this manual apply to both versions, except where noted.

This manual includes instructions for how to modify or tune parameters to optimize performance for a particular application. This feature is not supported for safety-related applications in production. Any modifications to tune-able parameters for a safety-related production application must be coordinated with Ainstein, as revalidation may be required.

Quick-Start Guide - Test Bench

The following section documents how to get your O-79 Imaging Radar set up on a test bench and reporting tracked objects over CAN. These instructions are not intended for installing the radar in a production application - see the Installation section for such information.

1. Connect the main cable to the radar connector; the default orientation has the connector on the right side when looking at the front of the sensor.

Figure 1. O-79 Imaging Radar with cable attached

2. Provide 12 VDC power to the **red (DC+)** and **black (DC-)** as shown in Figure 2.

Figure 2. O-79 power connections

3. The radar boots into “standby” mode for initialization, during which it should draw approximately **0.4A** as shown below. After a short time (5-10 seconds) the radar will begin operation automatically; ensure that your power supply can provide **up to 1.0A** to the sensor during operation.

Figure 3. O-79 voltage and current draw in standby mode

4. When initialization completes, the radar will begin to continuously output tracked object information over **CAN at 250k baud**; see the Communication section of this document for message definitions and parsing.
   a. To verify CAN output using a PEAK-CAN USB converter, set up the converter as shown below. A **120 Ohm resistor** is required between CAN high and low.
   b. CAN messages can be monitored using **PCAN-View software** on Windows or using the **PCAN-Linux driver** on Linux. For Ubuntu Linux, configure the *can0* interface as follows before using *candump can0* for CLI monitoring.

```
$ sudo apt update
$ sudo apt install can-utils

$ sudo ip link set can0 down && sudo modprobe peak_usb && sudo
ip link set can0 type can bitrate 250000 && sudo ip link set
can0 up

$ candump can0
```

Figure 4. PEAK-CAN USB converter connected to O-79 cable (pin 2 is CAN LOW, pin 7 is CAN HIGH).

Installation

Mounting

Mount the radar through the enclosure mounting holes using suitable fasteners per the customer application such that the connector is on the right when facing the front of the radar (see Figure 1) and the vibration of the radar does not exceed TBD m/s^2. The mounting torque must not exceed TBD Nm.

There must be nothing obscuring or overhanging any part of the plastic radome that makes up the front cover of the radar.

The mounting mechanism must keep the top and bottom of the back of the radar unobstructed, so that air can flow freely through the heatsink fins that make up the back of the radar.

The radar is not designed to be used as a step or handle or hand hold. The customer is responsible for mounting the radar in such a manner as it will not be stepped on or used as a handle or hand hold.

Mount the radar with appropriate tilt in the azimuth direction such that the radar's field of view encompasses the area in which the customer requires that objects be detected. The azimuth field of view is approximately 90°, but can vary depending on the object to be detected and relative movement between the object and the radar.

Mount the radar with 8° ± 1° of tilt in the elevation direction. This means the front face of the radar is tilted slightly up from perpendicular to level ground.

The customer is responsible for validating that the radar provides sufficient detection coverage per their application's mounting position and orientation and objects to be detected.

Figure 5. Radar Front View

Cable and Connector

The O-79 Imaging Radar contains power, CAN, and Ethernet (Pro version only) connections in a single connector. Connections must be made through a cable and connector that conforms to the specifications in O-79 Example Cable Drawing, with suitable connector(s) per the customers application requirements in place of tinned wires on the customer side. The total length of the cable must not exceed 4100 mm, but may be shorter. The wire colors and cable sleeve colors may be specified by the customer. The Ethernet wires are needed for Pro versions only.

An example prototype cable is shown in Figure 6, with pinout shown in Figure 7 and Table 1.

The customer is responsible for securing the cable such that it will not become pinched, cut, stretched, or otherwise compromised during or after installation.

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Figure 6. Prototype O-79 cable

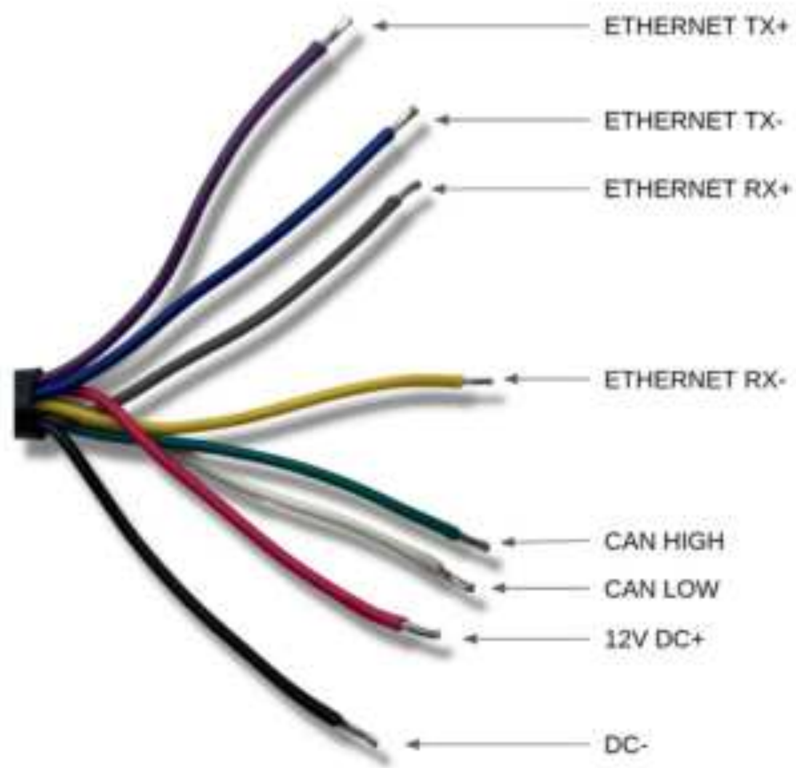

Figure 7. O-79 prototype cable breakout (power, CAN, Ethernet)

Table 1. O-79 prototype cable wire breakout

Color	Function
Red	DC IN (12v)
Black	DC Ground
White	CAN Low
Green	CAN High
Yellow	Ethernet Rx-
Grey	Ethernet Rx+
Blue	Ethernet Tx-
Purple	Ethernet Tx+

Power Requirements

The O-79 Imaging Radar must be supplied by a power bus at 8 VDC - 26 VDC that is capable of supplying up to 12W continuously. The customer is responsible for selecting and integrating a power connector that is suitable for their application. See the power pin locations in the O-79 Example Cable Drawing.

CAN Connection

The O-79 Imaging Radar does not include a 120 Ohm CAN termination inside the unit.

The customer is responsible for selecting and integrating a CAN connector that is suitable for their application and making connection to their CAN 2.0 compliant bus. See the CAN pin locations in the O-79 Example Cable Drawing.

Environmental

The O-79 Imaging Radar is designed to work in ambient temperatures from -40 °C to 65 °C. The customer is responsible for ensuring that the radar is not used in temperatures outside of this range.

Maintenance

The customer is responsible for ensuring that the radome (see Figure 5) remains clean and unobstructed while the radar is in use. The radome can be cleaned using water, and if necessary, a mild detergent such as dish soap. Water sprayed onto the unit must not exceed 4 gallons per minute and 1450 psi. Do not spray the radar with a nozzle closer than 6 inches from the radar.

The customer is responsible for ensuring that the heatsink fins remain unobstructed while the radar is in use.

Ethernet Communication (Pro Only)

The O-79 Imaging Radar Pro supports Ethernet communication using both UDP and TCP over Ethernet. To use a standard Ethernet cable, the O-79 prototype cable (see the Connections section above) must be connected to a RJ45 breakout adapter as shown in Figure 8 below. If a customer-supplied cable is used, the customer is responsible for integrating a suitable Ethernet connector per their application. See the Ethernet pin locations in the O-79 Example Cable Drawing.

Figure 8. RJ45 adapter setup with O-79 prototype cable

Table 2. O-79 prototype cable to RJ45 breakout adapter pinout

O-79 Cable	RJ45 Adapter
O-79 Pin 6 (yellow, Rx-)	Breakout Pin 6
O-79 Pin 8 (grey, Rx+)	Breakout Pin 3
O-79 Pin 10 (blue, Tx-)	Breakout Pin 2
O-79 Pin 12 (purple, Tx+)	Breakout Pin 1

Ethernet Configuration

The O-79 Imaging Radar supports **Fast Ethernet (10/100Mbps)** - when connected and powered, the radar automatically defaults to this mode rather than auto-negotiating the connection speed.

Table 3 details the radar's default network configuration:

Table 3. O-79 default networking parameters

Network Parameter	Value
Radar IP Address	10.0.0.10
Radar Port	7
Netmask	255.255.255.0
Gateway	10.0.0.1

The radar supports connectionless communication via UDP on radar port 7, sending and receiving messages to/from a host device. The radar must know the host's IP address, Netmask, and Gateway, as well as which of the host's ports it expects to see traffic on. These values can be set using the O-79 Configuration App; the default values are shown in Table 4.

Table 4. Default host network parameters stored on the radar

Network Parameter	Value
Host PC IP Address	10.0.0.75
Radar Port	1024
Netmask	255.255.255.0
Gateway	10.0.0.1

The radar also supports **connection-oriented communication via TCP** on radar port 7; this is used for firmware flashing and configuration. It is recommended to use the O-79 Configuration App for these purposes.

O-79 Configuration App

The O-79 Configuration App is used for updating firmware and configurable parameters via a TCP connection to Pro versions of the radar during development. The app also provides an easy-to-use interface to ROS for viewing, recording, and playing back data from the radar. The app and the capability to modify parameters are **for development only**. The app requires that the host computer be running Ubuntu 20.04. The types of information currently configurable on the radar are:

Primary Firmware: The firmware which boots on the device when powered.

Recovery Firmware: The firmware which boots when the primary firmware is corrupted, allowing for recovery.

Network Parameters: The networking configuration used for Ethernet (TCP/UDP, Pro only) connections.

CAN Source Address: The source address used by the radar for J1939 CAN communication

Device Identifiers: Device MAC Address, serial numbers, and other password-protected device parameters (developer usage only).

Configuration: Settings for various configurable parameters on the radar

Ethernet Connection (Pro Only)

In order to connect to the radar for configuration, use your operating system's network settings application to create a new **static** wired connection with the following IPv4 settings in Ubuntu:

IPv4 Address: 10.0.0.75
Netmask: 255.255.255.0
Gateway: 10.0.0.1

IPv4 settings in Windows:

IP Address: 10.0.0.75
Subnet prefix length: 24
Gateway: 10.0.0.1

After connecting the radar via Ethernet and providing power, you should be able to ping it at its default address with *ping 10.0.0.10* from a command prompt/terminal.

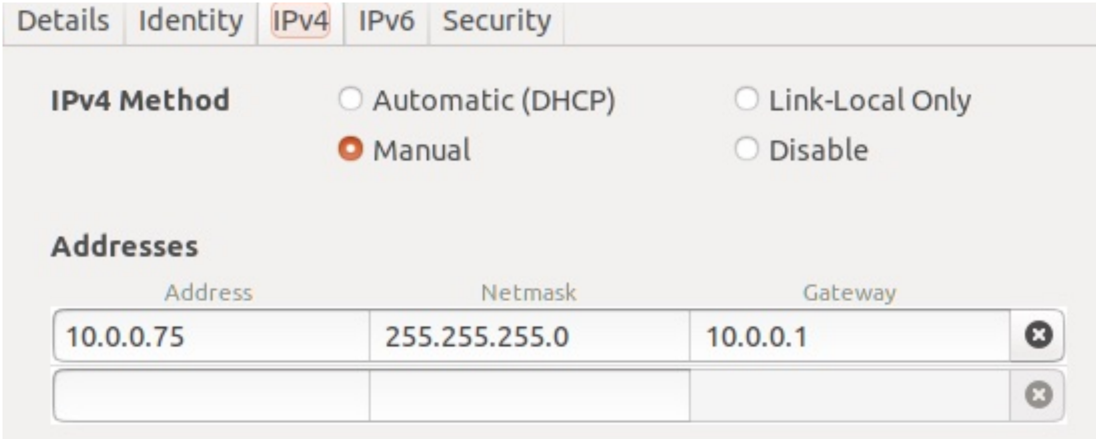

Figure 9. Example static network configuration in Ubuntu

After a TCP connection is made, the app can be used to update the expected Host network parameters stored on the radar - see below. Be sure and update the host's static network configuration to match any changes that you send to the radar.

Changing the Radar's Ethernet Settings

It is sometimes necessary to change the Ethernet settings of the radar to something other than the default. For example, if multiple radar's are being used, they each must have a unique IP and MAC address, and they must be set to each use a different host port. These settings can be changed with the App.

The radar's Ethernet settings can be updated from the Networking tab. Power on the radar, connect to it in Ethernet mode, enter new values, and press Update Network Params. The App should report a successful reconfiguration. This is shown in Figure 10

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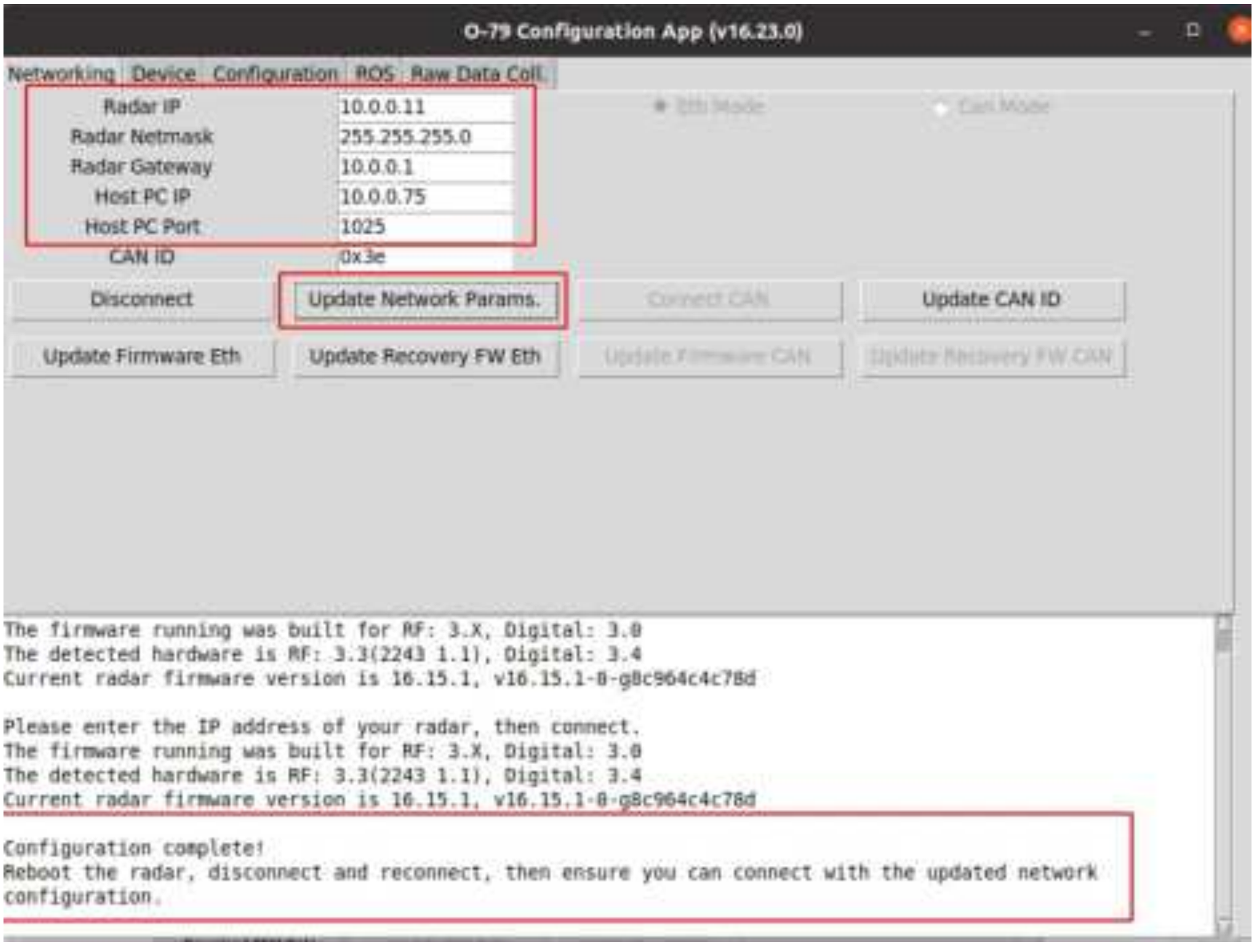


Figure 10. Updating Radar IP and Host PC port in the O-79 App

The radar's MAC address can be updated from the Device tab of the App. First, enter the Unlock Password and select Unlock Device Functions. Contact Ainstein for the current unlock password if this functionality is needed.

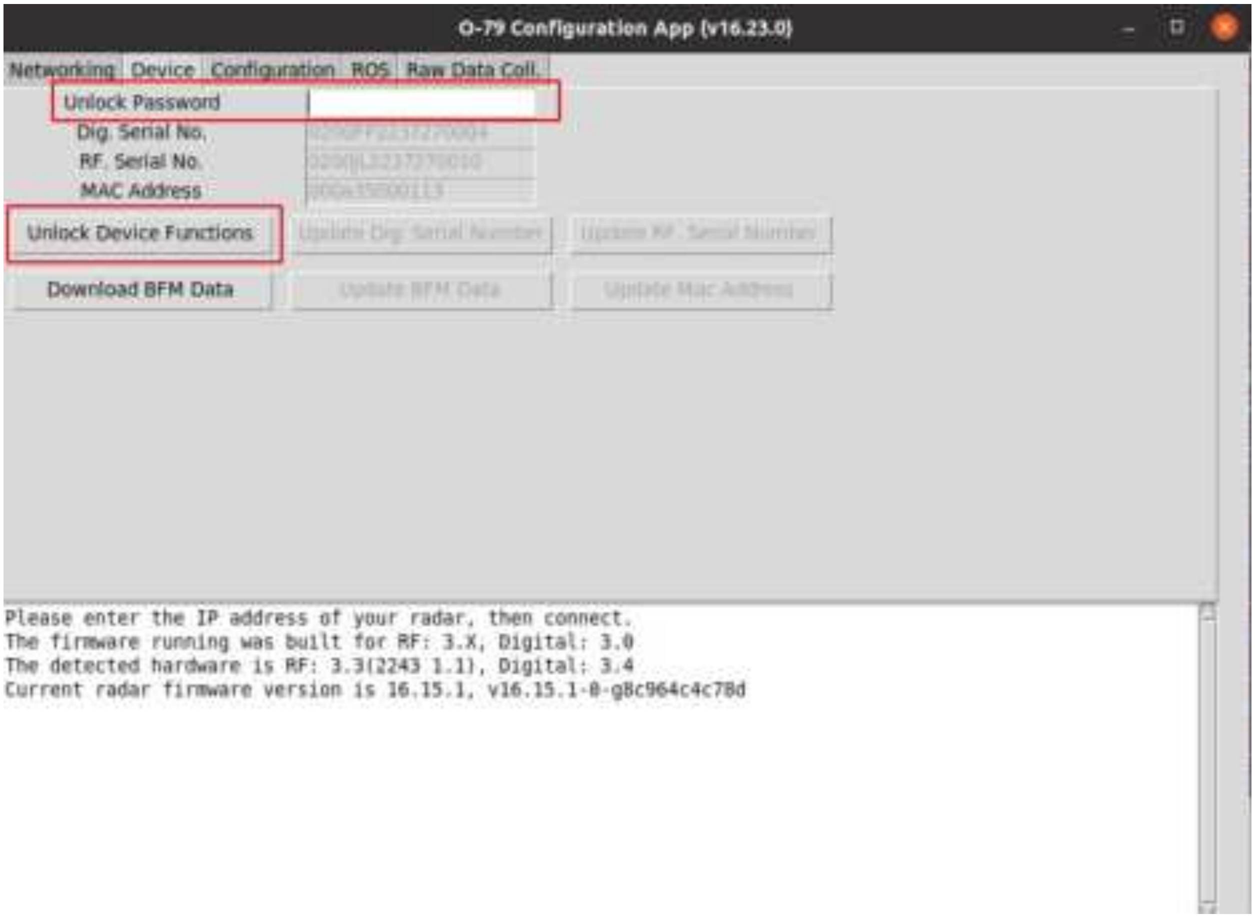
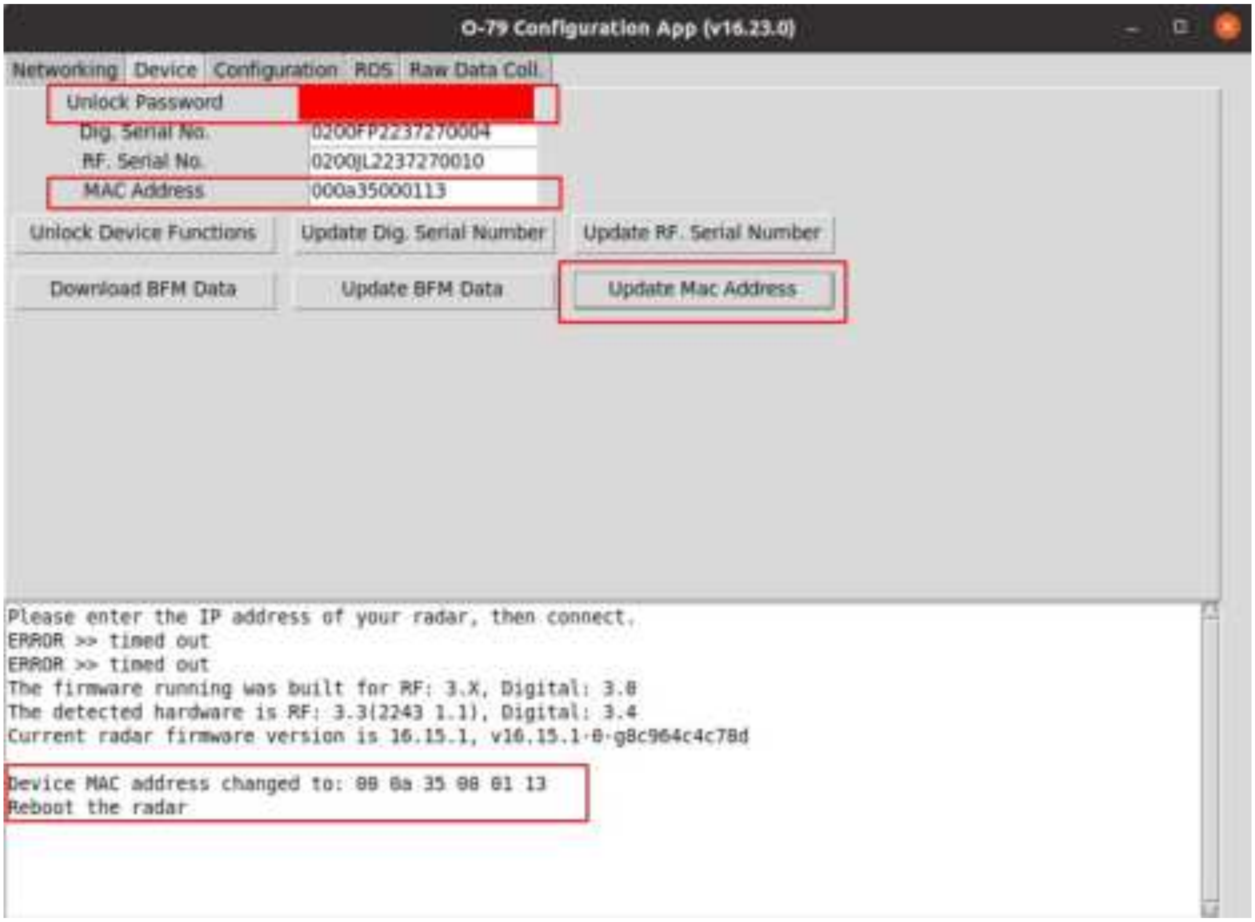


Figure 11. Unlock Device Functions

Then enter the new MAC address and select Update Mac Address. The App should display a confirmation message.



Primary Firmware Update

Firmware flashing from a host PC is currently supported over Ethernet using TCP. Following are instructions for updating the firmware:

1. Power on the radar and wait approximately 15 seconds for it to initialize.
2. Change the IP address in the *Radar IP* input field to your radar's IP address; this is **10.0.0.10** by default. Press *Connect* to connect to the radar.

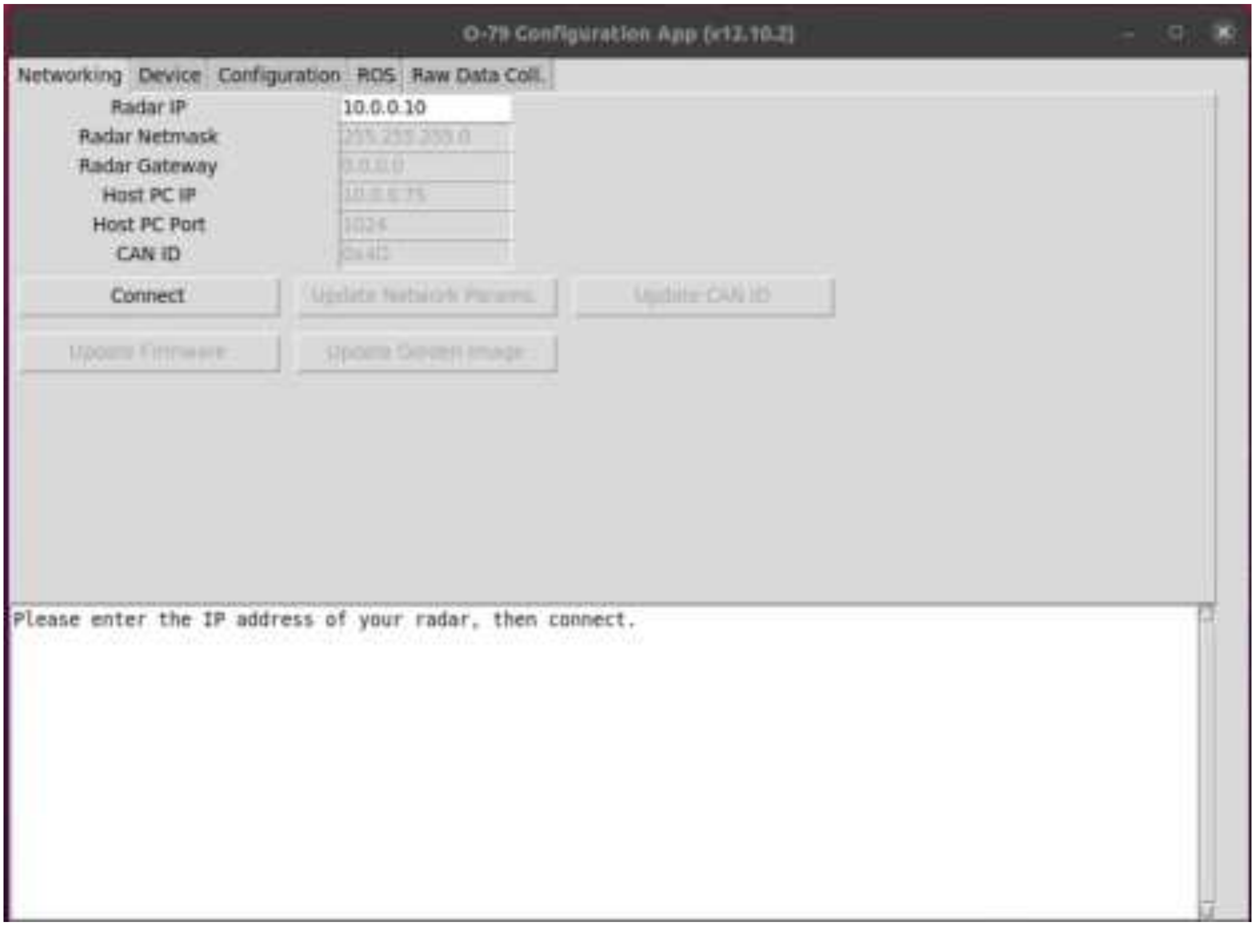


Figure 12. O-79 Configuration App initial view

3. The radar should connect successfully and fill the remaining input fields with the network configuration currently stored in flash memory.

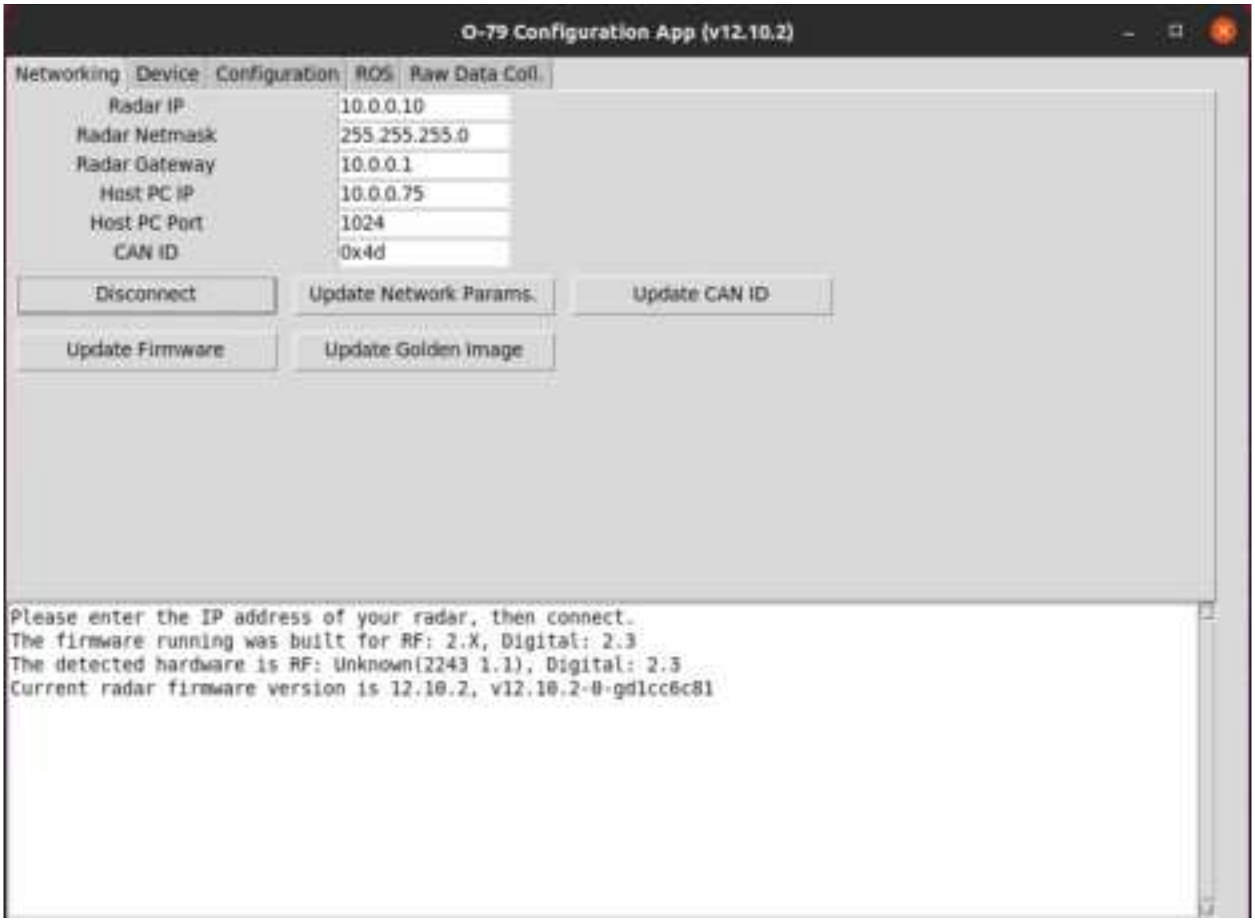


Figure 13. O-79 Configuration App, connected to a radar

4. Now, press the *Update Firmware* button, which opens a file system dialog; navigate to the firmware file you wish to flash and press *Open* to begin the firmware update.

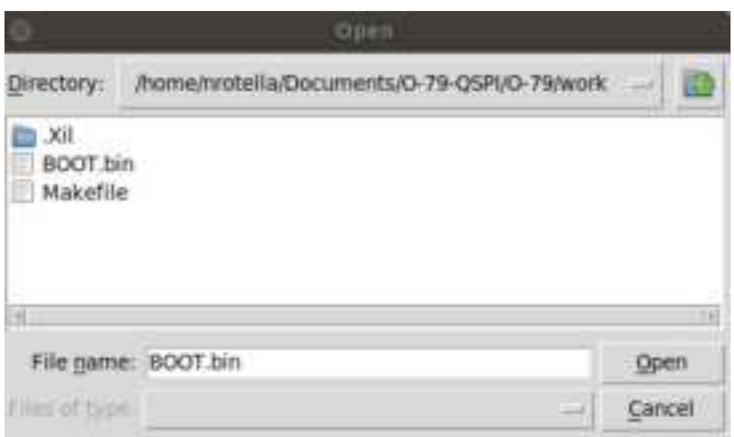


Figure 14. File system dialog window and firmware file

5. The file system dialog window will close and the firmware update will begin immediately, with the host PC sending the binary firmware file to the radar which writes them into flash memory. You will see a progress indicator updated as the file is sent.

Figure 15. Firmware update in progress with status displayed

6. After the firmware is sent to the radar, the app will display a message about the firmware being written to flash.

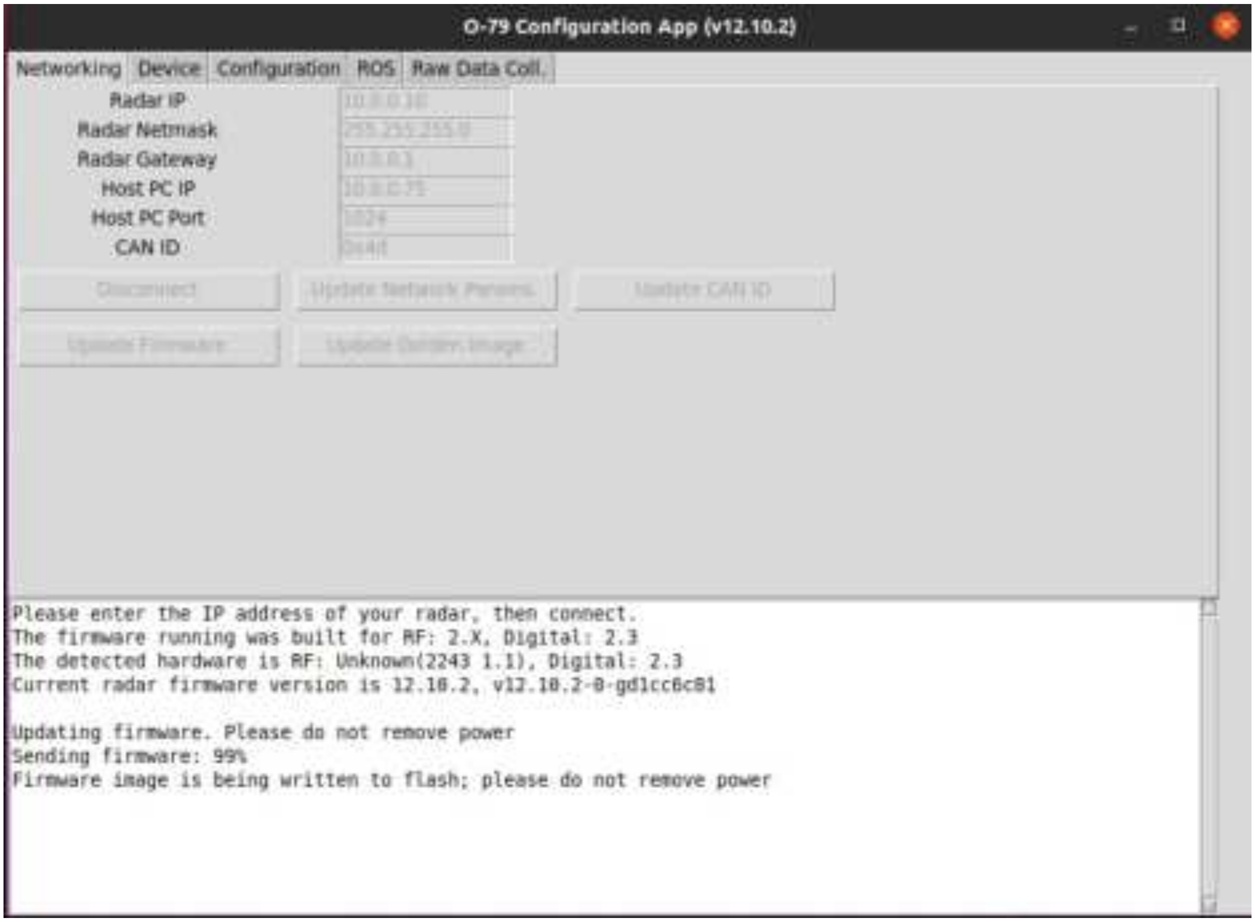


Figure 16. Firmware finished sending to the radar, writing to flash memory.

7. When the file is finished being written to flash memory, the app receives a notification from the radar, a success message should be displayed in the app.. The radar must be rebooted, at which point it will execute the new firmware which was just flashed. The app must be disconnected (with the Disconnect button) before it can connect to the radar again after it has rebooted.

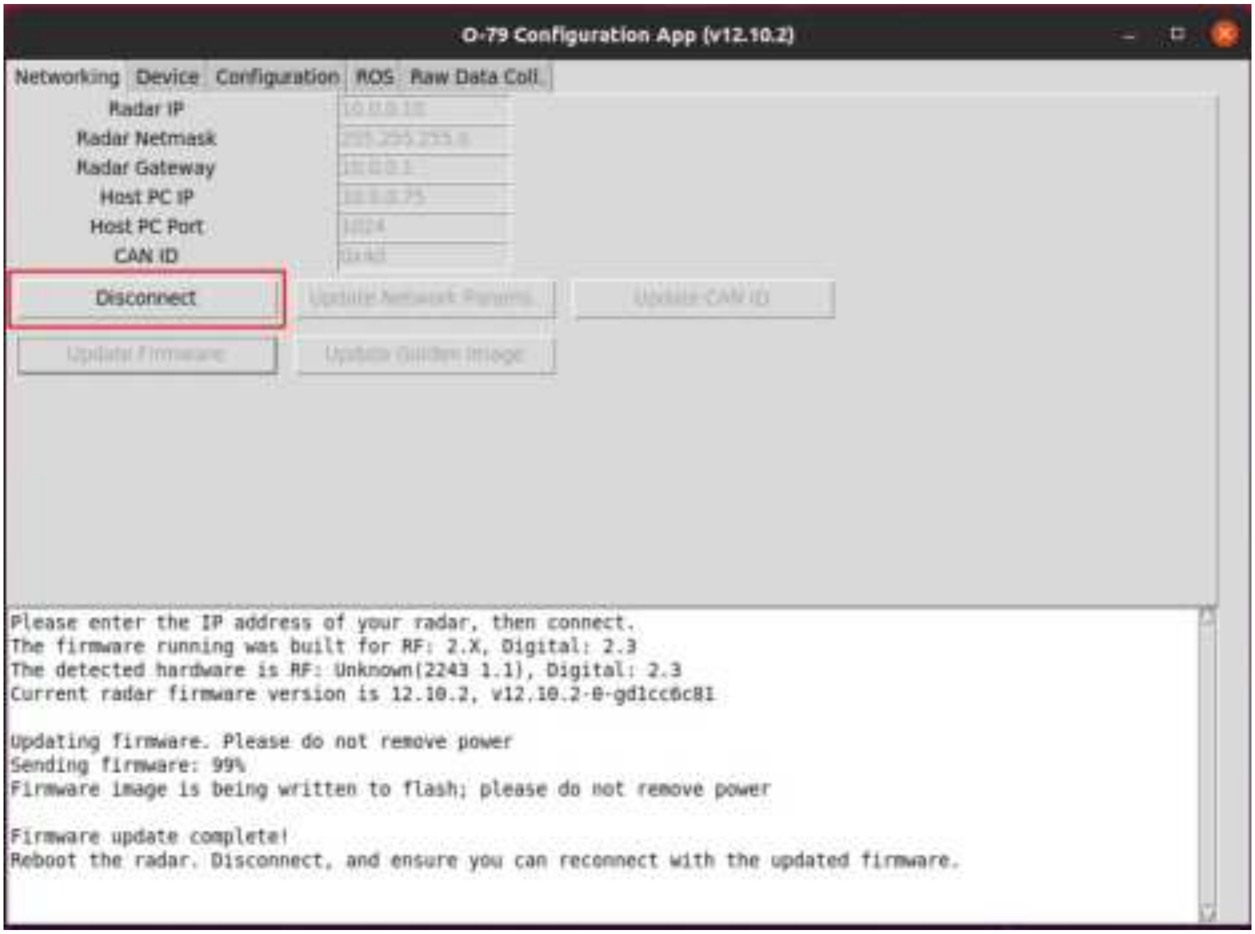


Figure 17. Firmware update complete, reboot the sensor.

Recovery Firmware Update

The recovery firmware is stored in flash memory, and allows the radar to boot when the primary firmware is found to be corrupted. This recovery firmware has minimal functionality, allowing connection to the O-79 Configuration app to update the primary firmware to a valid file.

The process for updating the recovery firmware is identical to that for the primary firmware detailed above; instead of choosing the *Update Firmware* option, choose *Update Recovery FW Eth* in the app and follow the same process.

If the radar boots into the Recovery Image, the firmware version reported by the app will begin with 0. For example, 0.4.0. If this happens, use the Update Firmware button to load valid firmware onto the radar.

Device

The Device tab can be used to update a radar's serial numbers and/or mac address, all of which are stored in flash memory. A password is required to update these parameters, mainly to prevent accidentally changing them. Please contact Ainstein if either of these parameters need to be updated.

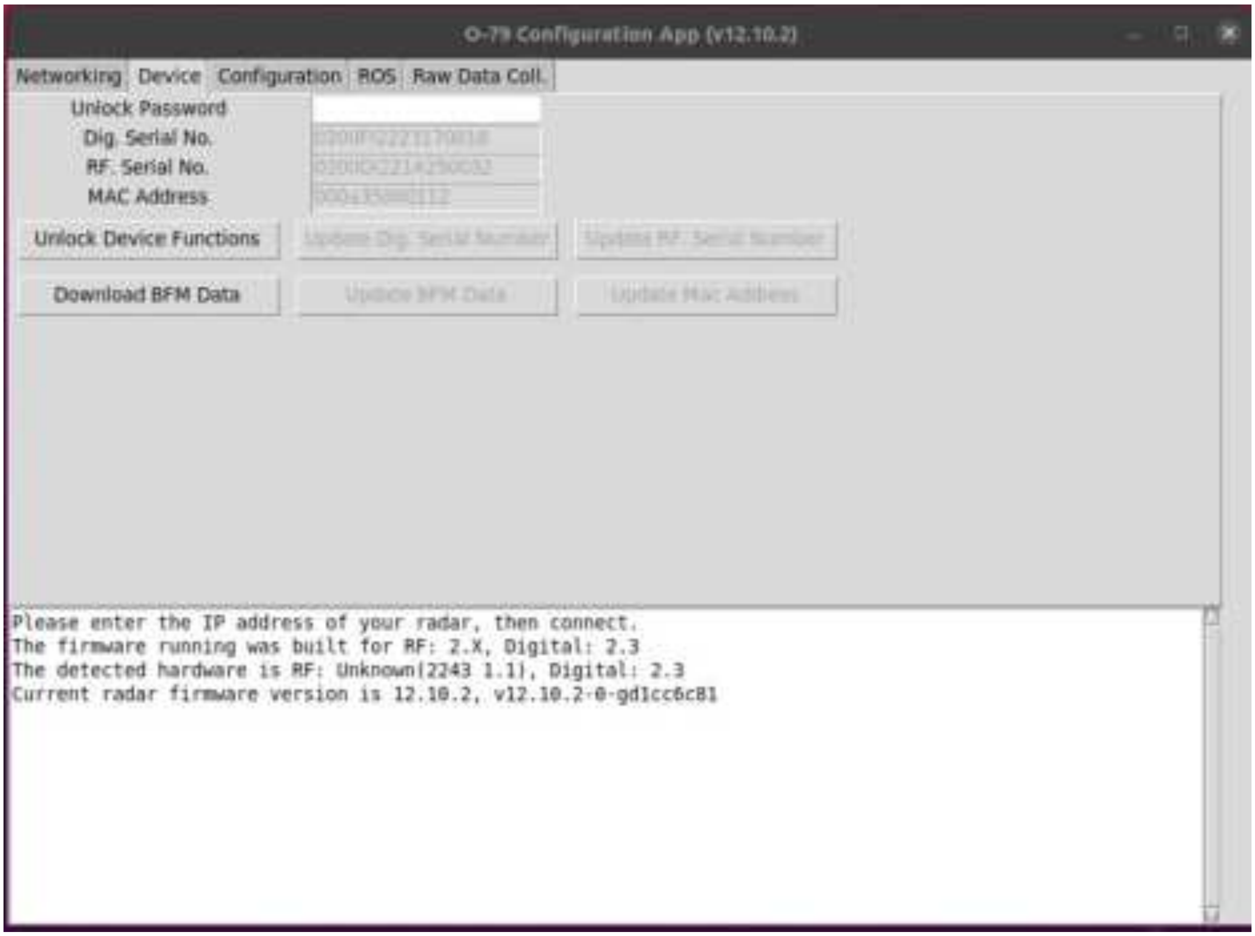


Figure 18. Device Identifiers Tab

Configuration & Tuning

The Configuration tab can be used to modify various configuration parameters that are stored in the radar's flash memory. Not all of the configurable parameters may be fully supported for every version of firmware.

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Use

When the app successfully connects to the radar, all of the buttons on the Configuration Tab become active. When the "Download Current Settings" button is pressed, the radar sends the Configuration values currently stored in its flash memory to the app, and they populate the selection options. This is shown in Figure 19.

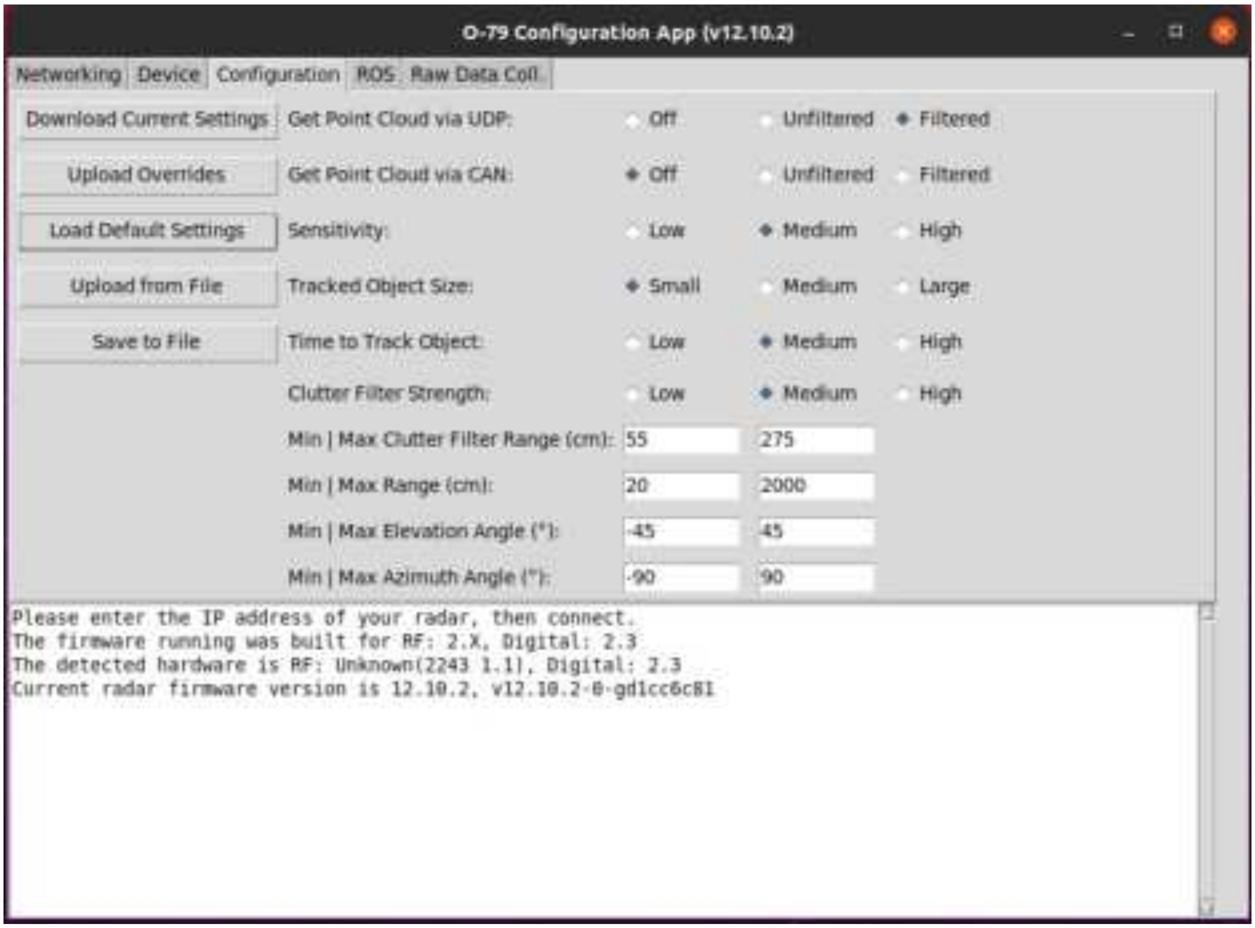

Figure 19. Configuration Tab

The radio buttons can be selected, and entry boxes edited, to set different configuration values. Once the entire set of selections is ready to be sent to the radar, press the "Upload Overrides" button. When the radar loads the configuration on its next power up it will use default values in place of out of range and unselected ones. **The radar must be power cycled for the new overrides to take effect.**

Tuning

The configurable parameters for the radar are shown in Table 5. The default value for each parameter depends on the firmware version. The defaults can be examined using the "Load Default Settings" button in the Configuration App. The capability to modify tune-able parameters is for development only. It is not supported for production in safety-related applications.

Table 5. Configuration App's tunable parameters

Option	Description	Range of acceptable values
Get Point Cloud via UDP/CAN	Enables the viewing and collection of filtered, unfiltered, or no points via each communication protocol. The filtered point cloud is the result of passing the unfiltered point cloud through Ainstein's proprietary clutter filtering algorithms. The filtered point cloud is passed to the onboard tracking software.	N/A
Sensitivity	Adjusts the likelihood for the radar to pick up points.	N/A
Tracked Object Size	Controls how spread out points can be and still be grouped into one cluster. Smaller results in a greater number of tracked objects at closer distances.	N/A
Time to Track Object	Adjusts the amount of time between detection of points and those points becoming a tracked object. Lower reduces the latency to track an object but may result in more short-duration transient tracked objects.	N/A
Clutter Filter Strength	Adjusts the likelihood that the radar will filter out clutter, such as from the ground. Lower increases the likelihood that low objects will be tracked, but also increases the likelihood that tracked objects from the ground will appear.	N/A
Min/Max Clutter Filter Range	Adjusts the range at which the clutter filter is applied.	20-1000 (cm)
Min/Max Range	Adjusts the range at which the radar will detect points.	20-2000 (cm)
Min/Max Elevation Angle	Adjusts the down/up (negative/positive) field of view within which the radar will detect points	-45 - +45 (°)
Min/Max Azimuth Angle	Adjusts the right/left (negative/positive) field of view within which the radar will detect points	-90 - +90 (°)

ROS

The O-79 Configuration App provides a simple interface with ROS and RViz to visualize, record, and playback data from O-79. ROS, and the ainstein_radar package, must be installed in order to use this functionality. Instructions for installing ROS and building the ainstein_radar package can be found here. ROS can only be used with O-79 from a host device running Ubuntu.

Viewing and Recording Data

1. Connect to the radar with the Connect button on the Networking Tab
2. Switch to the ROS tab and press "Start ROS." The App will attempt to set up the ROS environment automatically.
    a. If the setup file can't be found, a file selection dialogue box will appear. Navigate to the setup.bash file that was created in the catkin workspace directory that was created when building the ainstein_radar package and press "Open." The ROS environment will be set up.
    b. Note: the app will remember the setup.bash file chosen on subsequent starts, so this file only has to be selected once.

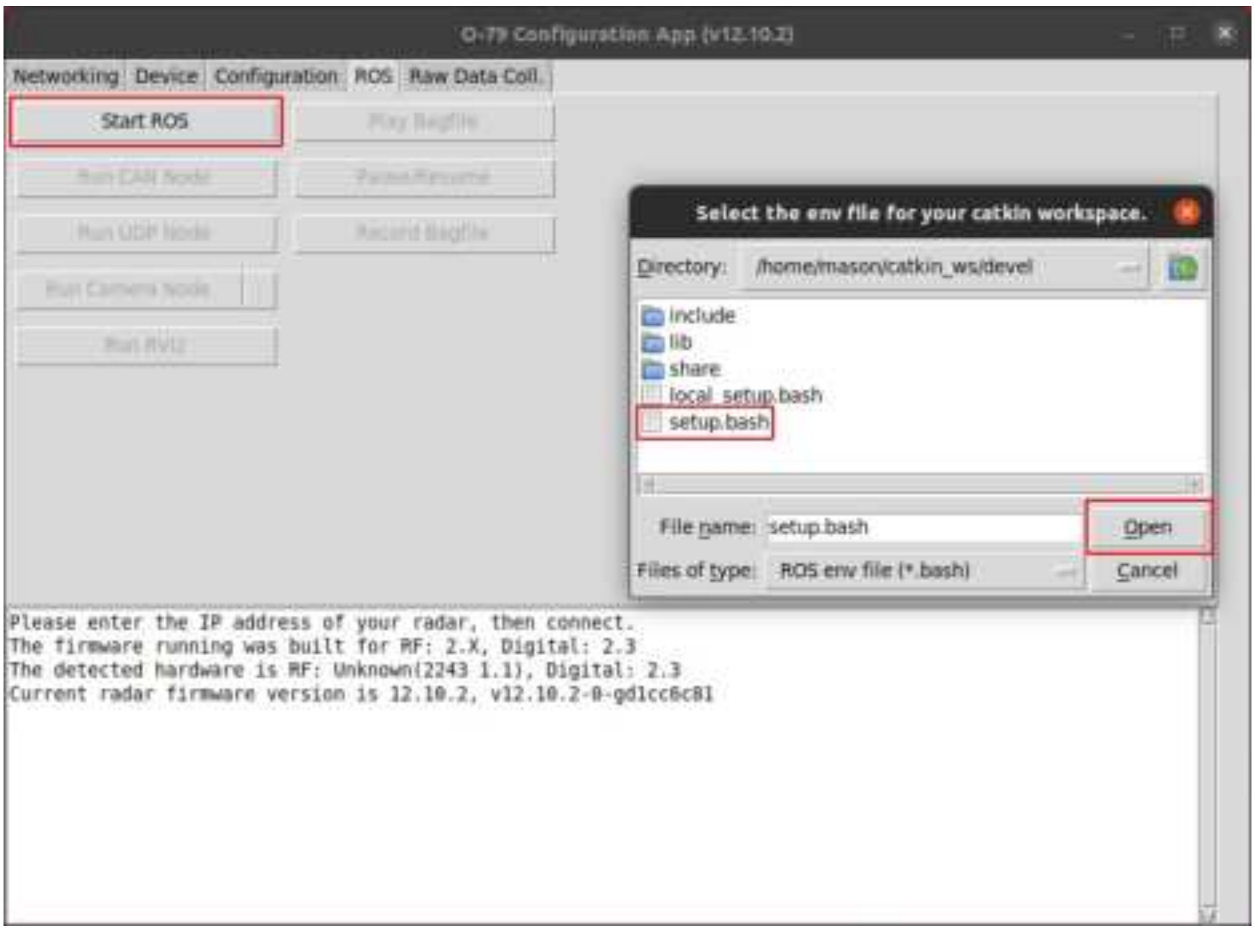

Figure 20. Starting ROS from the app

3. Press the "Run UDP Node" button and/or the "Run CAN Node" button
    a. Additional hardware and drivers are required to run the CAN node on a PC. Please contact Ainstein if more information is needed about this functionality.

4. If a USB camera is connected to the host, press the "Run Camera Node" button to display its feed in RViz.
    a. v4l2-ctl must be installed for the camera integration to work correctly

    ```
    sudo apt-get install v4l2-ctl
    ```

    b. Extra steps may be needed to use the camera if the host is running Ubuntu as a virtual machine (VM). For example, the user may need to direct the camera to the Ubuntu VM, and may also need to set the USB controller compatibility to USB 3.1 or another appropriate setting for the particular camera.
    c. The default camera runs at a default resolution of 320x240. If a non-default camera and/or resolution is desired, the user may click the three dots(⋮) to the side of the "Run Camera Node" button. This will open a "Camera Settings" window where the camera device and/or resolution can be set.
5. Press the "Run RViz" button. RViz will start and the data from the radar will be displayed.

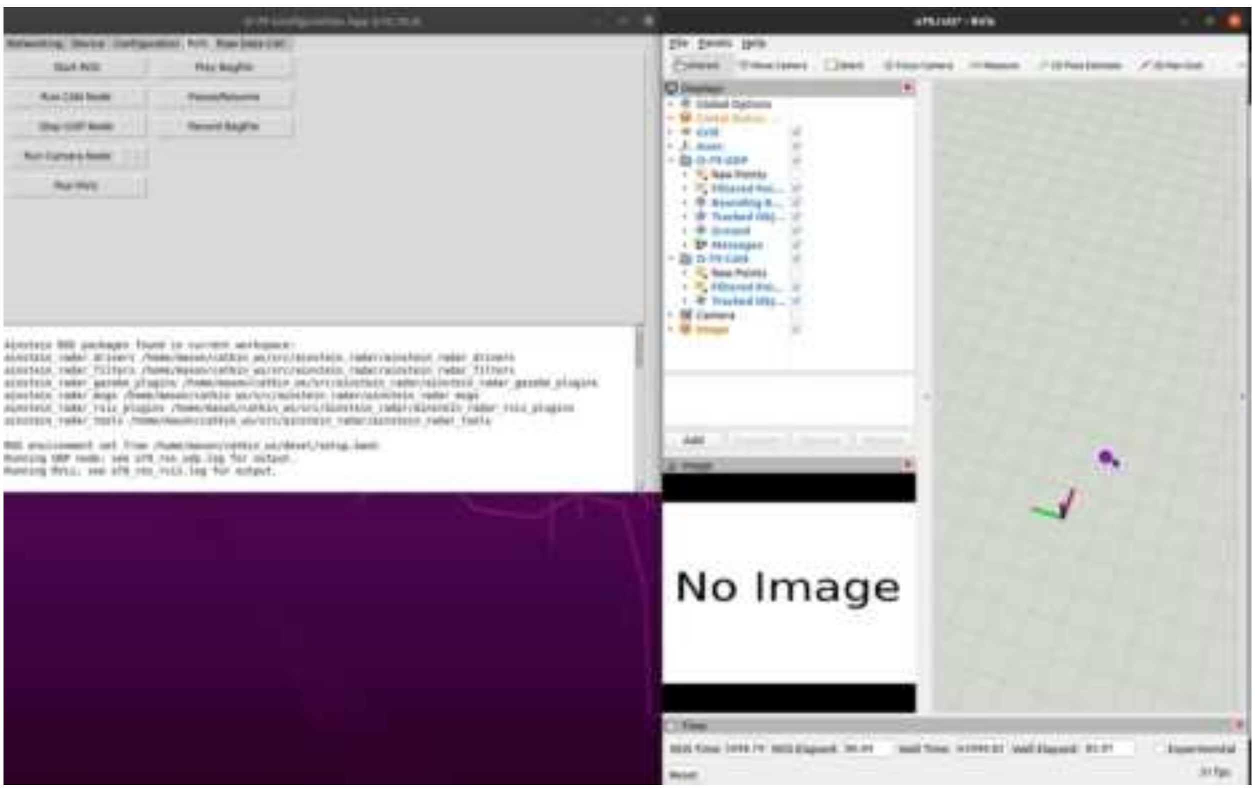

Figure 21. RViz

6. Press the "Record Bagfile" button in the app to start logging data through ROS. A pop-up will appear to specify a location and name for the bagfile to be saved.
    a. The Advanced Configuration values stored in radar flash will be automatically downloaded and saved with the same file name as the bagfile, with _advcfg.txt appended to the end.
7. Press the "Record Bagfile" button again to stop recording.

Playing Back Data

1. Start the app and switch to the ROS tab
2. Press "Start ROS." If prompted, select the setup.bash file that was created in the catkin workspace directory that was created when building the ainstein_radar package and press "Open."
3. Press "Run RViz"
4. Press "Play Bagfile" and select the bagfile you wish to view. The data will start playing back in RViz
5. Press "Pause/Resume" in the app to pause and resume playback

Communication

The O-79 radar supports communication over both CAN and Ethernet (Pro only). This section describes the types and formats of the messages the radar may send and receive on each communication medium, as well as how to interpret the data.

Coordinate Frame and Units

The sensor coordinate frame is the same for all communication interfaces. In accordance with ROS REP 103 - Standard Units of Measure and Coordinate Conventions, the sensor coordinate frame has x forward, z up, and y left to complete a right-handed frame; see the diagram below for clarification.

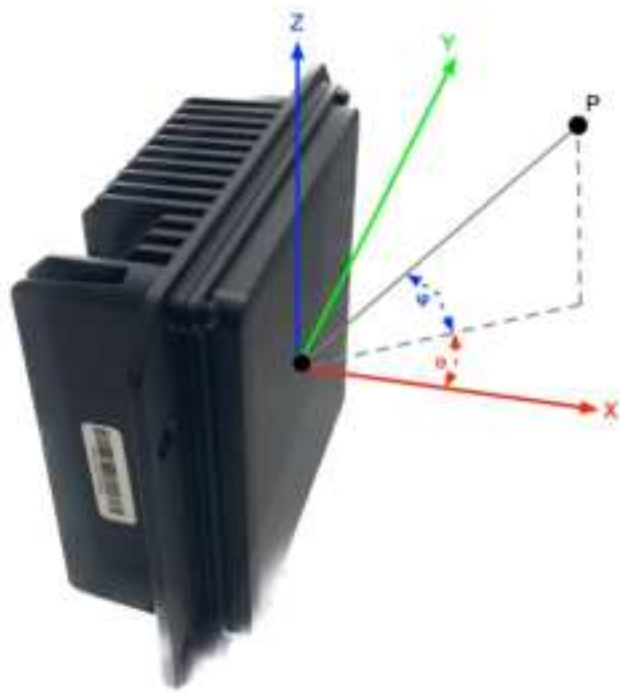

Figure 22. Sensor coordinate frame definition.

The azimuth angle, denoted by **θ**, is measured as a rotation around the positive Z axis a, while the elevation angle, denoted by φ, is measured as a rotation around the negative Y axis. For example, the point, P, in the diagram has positive azimuth and positive elevation angles. From the radar's point-of-view, P is left and up from the origin.

Deviating from ROS REP 103, all angular measurements are in units of **degrees** instead of radians. This was chosen for readability and consistency with existing Ainstein radar sensor modules. Distance and speed/velocity quantities are measured in units of **meters** and **meters per second**, respectively, as recommended by REP 103.

CAN Messages

Please contact Ainstein for information on the CAN messages supported by the O-79.

UDP Messages (Pro only)

All object messages are sent over UDP in the following format, with an 8 byte header followed by data of any length (depending on the message type):

Header	Data Message/Fra	Data Message/Fra	...	Data Message/Fra

	me 1	me 2		me N

The contents of the Header message (UDP) or Header frame (CAN) are shown in Table 6. Not all Message Types are supported by both CAN and UDP.

Table 6. UDP Header Message (UDP) or Frame (CAN)

Data Byte	Description	Signed/Unsigned	Scaling
DATA0 DATA1	Frame Number	Unsigned	Frame ID = DATA0 * 256 + DATA1
DATA2 DATA3	Number of Data Objects	Unsigned	Number of data objects to follow = DATA2 * 256 + DATA3 *Note: some message types have multiple frames per object*
DATA4	Message Type ID	Unsigned	0: Raw spherical point cloud, Rev. A (not used) 1: Tracked spherical, Rev. A (not used) 2: Bounding Boxes, Rev. A 4: Tracked Cartesian, Rev. A (2 frames per object) 5: Ground Cartesian, Rev. A (2 frames per object) 6: Raw spherical point cloud, Rev. B 7: Alarm Status 8: Filtered spherical point cloud, Rev. B 9: Tracked Cartesian, Rev. B 12: Reserved 13: Reserved 14: Reserved 255: Legacy
DATA5	Reserved	N/A	0xFF
DATA6	Reserved	N/A	0xFF
DATA7	Reserved	N/A	0xFF

Point Cloud in Spherical Coordinates

Points and tracked objects in spherical coordinates are sent over UDP in the following format:

Header	Object 1	Object 2	...	Object N

where each of the N objects' information is packed into 8 bytes as shown in Table 7. The Message Type ID field in the Header message is 0x06 (unfiltered), or 0x08 (filtered).

Table 7. UDP Spherical Object Frame, Rev. B (message type 6 (raw) or message type 8 filtered)

Data Byte	Description	Signed/Unsigned	Scaling
DATA0	Signal Power	Unsigned	1 LSB = 1 power unit
DATA1			
DATA2	Range	Unsigned	1 LSB = 0.01 m
DATA3			
DATA4	Speed	Signed	1 LSB = 0.005 m/s
DATA5			
DATA6	Azimuth Angle	Signed	1 LSB = 1 degree
DATA7	Elevation Angle	Signed	1 LSB = 1 degree

Tracked Bounding Boxes

The bounding box associated with each tracked object is also output over UDP, in its own message of the format shown in Table 8, with message type ID = 2. . Similar to point cloud and tracked object messages, the message format is as follows:

Header	Bounding Box 1	Bounding Box 2	...	Bounding Box N

where each of the N bounding boxes' information is packed into 9 bytes as follows:

Table 8. UDP Bounding Box Frame (message type 2)

Data Byte	Description	Signed/Unsigned	Scaling
DATA0	Box Center X Position	Signed	1 LSB = 0.01 m
DATA1			
DATA2	Box Center Y Position	Signed	1 LSB = 0.01 m
DATA3			
DATA4	Box Center Z Position	Signed	1 LSB = 0.01 m
DATA5			
DATA6	Box Size X	Unsigned	1 LSB = 0.1 m
DATA7	Box Size Y	Unsigned	1 LSB = 0.1 m
DATA8	Box Size Z	Unsigned	1 LSB = 0.1 m

Objects in Cartesian Coordinates

Objects in Cartesian coordinates are output **only when the Cartesian tracking filter is enabled**; see the O-79 Configuration App section for details on how to switch between tracking filters. The message type ID field for tracked objects is 4 (standard tracked objects) or 5 (ground tracked objects). Tracked objects in Cartesian coordinates are sent in the following format:

Header	Object 1	Object 2	...	Object N

where each of the N objects' information is packed into 12 bytes as follows:

Table 9. UDP Cartesian Object Frame (message type 4 or 5)

Data Byte	Description	Signed/Unsigned	Scaling
DATA0	Object ID	Unsigned	1 LSB = 1 object ID count
DATA1	X Position	Signed	1 LSB = 0.01 m
DATA2			

DATA3 DATA4	Y Position	Signed	1 LSB = 0.01 m
DATA5 DATA6	Z Position	Signed	1 LSB = 0.01 m
DATA7 DATA8	X Velocity	Signed	1 LSB = 0.005 m/s
DATA9 DATA10	Y Velocity	Signed	1 LSB = 0.005 m/s
DATA11 DATA12	Z Velocity	Signed	1 LSB = 0.005 m/s

Appendix A - RF Exposure Requirements and Limits and Warnings

Changes or modifications not expressly approved by the manufacturer could void the user's authority to operate this equipment.

This product meets the applicable FCC Part 95 rules. Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

To limit RF exposure, please ensure 8 inches (20 cm) of separation from the device at all times.

This device complies with Industry Canada's license-exempt RSSs. Operation is subject to the following two conditions:

1. This device may not cause interference; and
2. This device must accept any interference, including interference that may cause undesired operation of the device.

This equipment should be installed and operated with a minimum distance of **20cm** between the radiator and your body.

Cet appareil est conforme aux RSS sans licence d'Industrie Canada. Son fonctionnement est soumis aux deux conditions suivantes:

1. Cet appareil ne doit pas provoquer d'interférences; et
2. Cet appareil doit accepter toute interférence, y compris les interférences susceptibles d'entraîner un fonctionnement indésirable de l'appareil.

Cet équipement doit être installé et utilisé avec une distance minimale de **20 cm** entre le radiateur et votre corps.

Appendix B - Advanced Configuration

Advanced Configuration

The Advanced Configuration tab can be used to modify any of the configuration parameters that are stored in the radar's flash memory. **These parameters should only be modified after consulting with Ainstein developers.** Not all of the configurable parameters may be fully supported for every version of firmware.

This feature is not supported for safety-related applications in production. Any modifications to tune-able parameters for a safety-related production application must be coordinated with Ainstein, as revalidation may be required.

Use

When the app successfully connects to the radar, all of the buttons on the Advanced Configuration Tab become active. When the Download Overrides button is pressed, the radar sends the Advanced Configuration values currently stored in its flash memory to the app, and they are displayed in the text box. These will not be the full list but only the values that have overrides from the default values. This is shown in Figure 23.

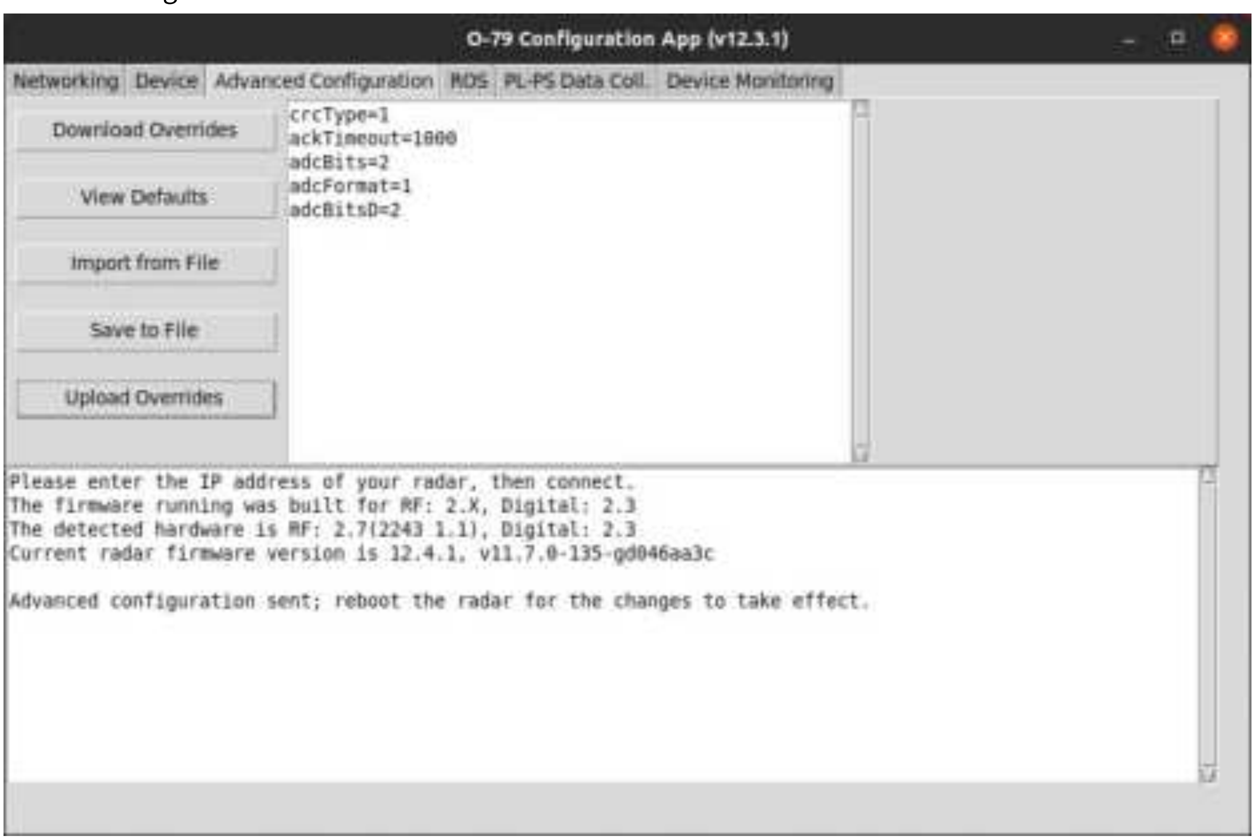

Figure 23. Advanced Configuration Tab

The text in the textbox can be edited to set different configuration values. Once the text is ready to be sent to the radar, press the “Upload Overrides” button. A pop-up message will appear if unsupported values have been sent - this is usually due to a typo. The configuration specified in the textbox will be sent to the radar and stored in flash. When the radar loads the configuration on its next power up it will ignore unsupported values and use default values in place of missing ones. The more overrides that have been specified, the longer it will take the radar to boot. So, if the desired value is the default it should not be sent. **The radar must be power cycled for the new overrides to take effect.**

Example: If crcType is changed to crcTypo, then sent to the radar, the app will create a warning pop-up reporting that an unsupported value, crcTypo, is being sent.

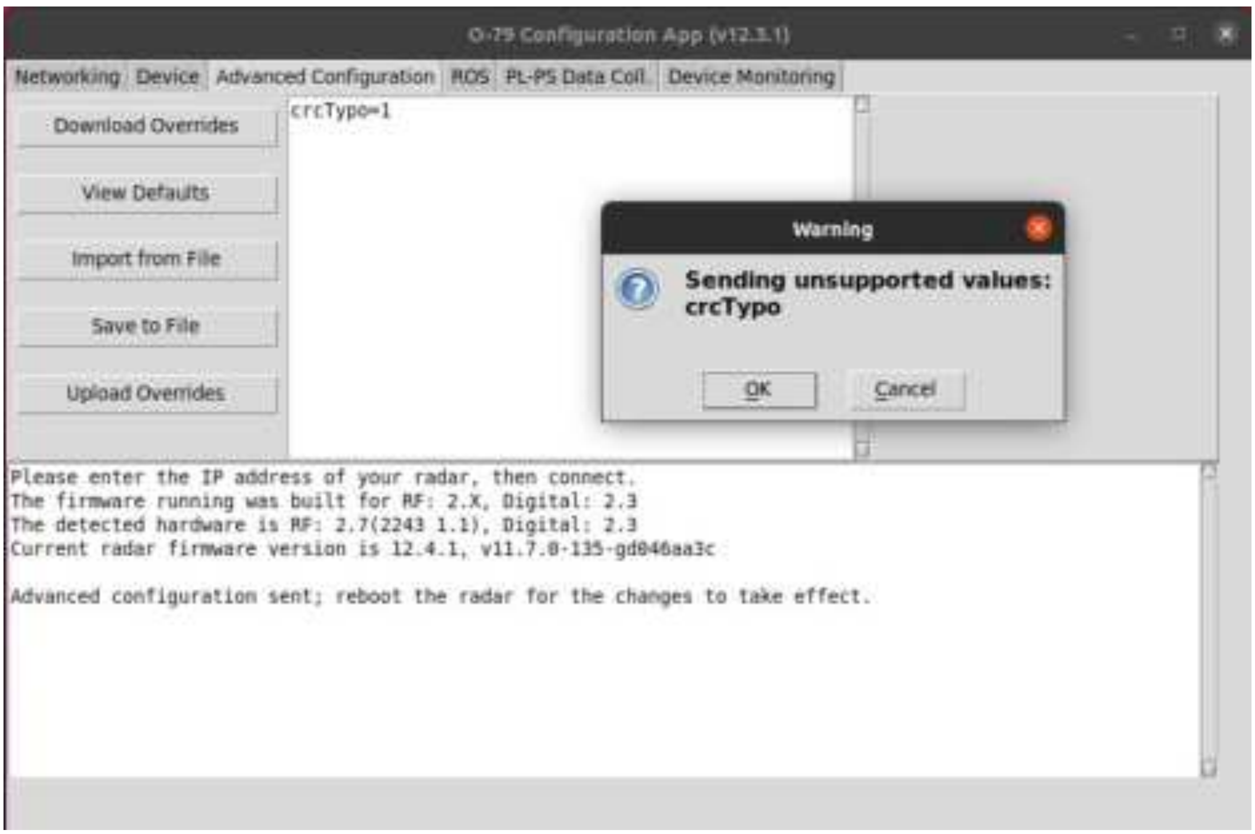

Figure 24. Unsupported Overrides Warning

Tracking Filter

The radar runs a Kalman filter tracker onboard, in real time. It uses a nonlinear update step in order to provide full three-dimensional velocity and position information. The configurable parameters for the tracking filter, which are part of the Advanced Configuration, are shown in Table 5. The default value for each parameter depends on the firmware version. The defaults can be examined using the “Load Default” button in the Configuration App.

Table 10. Tracking filter configurable parameters, descriptions, and ranges.

Name	Description	Min	Max
Process Rate (ms)	Determines the rate at which tracked objects are integrated internally and output over CAN/UDP; higher process rate results in smoother tracking and faster data output.	50	1000
Confidence Level	Determines how strongly new points are considered to be unique tracked objects. Higher means more tracked objects with smaller clusters and better ability to distinguish objects in close proximity, lower means fewer tracked objects with larger clusters and more robustness to clutter and noise.	1	9
Minimum Range (cm)	The minimum range of points which are passed to the onboard tracking filter for continuous object tracking. A small minimum range is currently used to filter very close noisy detections.	10	1000
Maximum Range (cm)	The maximum range of points which are passed to the onboard tracking filter for continuous object tracking. Note: the radar chirp parameters must be coordinated with this value; increasing this value along will not result in greater range.	10	5000
Velocity Process Noise X/Y/Z (cm/s)	Determines how quickly the tracked three-dimensional velocity vector can change in each component due to new measurements; lower means smoother changes, higher means faster change tracking. For certain applications, it may improve tracking to tune these X/Y/Z noise components independently.	1	500
Speed Measurement Noise (cm/s)	Sets the confidence with which point cloud radial speed measurements are used to update the filter state.	1	1000
Position Measurement Noise (cm)	Sets the confidence with which point cloud position measurements are used to update the filter state.	1	100

The Tracking Filter uses a state machine to provide debouncing and track extension. Debouncing is used so that not every transient point cloud point becomes a tracked object, and extension is used to allow tracked objects to "ride through" short periods of time when no point cloud points are actively updating them. A state flow diagram for the state machine is shown in Figure 25.

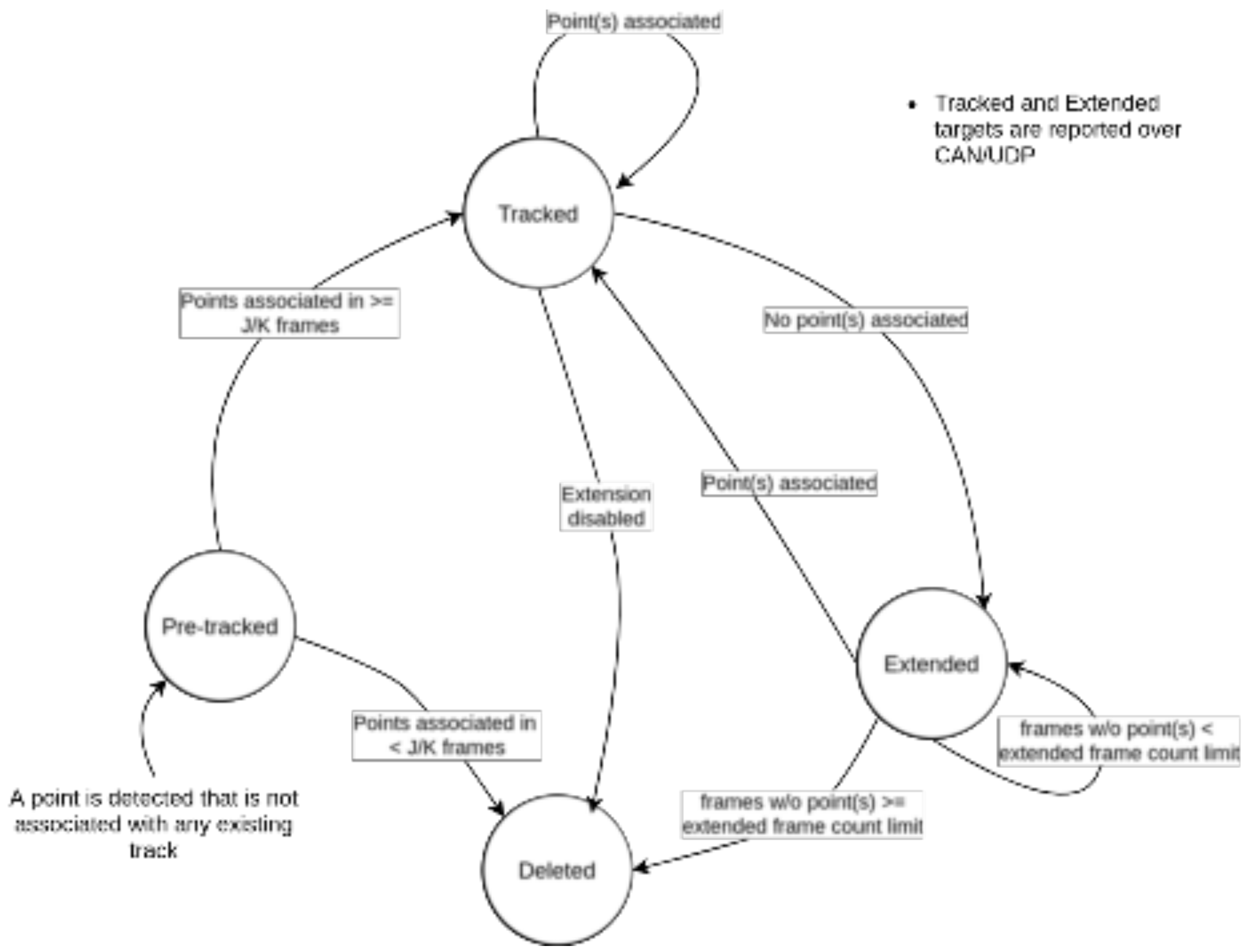

Figure 25. Tracker State Flow Diagram

The Advanced Configuration parameters related to the state machine are as follows:

- minCntTrack: minimum number of frames for which the track must have new points associated before it is moved to the Tracked state.
- maxCntPreTrack: maximum number of frames for which a track is allowed to remain in Pre-tracked state. If a track in the Pre-tracked state has not had any points associated with it in minCntTrack/maxCntPreTrack frames, it is deleted.
- maxCntExtTrack: maximum number of frames for which a track is allowed to remain in Extended state. If a track in Extended state has not had any points associated with it in maxCntExtTrack frames, it is deleted.

Appendix C - CRC

CRC

The details of the CRC (Generic CRC-32) referred to in this document, unless specified otherwise, are shown in Table 11.

Table 11. Generic 32-bit CRC

Byte	Specification
DATA0	Polynomial: 0x04C11DB7 Initial value: 0xFFFFFFFF Pre-reflection: byte-wise Post-reflection: 32-bit Post-inversion: 0xFFFFFFFF
DATA1	
DATA2	
DATA3	

Appendix D - General Specifications

Table 12. General Specifications

Parameter	Value
Transmit Frequency Range	76 - 81 GHz
Maximum Transmit Power	13 dBm
Audible Noise	Negligible
Weight	< 2 lbs