EchoGuard™ INTL
Security and Surveillance Radar
User Manual

EchoGuard-INTL Model #s:	**700-0005-206-100** (white, convective heatsink)
	700-0005-206-200 (tan, convective heatsink)
	700-0005-207-100 (white, cold plate)
Frequency of Operation:	**24.05-24.25 GHz**

Release Date: **March 2023**

Doc #: **300060-001 rev03**

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CHANGE SUMMARY

REV DATE	CHANGE NOTES & HIGHLIGHTS	AUTHOR
2021-May	Creation in support of CE RED Type Certification	S Straka
2022-June	Corrected radar default IP address to be 169.254.1.10	S Straka
2023-May	Updates based on 2023 CE Type Cert refresh	D Garrison

1. PRODUCT OVERVIEW

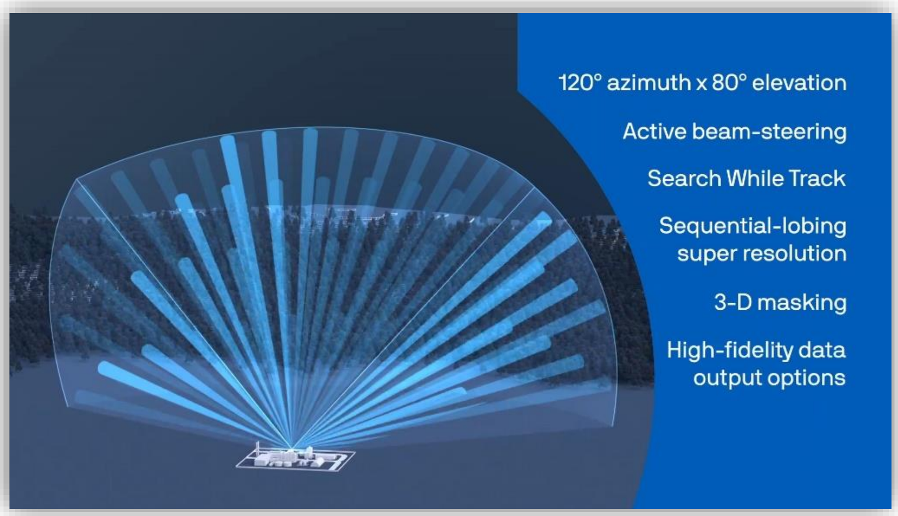
1.1 Introduction to Echodyne's Echoguard MESA Radar

Echodyne's MESA (Metamaterial Electronically Scanning Array) technology is a new architecture for forming and controlling a beam of radiating energy from a surface. The MESA architecture is inherently simpler than alternatives as it does not require the moving parts of dish antenna systems, nor the phase shifters of phased array antennas. This simplicity allows MESA to make imaging radar solutions accessible to a broad range of applications, even platforms which may be highly C-SWAP (Cost, Size, Weight, and Power) constrained.

EchoGuard™ Security and Surveillance Radar (SSR) is uniquely designed to enable multiple missions such as perimeter security for border or critical infrastructure applications, counter-UAS (cUAS) detection and tracking of intruders and Ground-Based Detect and Avoid (GB-DAA) applications. It can provide the same level of safe operation for small UAS vehicles too small to carry their own radar system, by providing localized situational pilot awareness of both own-ship position, along with cooperative and non-cooperative intruder air vehicles. Multiple EchoGuard units may be combined into flexible local networks for increased coverage. EchoGuard provides 20-30% longer range than EchoFlight™ (Airborne Detect and Avoid Radar) by maximizing transmitter power, waveform processing and through design of an all-passive cooling system (no forced air cooling) optimized for fixed and portable ground-based use.

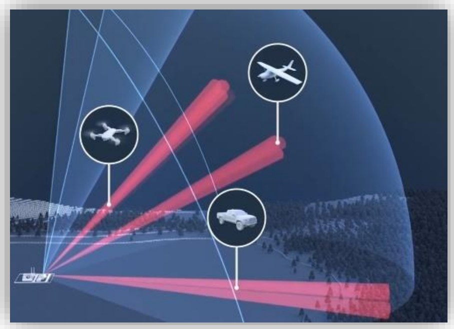
EchoGuard MESA Key benefits of true electronically scanning beam radar are:

1) Active SWT (Search While Track) of detected intruders with high accuracy and track retention
2) The EchoGuard beam scheduler intelligently allocates beam time on target to optimize tracking accuracy and search time while in the SWT mode.
3) Improved clutter suppression and false-alarm rejection
4) IMU-based self-stabilization to work with platform dynamics.
5) All-electronic architecture eliminates mechanical failure mechanisms.
6) Reduced false alarm rates for objects being tracked.
7) Dynamically reconfigurable Field of Regard (FoR) for changing system needs.



Traditional security radars are expensive and have largely focused on ground intruders such as walkers and land vehicles. The EchoGuard radar incorporates full electronic elevation and azimuth scanning adding the capability to detect and track in-coming airborne drone threats simultaneously while monitoring ground activity.

1.2 EchoGuard Radar Use Cases



If an ESA radar could be reduced to the size of a paperback book with COTS pricing, it would be used everywhere. Echodyne delivers this breakthrough with its innovations in software-defined radar technology. Echodyne radars can operate standalone or as part of a larger system. We work with solution integrators, defense contractors, and military and government agencies to ensure mission requirements are met to accurately track air and ground targets in real-world conditions at best-in-class ranges.

1.2.1 Counter-UAS Detection

EchoGuard is the ideal radar for counter-UAS site protection. With a large vertical field of view and fast update rates thanks to true 3D electronic beam steering, EchoGuard accurately detects, tracks, and classifies small UAS where it matters most - within 1 km of your protected site. It provides precise and reliable target location for putting eyes on target, cueing optical sensors, and directing mitigation responses.

With proven performance in live operations and in countless defense, federal, and private tests across diverse environments (urban, suburban, rural, maritime, and even airborne), EchoGuard has earned its place as the preferred C-UAS radar for dozens of counter-UAS system suppliers. Echodyne offers the counter-drone radar of choice for defense and homeland applications.

1.2.2 Border Security Radar

Unauthorized border crossings by ground, sea, or air threaten national security across the globe. Yesterday's fixed surveillance towers were large, expensive, and left vast expanses of borders unprotected. The portable kits were anything but portable.

Today's innovative autonomous towers benefit from Echodyne's 3D radar surveillance capabilities to anchor their sensor suite. Powerful radar data cues multi-spectral cameras to create real-time situational awareness of air, ground, and marine domains. The same powerful and highly portable radar on a tripod or vehicle acts as a robust and cost-effective force multiplier for field agents.

1.2.3 Base Security & Force Protection Radar

3D radar is an essential perimeter surveillance sensor for sensitive facilities and high-risk locations. EchoGuard's ultra-low SWaP-C, built-in interference mitigation, and extensive software-defined masking capabilities make it easy to network multiple radars around a single site or perimeter, delivering 3D perimeter surveillance with robust coverage and low false alarms.

Rich data output from the radar precisely cues EO/IR sensors for visual tracking and object confirmation, ensuring timely security response. Echodyne radars offer unrivaled data integration options for robust ground and air domain surveillance with extraordinary accuracy – all at commercial prices.

1.2.4 Critical Infrastructure

Comprehensive ground + airspace surveillance from one radar. Ideal for integrators and resellers for use with existing security systems. Rich data for systems integration and optical sensor slew-to-cue for "eyes on object". High-performance radar at commercial prices. Outperforms every other radar in its class. The new standard in affordable 3D security for critical infrastructure. Typical tracking ranges exceed all comparable radars. ESA performance at commercial prices.

1.2.5 Portable ISR Radar

Until now, high-performance 3D ESA radar was not feasible for portable ISR needs. But with its ultra-low SWaP and a rugged solid-state design, EchoGuard is a truly man-portable high-performance radar -- less than ten kilograms total system carry weight for ten hours of battery powered field use.

Whether deployed standalone or integrated with additional sensors (optical/thermal), EchoGuard's actionable radar data enhances ISR, acts as a force multiplier, and contributes to improved intelligence, surveillance, and reconnaissance.

1.2.6 Law Enforcement, Fire, Search and Rescue

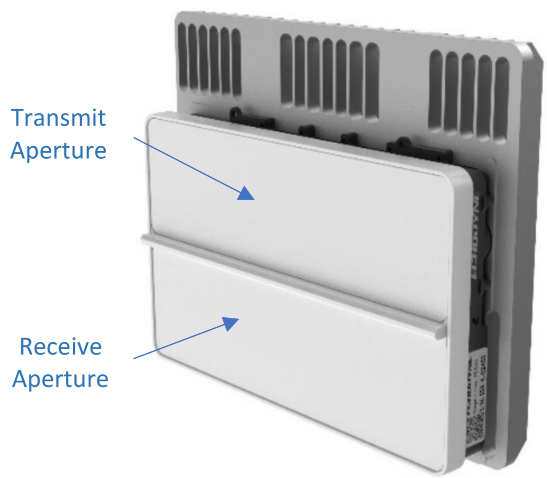
Robust temporary ground and airspace security is both necessary and possible. Whether ensuring clear airspace for first responders or protecting public events, radar can detect, track, and classify drones, and create a 3D evidence record needed for prosecution. Ideal for law enforcement, wildfire, and search and rescue missions. Proven at major sporting events for counter-drone security, Echodyne radars are rapidly deployable, all-weather, lightweight, solid-state, and low power, all while delivering superior performance.

2. PRODUCT PHYSICAL FEATURES

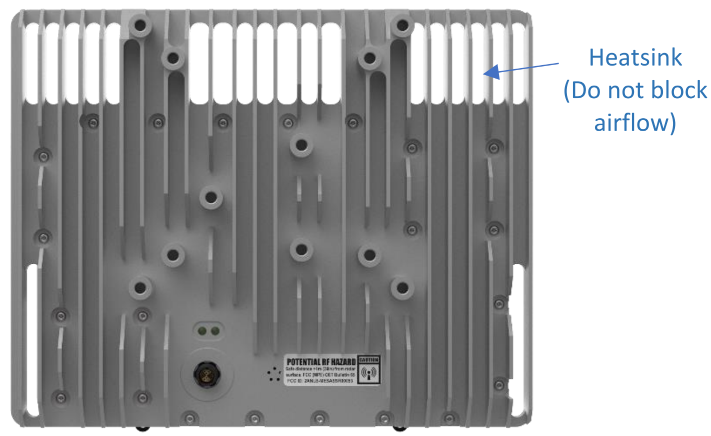
2.1 EchoGuard Radar – Front & Rear

The pictures below show the EchoGuard radar front and rear detail with the white radome protecting the top transmit and bottom receive antenna apertures which are aimed at the target region of interested (ROI).

FRONT (Radome Aperture)

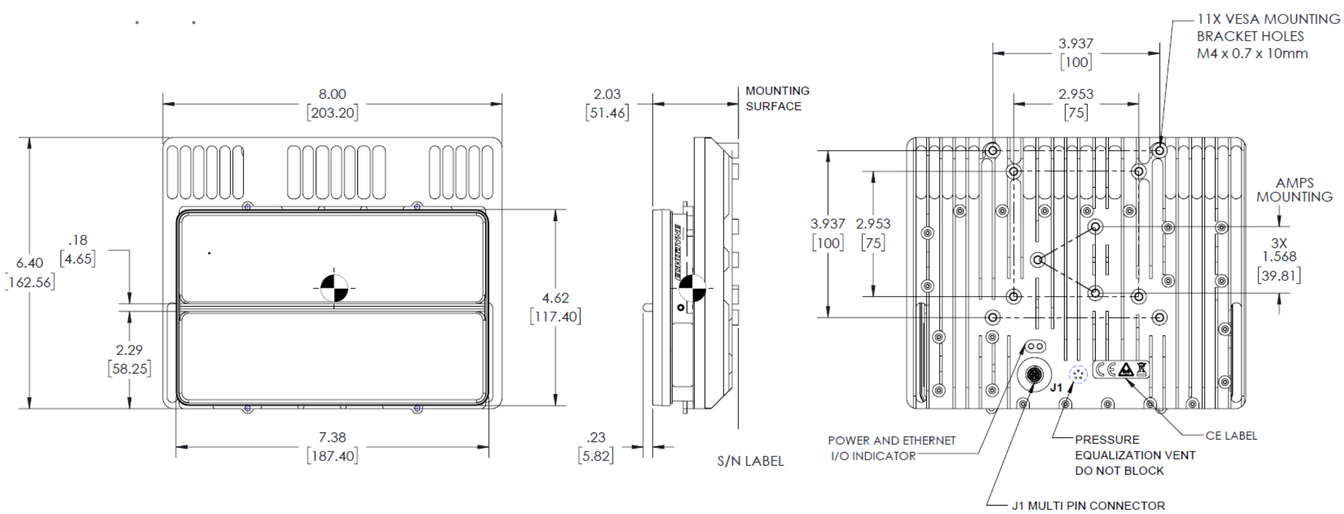


REAR (Heatsink mounting & I/O)



2.2 EchoGuard Radar – ICD

The picture below is an excerpt from the official Interface Control Drawing (ICD) for the EchoGuard International Radar p/n 700-0005-206-100 with dimensions shown in inches [millimeters].



WARNING: Only apply power and operate after the radar is properly installed and pointed at the area of interest to avoid inadvertent exposure to RF energy. Observed the 1 meter keep clear distance.

CAUTION: The radome surface is delicate and should be treated similar to a camera aperture, keeping protected from tools and other blunt or protruding objects.

CAUTION: The 11x M4 mounting bolts have a maximum torque rating of 10 in-lb. [1.3 Nm].

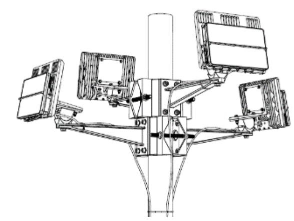
2.3 EchoGuard Radar System Components

Deploying an Echoguard radar to the field requires the typical system components shown below. Echodyne software and documentation is available on the secure Customer Portal. Contact support@echodyne.com for access as well as additional details regarding cabling, mounting solutions and software integration options.

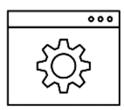
EchoGuard Radar

Radar Cable
2' [0.6m], 8' [2.4m] or 20' [6.1m]

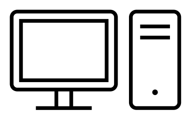
Mounting Hardware
(Purchased separately)



Off-Radar Software
(BNET, RadarUI, customer C2, etc.)



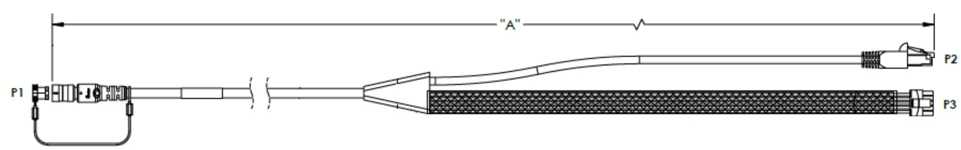
Command & Control (C2) PC
(Customer supplied)



DC Power Source – 24VDC
(Customer supplied, 50W/radar)

2.4 Radar Primary Power, Control & Data Cable

The single electrical port (J1) on the EchoGuard radar is a Fischer MiniMax IP-68 circular snap lock connector which mates with a custom EchoGuard cable. All DC power, radar data and command control is provided through this single connector which has a "Y" configuration shown below. Echodyne provides three standard lengths for this cable ("A" dimension = 2' [0.6m], 8' [2.4m] or 20' [6.1m]) as well as an unterminated 20' [6.1m] version.



The "Y" cable splits the 12-pin circular connector radar interface into a standard RJ-45 Gig-Ethernet on one connector and a MOLEX DC Power input connector on the other. The user may choose to either use the provided MOLEX connector and mate for DC Power prime input power or cut this off and direct wire to an alternate connector of choice. Any alternate connector chosen must support 24VDC and > 2.5 Amperes current rating (22 AWG wire or larger is recommended). The following table is intended as a reference for color codes and pinouts of the supplied "Y" cable assembly.

SIGNAL NAME	P1	WIRE	P2	WIRE	P3
BI_DD+	6	ORANGE TwPr4	7		
CTL1	2	YELLOW		ORANGE	3
BL-DB-	3	GREEN TwPr2	6		
CTL2	4	VIOLET		GREEN	4
DC INPUT	5	RED 24		RED	1
BL-DD-	1	GRAY TwPr4	8		
BL-DC-	7	CLEAR TwPr3	5		
BL-DC+	8	BLUE TwPr3	4		
DC RTN	9	BLACK 24		BLACK	2
BL-DB+	10	WHITE TwPr2	3		
BL-DA-	11	PINK TwPr1	2		
BL-DA+	12	BROWN TwPr1	1		
SHIELD	BODY	SHIELD	BODY	WHITE	5

3. KEY RADAR SPECIFICATIONS

EchoGuard International radar configuration SKUs:

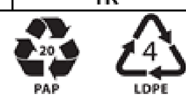
- **700-0005-206-100** (white radome, black chassis, silver heatsink)
- **700-0005-207-100** (white radome, black chassis, cold plate variant, contact for ICD)

Note: Specifications subject to change without notice.	
INTERFACES	
DC/Control Cable Assembly	The radar is powered and controlled through a single Fischer MiniMax IP-68 watertight snap lock circular connector and custom cable harness. Only the snap lock radar end (P1) is watertight. A cable assembly is provided with each radar and additional cables may be purchased as needed. It is intended that the user would route the non-watertight P2/P3 inside a watertight enclosure for C2 integration. P1 – (Radar-End) Snap Lock watertight 12 pin connector. P2 – (User End) standard RJ45 shielded non-watertight Gbit Ethernet P3 – (User End) Molex 43645-0500 5 socket contact connector for DC power and discrete digital control lines.
DC Power	DC Power is connected through the P3 Molex connector of the cable harness and is routed to the P1 radar interface connector. PIN 1 - RED Wire +VDC 22 AWG PIN 2 – BLACK Wire -VDC RTN 22 AWG Note reduced maximum Input Voltage for CE/International model. **Recommended DC power: +15 to +24 V_{DC} @ typically 45 Watts.** **Abs Max DC power: +12 to +25 V_{DC} @ 50 Watts** Note: Maximum current in harness and contacts is 5 Amperes. Current will vary as a function of the input voltage. Size the DC supply accordingly. EchoGuard Current Limit = 50 Watts/$V_{OPERATING}$ Power on Hot Standby (No Transmission) ≤ 7 Watts
Discrete Control Digital Lines	Discrete 3.3V TTL Control Wires PIN 3 – ORANGE – RESET_N (PIN2-BLK GND Hold 10 sec =Factory Reset) PIN 4 – GREEN – CTRL2 (Designed for future Use) PIN 5 – WHITE – Digital Shield Ground Note: These need not be connected at all in the base model radar. They should be taped off and insulated well to prevent damage. PIN 3 may be configured to reset the unit to factory configuration. Contact Echodyne Applications engineering for specific use case.
RF Transmit Power	Maximum RF power emission under all conditions < 4 watts. RF safe distance from aperture under operating conditions: >1m for FCC Maximum Human Exposure (MPE) per FCC Bulletin 65
PERFORMANCE	
Radar parameters	
Operation center frequency	24.05-24.25 GHz
Operating bandwidth	Baseline Configuration: Mode A1 (45MHz swept BW with 200uSec chirp – NTIA compliant Mask) Channel A1-A 24.0675 to 24.1125 GHz (Fc=24.09 GHz / 45MHz swept BW) Channel A1-B 24.1275 to 24.1725 GHz (Fc = 24.15 GHz / 45MHz swept BW) Channel A1-C 24.1875 to 24.2325 GHz (Fc = 24.21 GHz / 45MHz swept BW) Note: NTIA spectrum mask allows for about 15MHz overshoot on each edge.
Frequency Accuracy	± 10ppm (± 250kHz) including temperature and aging 8 years
Waveforms	FMCW 32 chirp CPI with 45MHz swept BW over 200uSec SAWTOOTH (default) with power blanking.
Transmitted Power	3.2 Watts CW (35 dBm) Blanking (~-50 dB) when not in use

	Transmitter only enabled during valid radar trigger event. Transmitter not enabled during BIT fault or bootup until issuing START
Aperture Characteristics	
Polarization	Linear, Horizontal
Cross-pol	Typically, 20 dB
AZ/EL (HPBW), typical	2° horizontal (E-plane, at broadside), 6° vertical (H-plane, at broadside) Note: Beam width increases 30-50% at FOV edges.
Field of regard Azimuth/Elevation	± 60° / ± 40°
Beam Step resolution/accuracy	2° Resolution, ≤1° pointing accuracy
Realized Gain at broadside	21 dBi typ. (safety absolute maximum gain of 22 dBi)
Gain average roll-off	2.0 dB typical over full field of regard
Side lobe level	Two-way radar Sidelobes Center (< ±40° Az or El) SLL -32 dB average Edges SLL -28 dB average
Next-beam buffer time	< 100 microsecs (serial write time)
Beam-to-beam transition time	< 1 microsecs (after enable)
Object Detection parameters	
Object RCS	-30 to +100 dBsm (Approximate User settable window – See RCS commands) 0dBSm @ >2500m @ 90% $P_D/10^{-6}$ P_{FA} Typical
Range	Minimum 20 meters, Maximum 5987 meters operational
Range Resolution	3.25 m typ.
Velocity Resolution	0.91 m/s typ.
Angular Resolution	±1° Az and ±3° El while in Search Mode, smaller for tracked targets
Search & Track	
Search	User configurable scan volume
Track acquisition	New tracks are acquired in < 1 sec
Track updates	5-10 updates /sec (for each track) depending upon Operation Mode
Max Tracks	20 simultaneous tracks dynamically allocated via i-SCAN
Modes	Search & Search-While-Track
General Physical	
External Finish	Anodized Aluminum Body Radome: 1mm polycarbonate with white/tan overpaint
Size (Packaged)	18.7cm x 16.2cm x 5.1cm
Weight (Packaged)	EchoGuard < 1250 grams fixed install natural convection (no-fans)
Mechanical Interface	EchoGuard has 75mm and 100mm square VESA mounting holes using standard M-4 screws. See – Mechanical ICD 700-0005-203
ENVIRONMENTAL	
Operational Temp	-40 ° C to 75 °C Continuous Operation
Storage Temp	-55 ° C to 95 °C (Non-Operational)
Humidity (operation)	< 95 % non-condensing
Moisture Resistance	Main Radar package is an IP67 moisture and dust protected package as delivered. It has a Gore vent gasket that supports air transport pressure changes
Fungus	None Specified
Salt Fog	None Specified
Sand & Dust	Tolerant with protective cap or connector attached.
MTBF	110,000 hours; per MIL-STD-217, Ground Fixed environment
Operational altitude	0-30,000 ft (0 to 9.1 km) AGL
Shock	None Specified
Vibration	Typical mounting on fixed structures requires no special mechanical isolation mounts. Care should be exercised with mount designs to avoid resonant modes in the 100-3000 Hz range with large deflections as this could potentially generate false Doppler signatures and impact angular pointing accuracy.
Prime Power	1. Maximum ripple provided to radar on prime power required to be less than 200 mV P-P 2. Ramp-Up Prime power voltage < 50 msec
ESD	Handle with normal sensitivity (Standard HBM)
Lightning	None Specified

4. REGULATORY & SAFETY NOTIFICATIONS

AT	BE	BG
CH	CY	CZ
DE	DK	EE
EL	ES	FI
FR	HR	HU
IE	IS	IT
LI	LT	LU
LV	MT	NL
NO	PL	PT
RO	SE	SI
SK	TR	UK(NI)



4.1 EU and UK Country Specific Spectrum Licensing Requirements

In accordance with 2014/53/EU Article 10(10), the above pictogram on the packaging indicates that the device has the following restrictions in the countries shown.

In each of the countries listed the EchoGuard radar **must** be licensed to operate in the 24.05-24.25 GHz frequency band. The user of the radar must apply to the relevant national telecommunications authority for a license covering one or more specific installations of the radar. Such a license may be referred to as an individual license, a regional license, a site license, a frequency authorization, etc. depending on the rules in the particular jurisdiction.

4.1.1 UK Specific Spectrum Licensing Requirements

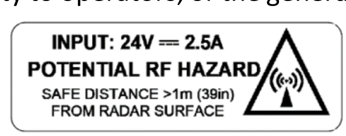
In the United Kingdom, the EchoGuard radar must be licensed in order to operate in the 24.05-24.25 GHz frequency band. The user of the radar must apply to OFCOM UK for a license covering one or more specific installations of the radar.

The user of the radar may contact Echodyne for advice and assistance in preparing a license application for a national telecommunications authority.

4.2 RF Radiated Emission Hazard

The EchoGuard International band radars have a primary operating frequency centered at 24.15 GHz with maximum transmit power under 4 watts. While the transmit power is like other low power radios that humans encounter (cellular phones, handheld radios, CB radios etc.) there is slightly more risk due to the focused beam of the radar. A focused beam with a nominal gain of 21 dBi and an absolute maximum gain of 22dBi (Factor of 160) multiplies the effective power radiated. To address this, Echodyne has reviewed the FCC Maximum Permissible Exposure (MPE) as described in FCC OEP Bulletin 65 and used the principles and guidelines to develop a conservative safe operating distance to recommend. This is exactly the process used by marine radar manufacturers to recommend safe operational distances for humans.

For safe operation, the radar should be in such a position to ensure closest proximity to operators, or the general population is greater than 1 meter (39 inches) radial arc over the 120˚ azimuth and 80˚ elevation scanning field of view. Do not transmit with radar and antenna when persons are within the MPE radius of the antenna. The MPE radius is the



minimum distance from the antenna axis that humans should maintain to avoid RF exposure higher than the allowable MPE level set by FCC.

CAUTION: It is the responsibility of the radar operator to ensure that the maximum permissible exposure limits as labeled as are observed at all times during radar transmission.

4.2.1 Declaration of Conformity

For International operation (non-US/FCC), EchoGuard MESA radars have an operating frequency centered at 24.15 GHz with maximum transmit power under 4 watts and an operation frequency band of 24.05 to 24.25 GHz with three sub-channels. For any questions regarding country availability and UKCA and CE Declaration of Conformity (DoC) documentation including translations, please contact Echodyne. The translated DoC for the country of destination will be included in the radar shipment.

4.2.2 EchoGuard International - Export Requirements

The US Commerce Department limits export of certain commodities to specific countries. Based on the product type, Echodyne has determined it is contained within the EAR Export Classification **ECCN #6A008.e** for export licensing. The applicable HS Code is 8526.10. For additional export & shipping information, please contact Echodyne.

4.3 Radar Interference

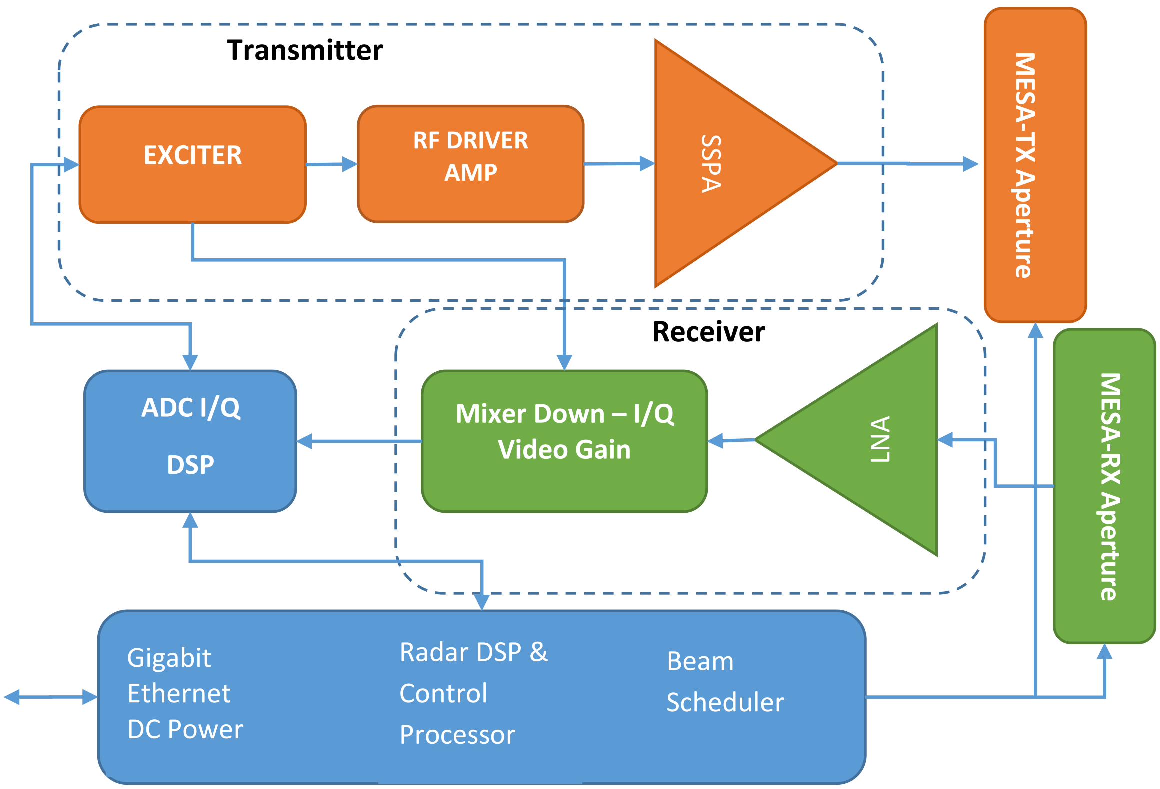
As with any RF device, the EchoGuard radar is subject to interference from nearby transmitters operating in the same frequency band. In the case of nearby EchoGuard radars within line of sight (LOS), a variety of built-in radar channelization options exist (frequency channels, time channels, PRISM coded channels) that enable deconfliction of operating radars to avoid any self-interference and resulting performance degradation.

For the case of non-cooperating RF transmitters in the vicinity and same frequency band, it is possible the radar will receive and demodulate those signals resulting in some degree of desensitization and/or spurious targets depending on the nature of the interference. The radar in this situation acts like an analog receiver with broad band interference serving to raise the received signal noise floor which can be monitored via the RVmap data ports or detection packets. In the case of narrow band in channel spectrum interference, these signals are not time aligned to the radar master oscillator and may cause spurious false detections rolling in range and angle through the radar field of regard.

Note: The radar is subject to in band (24.05 to 24.25 GHz) interference which can increase the noise floor and desensitize the radar or generate false detections. When operating and observing either an increase in the system noise floor or spurious target detections where no moving object exists, attempt to reposition the radar to remove a line-of-sight (LOS) link between interfering transmitter or select another frequency channel for radar operation.

5. RADAR ARCHITECTURE

The EchoGuard radar block diagram as illustrated below can provide insight into the basic radar architecture. Fundamentally this radar is a multi-chirp FMCW (Frequency Modulated Continuous Wave) radar that provides range and velocity information for each beam (look) direction. Range information from the delayed returned echo frequency spectrum is extracted from the first "Fast-Time" FFT (Fast Fourier Transform). Range rate is derived from the phase advance observed over multiple fast chirp cycles extracted from what is called the second or "Slow-Time" FFT. There are three main hardware sections of the radar: 1) Exciter Transmitter, 2) Receiver, 3) The Digital Controller and processor. The dual aperture architecture is classically referred to as Bi-Static since there are separate transmit and receive antenna. This separation provides greater than 60dB of TX to RX isolation allowing us to support simultaneous high-power CW transmission while maintaining a linear low noise figure receiver. The radar as delivered, has been fully tested and verified in our production synthetic target test chamber. This test system verifies the signal to noise ratio and detection of multiple objects at simulated velocity, ranges, and RCS levels over the entire radar field of regard, requiring no user calibration.



Radiating Apertures MESA-TX and RX – The Radar uses separate but identical MESA apertures for reception and transmission. Each aperture delivers a nominal gain of 21 dBi and has AZ/EL half power beam widths of 4°/12° respectively at bore sight. This results in a radar round trip half power effective beam width of nominally 2°/6° that is capable of scanning across 120° in azimuth and 80° of elevation. This phased array like performance is made possible by Echodyne's patented MESA technology. All possible antenna beam positions are pre-programed and verified requiring no user calibration.

Transmitter/Exciter – The transmitter is a solid-state balanced pair of PHEMT MMIC power amplifier devices set at a bias point to deliver 35dBm (3160mW) for EchoGuard. Transmit power is automatically blanked when radar is not being triggered to take data or when radar is stopped. Transmitter will also be disabled if the exciter is unlocked and reporting a BIT fault or if the control computer loses connection with the radar. To create the FMCW saw tooth radar waveform (chirp), an all-digital fractional N phase locked loop microchip is used to lock a high performance VCO to the system coherent reference crystal oscillator. This precisely controlled waveform generator drives the SSPA (Solid State Power Amplifier) and provides a second coherent sample to the receiver down-converter.

Receiver – The receiver consists of a single channel LNA (Low Noise Amplifier) followed by a high intercept balanced I/Q down-converter with video gain and filtering. The receiver is very robust against RF high power damage. First, the MESA antenna has a band-pass behavior with very high loss below 18GHz where most high-power emitters exist. Second, in-band reflected RF energy cannot damage the receiver until RX power exceeds +15dBm into the LNA. While our +35dBm transmitter is highly isolated from the receiver when radiating into free space, users are cautioned to maintain at least 1-meter safe distance from highly reflective surfaces to reduce risk of LNA damage. Following the down conversion, the I and Q signals are delivered to a precision balanced video gain chain that incorporates both high-pass and low-pass filter characteristics. The low-pass filter provides classic anti-aliasing while the high-pass filter blocks mixer DC-Offsets and prevents saturation from large close-range objects. The high-pass transfer function has a graceful R4 slope (-12dB Octave) creating a variable gain over the 0-200m range zone to reduce the effect of large-echo saturation at close ranges.

Digital Controller and Processer - The end user communicates with the radar via the fast TCP/IP Gbit Ethernet interface by selecting ports (described in a later section). The System on Chip (SoC) microprocessor parses commands, modes, and configures the user data stream selection. Once the radar is configured and triggered, all timing and control is managed using a synchronous FPGA (Field Programmable Gate Array) which aligns the sample timing with each radar waveform generation. Video I/Q Samples are delivered to the FPGA from the dual 14-bit analog-to-digital converters (ADCs). Dual FFT blocks process the I and Q data into a range velocity map and either package the data for delivery to the user or for further use in internal CFAR (Constant False Alarm Rate) detection and tracking algorithms. The radar processor also functions as the radar beam scheduler.

5.1 EchoGuard Scan Modes

The MESA radar can be pointed in a user-specified direction using an automated scan using either the MODE:SEARCH:START (Sequential raster scan defined FOV) or MODE:SWT:START commands (smart Search-While-Track algorithm).

At every beam pointing direction the MESA points to, called a 'beam step', the MESA collects a single set of radar data and then performs two types of data processing on the collected data set. The first type of data processing produces a RVmap (Range-Velocity Map) that represents the magnitude of the radar return from all ranges and radial-velocities observed in the current beam direction. The second type of data processing uses a CFAR (Constant False Alarm Rate) detector to identify the range and radial velocities of objects in the current RVmap.

In Search-While-Track mode, a third layer of data processing then correlates in space and time the detections produced from all beam steps as the radar scans the field of view to track distinct, persistent, intruders. Each tracked intruder has an associated ID and various properties are estimated about each of them.

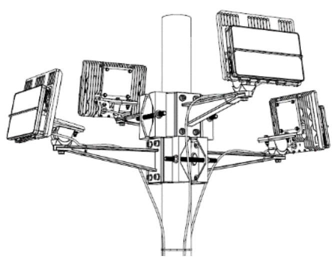
5.2 EchoGuard Channelization

The radar offers three (3) channelization methods (**Frequency**, **PRISM** and **TCM**) for mitigating the effects of radar self-interference when multiple EchoGuard radars are operated within line of sight (LOS) of each other. The signal from an in-band interfering radar will look just like a real target if the chirp start-times align to put the interference within the instrumented range. While normal radar operation requires transmitted energy to propagate to the target and back to the radar receiver, incurring greatly attenuated R^4 (where R=range) signal path losses along the way, nearby interfering radar energy need only propagate one-way (R^2 signal attenuation), resulting in potential self-generated interference false targets from distant radars without proper steps to deconflict through correct radar channel selection. By utilizing the 3 frequency channels, 4 PRISM channels and 4 TCM channels, <u>operators now have up to 48 channel combinations</u> (with supporting hardware) to address any realistic radar deployment density. Contact support@echodyne.com for advice on optimal channelization strategies and site-planning support.

6. RADAR INSTALLATION

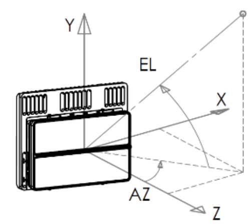
6.1 Physical Installation

The EchoGuard radar has a large backplate for natural convective cooling. Embedded in this backplate is a square VESA 75mm and VESA 100mm hole pattern for mounting brackets as well as an alternate three-hole AMP circular mounting pattern. Only one of these patterns need be used with standard industry brackets. Screws should be standard M4 x 0.7 x 10mm hardware and torqued to 1.3 Nm (10 in-lb.) for dry hardware (do not use thread lock liquid) in threaded steel inserts.



When mounting to a bracket or other physical installation, observe the coordinate system shown below (also laser engraved on top of radar) as it is tied to the internal coordinate reference system defined by Echodyne for beam scheduling and target tracking. The coordinate system defined for Echodyne radars is a standard Azimuth (AZ) / Elevation (EL) system with antenna coordinates defined in X/Y/Z coordinates. The official ICD provides a reference coordinate system anchoring the physical dimensions to the unit physical features. Also, for successful mounting, remember that the radar cable connector (J1, round, 12-pin Fischer connector) is towards the bottom of the radar and should be free and accessible for cable insertion and removal. The two LEDs should also be visible for confirming power and Ethernet link activity.

The radar should always be mounted with 0° roll (about the Z axis) and 0 to 20° pitch (about the X axis) depending on the target use case. Once mounted, the exact X, Y, Z radar geographic position (typically Latitude & Longitude in decimal degrees and Altitude in meters) should be recorded, typically measured via an external GPS instrument. Also, the final roll, pitch and yaw (compass heading) should also be measured and recording in degrees. For more information on mounting solutions and installation training, please contact support@echodyne.com.



6.2 Thermal Considerations

EchoGuard is designed to achieve maximum reliability with only natural convection in a fixed installed location without any forced air. It draws 45-50 Watts of DC wall power and must dissipate ~41-44W through thermal conduction to the environment. All internal circuits are thermally bonded to the T6061 aluminum housing and external heatsink.

The thermal path is through the case and heatsink fins to the ambient air. For maximum reliability, it is important to provide enough free air flow, such that the unit internal temperature is no more than 15-25C above ambient temperature. In a typical outdoor configuration with near still air (no moving air other than convection), at our specified maximum operating temperature of 75C, this will keep the power amplifier junction temperature under 140C, supporting an 8-10 year service life with margin.

CAUTION: The heatsink will become hot after prolonged operation in the sun. Allow to cool before touching.

6.3 DC Power Requirements

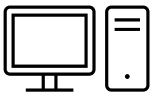
A 24VDC power supply capable of sourcing 50W (> 2.1A) per connected radar is required. The power supply should be sufficiently robust (operating temperature range and IP-rated sealing) to survive outdoor installation. We recommend 22 AWG (American Wire Gauge) stranded wire less than 8' (2.6m) from the power delivery point. If you require longer wiring runs, please size wire appropriately to support the voltage and current load to avoid unstable power to the radar and potential brownouts.

CAUTION: To avoid shock hazard in wet environments, observed a maximum voltage of 25VDC at all times.

7. BASIC OPERATION

To operate the radar, the following section shall be observed. For detailed radar configuration commands and advanced interface details including packet definitions, consult the Programmer's Manual.

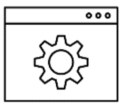
7.1 Command & Control Computer



A modern Intel i7 PC or equivalent should be obtained for controlling and interacting with the radar. The computer shall have a 100 Mbit or Gb (for RVmaps data) Ethernet connection for communicating with the radar. Depending on the nature of the deployment, sufficient hard disk space shall be provisioned to store the desired radar data products.

INFO: The radar does not support DHCP and has a fixed, default IP address at **169.254.1.10** which can be configured via software commands along with the subnet mask and gateway address.

7.2 Off-Radar Software

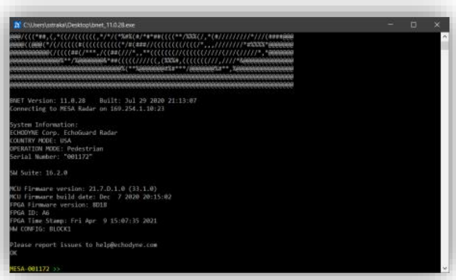


The EchoGuard radar is a purely digital 'bits in, bits out' TCP/IP configured sensor which is controlled remotely by a separate mission computer. This computer configures the radar with a variety of commands to customize operation (see Programmer's Manual), commands the radar to start operation and consumes the track, status, detection, and other data products to plot on a map or fuse with other sensor systems and end effectors pursuant to the mission objectives.

Echodyne provides a number of off-radar software solutions for interacting with the radar.

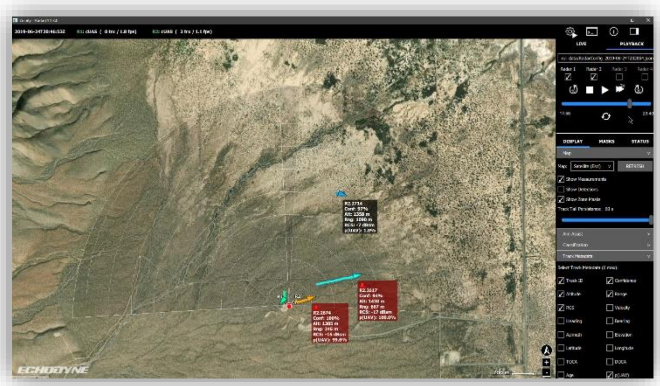
- **BNET** – Executable Command Line Interpreter (CLI) for Win10 & Linux
- **BNET** DLL – A dynamic linked C++ library for integration into customer C2 software solutions (Win10 & Linux)
- **RadarNet** – A headless radar network manager for automatically managed 12+ EchoGuard radars in a cooperative network.
- **Radar Update Utility –** A GUI for easily updating the radar embedded firmware over Ethernet connection (Win10 & Linux)
- **RadarUI –** A GUI for operating up to 4 EchoGuard radars and plotting the tracks on an interactive 2-D map.

BNET CLI/DLL
(Windows10 & Linux)



Update Utility
(Windows10 & Linux)

RadarUI
(Windows10 & Linux)



7.3 Power–on sequence and setup

1. With the not radar connected, set your DC power supply (if adjustable) to 24VDC and the current limit to 2.5A. This will ensure the unit has enough peak current to start properly but prevent damage to the cable assembly in the event of a problem such as short.
2. Next, make all connections shown in the diagram below. Connect the radar to cable harness P1 end while ensuring it snap locks into position at the correct clocking angle (white dot to white dot). Plug the RJ45 connector into your Ethernet switch or computer, plug the DC Power supply into the Molex connector RED/BLACK pins. Use a minimum of 22 AWG stranded wire for integration.
3. Turn "ON" the DC power source. As the unit boots up internally, the power will increase to about 10 Watts in IDLE state. It will hold here until given commands.
4. Within 60 seconds the radar should completely boot up and be ready to communicate through the Ethernet ports. Verify the LED indicator lights are illuminated and communicating with the port connection. The right-hand light should be steady. The right-hand light on confirms unit auto negotiation to GbE, left hand light indicates that the unit has negotiated to 100Mbit speed, and both LEDs illuminated indicate there has been a negotiation fault and is there is no communication to the radar. Please note that if no LEDs are lit, there has likely been an issue with the Ethernet connection or power supply. You can 'ping' the radar as well to confirm connection.
5. Proceed with control commands to query the radar. Execute the command line **BNET.exe** program provided and start with [*IDN?] which should respond with a message stack that includes serial number, firmware revision and MCU code revision.
6. You are now ready to begin operating your new radar, advancing to the RadarUI, RadarNet or other software integration solutions. Consult the appropriate software manual as necessary.

7.4 Basic Functional System Connections