Key Features and Benefits

The SEL-FLT Fault and Load Transmitter and the SEL-FLR Fault and Load Receiver act in unison as a wireless line sensor system for overhead distribution circuits. The sensor system provides fault detection and accurate load data to a centralized location, such as a SCADA system or outage management system (OMS). The line sensors and concentrator communicate via a purpose-built wireless protocol optimized for fault-monitoring applications.

➤ **Reliability Improvement.** Turn accurate fault data into actionable information to quickly identify fault locations and restore power.

➤ **Load Data Monitor.** Measure load current with a typical accuracy of 1 percent in near-real time for planning and making switching decisions.

➤ **High-Visibility Display.** Guide line crews to fault locations with the multifunctional LED display, which is visible from greater than 50 m (164 ft) during the daytime in any direction.

➤ **Simple Deployment.** Reduce installation risk to personnel with the user-friendly, lightweight design of the SEL-FLT. Installation requires just a single hot stick.

➤ **Expandable Network.** Grow the wireless sensor network as needed to meet schedules and availability. Start with a small deployment and increase the number of SEL-FLT devices to maximize coverage with as many as 168 devices connected to a single SEL-FLR.

➤ **Rugged Enclosure.** Monitor load and detect faults reliably in any application or environment with the outdoor-rated SEL-FLT compliant with the IEEE 495 standard.

➤ **Seamless System Integration.** Integrate the DNP3 protocol output easily into a SCADA network or OMS using any existing TCP/IP backhaul, including cellular.

➤ **Long Range.** Extend wireless communication as far as 16.1 km (10.0 mi) line-of-sight between the SEL-FLT and the SEL-FLR through use of the license-free 900 MHz frequency band.
➤ **Intuitive Interface.** Configure device settings and network settings through a secure web interface in the SEL-FLR.

➤ **Long Product Life.** Reduce ongoing maintenance with line-powering, over-the-air software updates, long product life, and a 10-year warranty.

## Functional Overview

![Functional Diagram](image)

**Figure 1** Functional Diagram

## Device Overview

**SEL-FLT**

![SEL-FLT Device Overview](image)

**Figure 2** SEL-FLT Device Overview
SEL-FLR

System Application Overview

Wide-Area Fault Indication and Load Monitoring

The Wireless Line Sensor System collects periodic load data and fault status and sends the information to a remote SCADA system via DNP3 messages. This allows utilities to pinpoint faulted branches on distribution circuits faster and monitor load fluctuations in a distribution circuit. An SEL-FLR located in a substation or a pole-mounted cabinet receives fault and load status from as many as 168 SEL-FLT sensors located as far as 16.1 km (10.0 mi) away. When a fault occurs, the SEL-FLT transmits a fault or outage status to the SEL-FLR. The SEL-FLR passes the sensor data through a wired or wireless network to the central SCADA master via DNP3 protocol. The SEL-FLT also reports average and peak load data as frequently as every five minutes for near-real-time load monitoring.
SEL-FLT Features

Durable, Lightweight Design

Quickly mount the SEL-FLT to overhead distribution conductors. The lightweight 3.6 lb design allows for simple installation using a single standard hot stick. The SEL-FLT clamp locks into place to ensure the sensor is securely installed.

The SEL-FLT is designed and tested to rigorous outdoor specifications of the IEEE 495-2007 standard, ensuring a long service life. The SEL-FLT is suited for a long service life and exceeds the IP-66 ingress protection rating.

Energy Harvesting

The SEL-FLT harvests required operating power from the overhead distribution line on which it is installed. With 3.5 A (rms) or greater load current, the SEL-FLT line sensor supports an operational life of greater than 15 years. In addition to energy harvesting, the SEL-FLT also has a backup battery system for power during extended outages and in low-current applications. The SEL-FLT flashes the LED display for 8 hours from harvested power during an outage before switching to the backup battery. The SEL-FLT supports greater than 1800 LED flash hours when powered by the backup battery.

LED Display

When a fault is detected and the system protection has locked out, the SEL-FLT illuminates six red and amber LEDs that rotate around the display to indicate a permanent fault.

Ultra-bright LEDs provide indications for different types of events and are visible from as far as 50 m (164 ft). The event display is configurable to display, and distinguish between, permanent faults, permanent outages, momentary faults, and momentary outages. The LED display automatically turns off when power is restored or after a display time-out.

Fault Identification

Locate faults quickly in any location on overhead distribution circuits. The SEL-FLT detects low-impedance fault currents through use of the self-adjusting AutoRANGER trip logic, which implements ten trip thresholds. The SEL-FLT continuously monitors load current and autoranges to the corresponding trip threshold (as shown in Figure 6). After detecting a fault, the SEL-FLT automatically determines if the event resulted in a protection operation. When protection locks out, a permanent fault event is registered and reported by exception (including the fault current magnitude up to 1600 A). Using the fault status reported by the SEL-FLT, personnel can pinpoint the fault location remotely.

Load Data

Monitor load current across an entire distribution circuit in near-real time with the SEL-FLT. The sensors continuously monitor system load current within ±(2.5 A + 2%) accuracy at every update interval. The SEL-FLT sends load data, such as average and peak rms values, to the SEL-FLR as frequently as every five minutes. The load alarms trigger alerts when the SEL-FLT measures load exceeding user-configurable thresholds.
SEL-FLR Features

Network Setup

Connect to the SEL-FLR webpage for easy network configuration. The webpage provides access to the sensors on the network, as well as settings for the sensors and the DNP3 server. Lock the device via the webpage to prevent further settings changes after deploying the SEL-FLR.

Network Statistics

Monitor all connected sensors from the SEL-FLR Dashboard webpages. Quickly view the status of connected sensors to identify faults, outages, errors, and alarm messages. Hovering over or selecting a sensor displays detailed device and radio statistics.

Over-the-Air Configuration and Updates

Upgrade deployed sensors by sending new firmware over-the-air to connected SEL-FLT sensors. You can also configure settings of in-service line sensors for specific applications without removing the sensors from the line. Users can modify specific units or make global changes to all devices connected to the network through use of the secure web interface.

Figure 7 SEL-FLR Dashboard Provides System Overview
## Accessories

### Table 1  SEL-FLT Orderable Accessories

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnet Tool</td>
<td>CRSRTT</td>
</tr>
<tr>
<td>Mini Current Loop</td>
<td>MCL120</td>
</tr>
</tbody>
</table>

### Table 2  SEL-FLR Orderable Accessories

<table>
<thead>
<tr>
<th>Description</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Feed Line</strong></td>
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</tr>
<tr>
<td>LMR-400 TNC Male to N Male Cable</td>
<td>SEL-C966</td>
</tr>
<tr>
<td>LMR-400 N Male to N Male Cable</td>
<td>SEL-C968</td>
</tr>
<tr>
<td>7/8” Heliax N Male to N Male Cable</td>
<td>SEL-C978</td>
</tr>
<tr>
<td>N Female to TNC Male Adapter</td>
<td>240-1809</td>
</tr>
<tr>
<td><strong>900 MHz Pole-Top Omnidirectional Antennas</strong></td>
<td></td>
</tr>
<tr>
<td>Low-Profile 3 dBi Omnidirectional, N Female Connector</td>
<td>235-0003</td>
</tr>
<tr>
<td>Vertical 7.15 dBi Omnidirectional, N Female Connector</td>
<td>235-0232</td>
</tr>
<tr>
<td>Vertical 9.15 dBi Omnidirectional, N Female Connector</td>
<td>235-0233</td>
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<tr>
<td><strong>900 MHz Base Station Omnidirectional Antennas</strong></td>
<td></td>
</tr>
<tr>
<td>Vertical 8.1 dBi Omnidirectional, N Female Connector</td>
<td>235-0234</td>
</tr>
<tr>
<td><strong>900 MHz Yagi Directional Antennas</strong></td>
<td></td>
</tr>
<tr>
<td>3-Element 8.5 dBi Yagi, N Female Connector</td>
<td>235-0221</td>
</tr>
<tr>
<td>5-Element 11.1 dBi Yagi, N Female Connector</td>
<td>235-0220</td>
</tr>
<tr>
<td>11-Element 14.1 dBi Yagi, N Female Connector</td>
<td>235-0222</td>
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<td><strong>900 MHz Indoor Antennas</strong></td>
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<tr>
<td>Indoor 20.32 cm (8 in) Omnidirectional, TNC Male Connector</td>
<td>235-0108</td>
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<tr>
<td><strong>Antenna Mounting Hardware</strong></td>
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<tr>
<td>Yagi Mount for 4.8 cm (1.9 in) Maximum Diameter Poles</td>
<td>Included With Yagi Antenna Purchase</td>
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<tr>
<td>Vertical Omnidirectional Mount for 35.56 cm (14 in) Maximum Diameter Poles</td>
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<tr>
<td>Yagi Mount for 35.56 cm (14 in) Maximum Diameter Poles</td>
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<td><strong>Power Supply</strong></td>
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<td>15 Vdc Power Supply</td>
<td>SEL-9322</td>
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<tr>
<td>15 Vdc Power Supply, 120–240 Vac Input With Tinned Leads</td>
<td>230-0604</td>
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<td><strong>Surge Protection</strong></td>
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<td>Radio Surge Protector With N Female Connectors</td>
<td>200-2004</td>
</tr>
<tr>
<td>In-Line Grounding Cable</td>
<td>240-0124</td>
</tr>
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</table>
Diagrams and Dimensions

Figure 8  SEL-FLT Diagram

Figure 9  SEL-FLR Diagram
Figure 10  SEL-FLT Dimensions
Figure 11 SEL-FLR Dimensions
SEL-FLT Specifications

Compliance
Designed and manufactured under an ISO 9001 certified quality management system

General
Operating Temperature Range: –40° to +85°C (–40° to +185°F)
Storage Temperature Range: –40° to +85°C (–40° to +185°F)
Operating Environment
Pollution Degree: 2
Relative Humidity: 5%–95%, noncondensing
Maximum Altitude: 2000 m (6562 ft)
Ingress Protection: IP-66
Clamp Range: 6.4–38.1 mm (0.25–1.50 in)
Dimensions: 159 x 192 x 252 mm (6.3 x 7.6 x 9.9 in)
Weight: 1.6 kg (3.6 lb)

System
Frequency Range: 50–60 Hz
Current Range: 3–600 A
Maximum Voltage: 69 kV (line-to-line)

Fault Detection
Trip Threshold Range: 25–1600 A
Fault Detection Accuracy: ±(2 A + 4%)
Maximum Fault Current: 25 kA for 10 cycles
Trip Response Time: 24 ms at 60 Hz (default)

Load Measurement
Current Range: 3–600 A
Measurement Accuracy:
±(0.25 A + 1%) from 5–600 A (typical)
±(2.5 A + 2%) from 5–600 A (maximum)
±3 A from 3–5 A (maximum)

Power
Minimum Continuous Operating Current: 3.5 A (AutoRange)
Battery Capacity: 19 Ah
Battery Shelf-Life: 20 years

Flash Hours
Harvested Power Flash Time: 8 hours (per outage)
Battery Flash Time: 1800 hours

Radio
Frequency Band: 902–928 MHz ISM band
Occupied Bandwidth: 850 kHz
Modulation: Digital modulation
Operating Mode: Point-to-multipoint
Power Output: 0.4 W (26 dBm)
Number of Channels: 25 non-overlapping channels
Sensitivity: –102 dBm ± 2 dB at 1% PER
Fixed Antenna Gain: –4 dBi
Polarization: Vertical
Link Data Rate: 62.5 kbps

Line-of-Sight Range: 16.1 km (10.0 mi)
Error Detection: 16-bit CRC
Encryption: AES 128-bit

Type Tests
Environmental Tests
Temperature Cycling: IEEE 495-2007
Test 4.4.1; 2 hours at –40°, +20°, and +85°C, 5 cycles
Trip Current: IEEE 495-2007
Test 4.4.9; –30°, +20°, and +70°C
Reset: IEEE 495-2007
Test 4.4.10; –30°, +20°, and +70°C
Short-Time Current: IEEE 495-2007
Test 4.4.7; 25 kA for 10 cycles
Adjacent Phase Immunity: IEEE 495-2007
Test 4.4.8; 25 kA at 18 inches
Time Current: IEEE 495-2007
Test 4.4.11; <1 ms
Class 2 Endurance
Class 2 Response
IEEE 495-2007
Test 4.4.6

Seismic Resistance: IEC 60255-21-3:1993
Class 2 (Quake Response)
IEEE 495-2007
Test 4.4.6

Salt Spray: IEEE 495-2007
Test 4.4.4
MIL-STD-810G: Method 509.5

Cold: IEC 60068-2-1:2007
–40°C, 16 hours
+85°C, 16 hours
Damp Heat, Cyclic: IEC 60068-2-30:2005
25°C to 55°C, 6 cycles, 93% relative humidity
Damp Heat, Steady State: IEC 60068-2-78: 2012
+40°C, 93% relative humidity
Outdoor Weathering: IEEE 495-2007
Test 4.4.3
ASTM G154-16

Ingress Protection: IP-66
Rain: MIL-STD-810G: Method 506.5
Procedure 1 Rain and Blowing Rain
Ice Build-Up: MIL-STD-810G: Method 521.4
Procedure 1
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<tr>
<th>Electromagnetic Compatibility Immunity</th>
<th>Electromagnetic Compatibility Emissions</th>
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<td>Electrostatic Discharge Immunity:</td>
<td>Radiated RF Emissions:</td>
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<tr>
<td>IEC 60255-26:2013</td>
<td>IEC 60255-26:2013</td>
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<td>Severity Level 4</td>
<td>FCC Part 15.247; ICES-001; RSS-210</td>
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<td>8 kV contact discharge</td>
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<td>15 kV air discharge</td>
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<td>8 kV contact discharge</td>
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<td>15 kV air discharge</td>
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<td>Severity Level 3</td>
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<td>15 kV air discharge</td>
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<td>Radiated RF Immunity:</td>
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<td>EN 60255-26:2013</td>
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<td>10 V/m</td>
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<td>35 V/m</td>
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<tr>
<td>1000 A/m for 3 seconds</td>
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</tr>
<tr>
<td>100 A/m for 1 minute</td>
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<tr>
<td>IEC 61000-4-8:2009</td>
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<tr>
<td>1000 A/m for 3 seconds</td>
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<tr>
<td>100 A/m for 1 minute</td>
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<tr>
<td>Pulse Magnetic Field Immunity:</td>
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<td>IEC 61000-4-9:2016</td>
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<td>1000 A/m</td>
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<tr>
<td>Damped Oscillatory Magnetic Field Immunity:</td>
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<tr>
<td>IEC 61000-4-10:2016</td>
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<tr>
<td>100 A/m</td>
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</tbody>
</table>

**Regulatory Compliance**

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions:

1. This device may not cause harmful interference, and
2. This device must accept any interference received, including interference that may cause undesired operation.

FCC Part 15, Class A; ICES-003

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment.

This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.

Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Section 15.21

User’s manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.
### SEL-FLR Specifications

**Compliance**

- Designed and manufactured under an ISO 9001 certified quality management system

**General**

- **Temperature Range:** –40° to +85°C (–40° to +185°F) per IEC 60068-2-1 and 60068-2-2
- **Pollution Degree:** 2
- **Relative Humidity:** 5%–95%, noncondensing
- **Maximum Altitude:** 2000 m (6562 ft)
- **Dimensions:** 216 mm x 165.1 mm x 44.5 mm (8.5 in x 6.5 in x 1.75 in)
- **Weight:** 1 kg (2.2 lb)
- **RF Connector:** TNC
- **Supported Web Browser:** Google Chrome

**Communications (Ethernet)**

- **Ports:** 2 rear, 1 front
- **Data Rate:** 10/100 Mbps
- **Rear Connectors:** RJ45
- **Standard:** IEEE 802.3

**Power Supply**

- **Input Voltage Range:** 9–30 Vdc
- **Power Consumption:** <10 W

**Radio**

- **Frequency Band:** 902–928 MHz ISM band
- **Occupied Bandwidth:** 850 kHz
- **Modulation:** Digital modulation 2-FSK
- **Operating Mode:** Point-to-multipoint
- **Power Output:** 0.4 W (26 dBm)
- **Maximum Allowed Antenna Gain:** 9.15 dBi (Omni)
- **Number of Channels:** 25, non-overlapping
- **Sensitivity:** –102 dBm ± 2 dB at 1% PER
- **Polarization:** Vertical
- **Link Data Rate:** 62.5 kbps
- **Line-of-Sight Range:** 16.1 km (10.0 mi)
- **Error Detection:** 16-bit CRC
- **Encryption:** AES 128-bit

**Alarm Output**

- **Rated Operational Voltage:** 24–250 Vdc
- **Contact Protection:** 300 Vdc, MOV-protected
- **Continuous Carry:** 2 A
- **Pickup Time:** ≤8 ms typical
- **Dropout Time:** ≤8 ms typical

**Type Tests**

- **Communications Equipment Tests**
  - **IEEE 1613-2009**
  - **Class 1**
- **Power Frequency Disturbances:** IEC 61850-3:2002

**Environmental Tests**

- **Vibration Resistance:** IEC 60255-21-1:1998
  - Class 2 Endurance
  - Class 2 Response
- **Shock and Bump Resistance:** IEC 60255-21-2:1998
  - Class 1 Shock Withstand
  - Class 1 Bump
  - Class 2 Shock Response
- **Seismic Resistance:** IEC 60255-21-3:1993
  - Class 2 (Quake Response)
- **Cold:** IEC 60068-2-1:2007
  - –40°C, 16 hours
- **Damp Heat, Cyclic:** IEC 60068-2-30:2005
  - 25° to 55°C, 6 cycles, 95% relative humidity
- **Dry Heat:** IEC 60068-2-2:2007
  - +85°C, 16 hours

**Safety**

- **Measuring Relays and Protection Equipment:** IEC 60255-27:2013
  - Power Supply: 3100 Vdc
  - Alarm Contact: 2500 Vac
  - Ethernet Ports: 1500 Vac
- **Insulation Coordination:** IEEE C37.90-2005
- **Dielectric (HiPot) Severity Level:**
  - Power Supply: 3100 Vdc
  - Alarm Contact: 2500 Vac
  - Ethernet Ports: 1500 Vac
- **Impulse Severity Level:** 5 J; ±5 kV, 1.2/50 ms
  - 2.4 kV on Ethernet Port

**Electromagnetic Compatibility Immunity Tests**

- **Electrostatic Discharge Immunity:** IEC 60255-26:2013
  - Severity Level 4
  - 8 kV contact discharge
  - 15 kV air discharge
- **Conducted RF Immunity:** IEC 60255-26:2013
  - 10 Vrms
  - 10 Vrms
- **Radiated RF Immunity:** EN 60255-26:2013
  - 10 V/m
  - 10 V/m
  - 10 V/m
- **Electrical Fast Transient Burst Immunity:**
  - 4 kV @ 5.0 kHz for power port
  - 2 kV @ 5.0 kHz for communications ports
- **Power Frequency Magnetic Field Immunity:**
  - 1000 A/m for 3 seconds
  - 100 A/m for 1 minute
  - 1000 A/m for 3 seconds
  - 100 A/m for 1 minute
IEC 61000-4-11:2004
IEC 61000-4-17:1999+A1:2001
+A2:2008
IEC 61000-4-9:2000

Surge Withstand Capability Immunity:
IEC 60255-26:2013

2.5 kV common mode
1 kV differential mode
IEC 61000-4-18:2006+A1:2010
2.5 kV common mode
1 kV differential mode
IEEE C37.90.1-2012
2.5 kV oscillatory
4 kV fast transient

Electromagnetic Compatibility Emissions

Radiated RF Emissions: IEC 60255-26:2013
FCC Part 15.247; ICES-001; RSS-210

Regulatory Compliance

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

FCC Part 15, Class A; ICES-003

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment.

This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications.

Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Section 15.21

User’s manual for an intentional or unintentional radiator shall caution the user that changes or modifications not expressly approved by the party responsible for compliance could void the user’s authority to operate the equipment.
Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com