SEL-FT50/SEL-FR12
Fault Transmitter and Receiver System

Accelerate Tripping, Speed Up Restoration, and Improve Safety on Distribution Feeders

SEL-RP50 not available in all regions

need new photo

Major Features and Benefits

The SEL-FT50/SEL-FR12 Fault Transmitter and Receiver System speeds up distribution-protection schemes by detecting and transmitting distribution feeder fault information to recloser controls or relays. Install the SEL-FT50 Fault Transmitters on laterals, branches, and the main line to broadcast fault status to one or more SEL-FR12 Fault Receivers. The SEL-FR12 communicates the fault data through MIRRORED BITS® communications to a relay or recloser control within 6 ms.

- **Real-Time Distribution Fault Detection.** Identify the faulted line segment with fault detection and low-latency communication while a fault is still active; for use in protection schemes.
- **Enhanced Protection.** Make real-time changes to the protection strategy based on information from the faulted distribution-line segment.
- **Improved Selectivity.** Trip a main feeder or branch recloser only when necessary. Avoid unnecessary entire-feeder outages.
- **Customized Reclosing Strategies.** Block or enable reclosing for specific line segments.
- **Improved Power Quality, Reduced System Stress, Limited Equipment Damage, and Enhanced Safety.** Leverage faulted feeder status to better coordinate between protective elements, leading to faster trip times.
- **Easy Operation.** Configure the fault transmitters and receiver without additional software.
- **SEL-RP50 Fault Repeaters facilitate SEL-FT50 installations in locations where line-of-sight might be obscured by terrain, trees, or buildings.**
- **No Batteries.** Power the SEL-FT50 and SEL-RP50 directly from line current.

➤ **Easy Installation.** Install the SEL-FT50 and SEL-RP50 on live lines by using familiar line tools and techniques.

➤ **Flexible Integration.** Install the SEL-FT50/SEL-FR12 system in an existing relay protection system.

Functional Overview

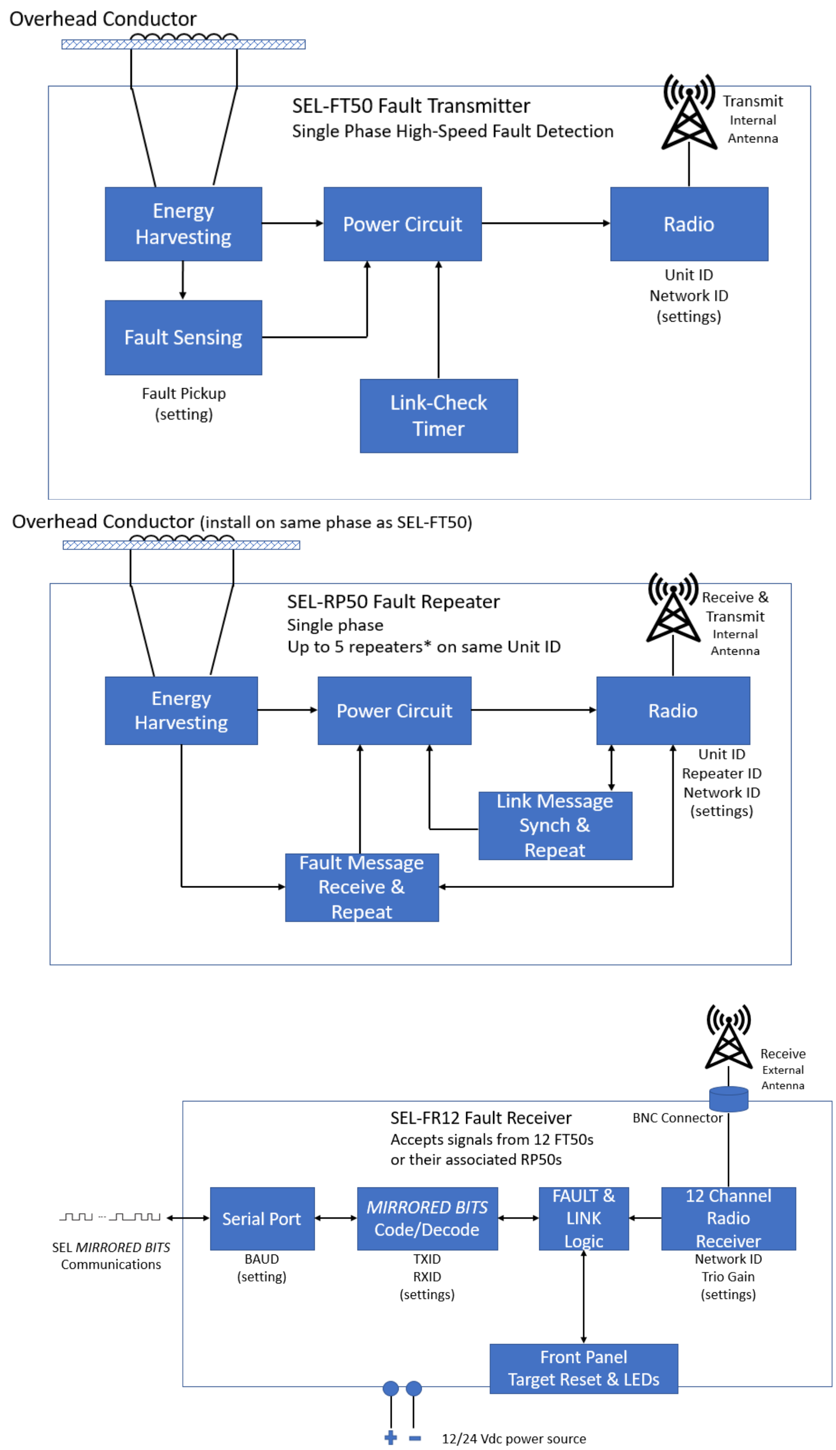


Figure 1 SEL-FT50, SEL-RP50, and SEL-FR12 System Overview -- need updated drawing

The SEL-FT50 and SEL-FR12 contain subsystems outlined in the upper and lower portion of *Figure 1*, respectively.

NOTE: Systems with SEL-FT50s manufactured before May 2021 only support one SEL-RP50 per SEL-FT50. See *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54* for required settings.

The SEL-RP50, outlined in the center portion of *Figure 1*, is available in certain markets. Installing one or more SEL-RP50s per SEL-FT50 can mitigate obstructions that otherwise compromise the radio path.

The SEL-FT50/SEL-FR12 system consists of as many as 12 SEL-FT50 Fault Transmitters and 1 SEL-FR12 Fault Receiver. The SEL-FT50 is mounted on distribution conductors with voltages as high as 38 kV. The SEL-FR12 is mounted in a recloser control cabinet or in a substation control house.

When one or more SEL-FT50 Fault Transmitters detect a fault, they send a wireless signal to the SEL-FR12. The SEL-FR12 transfers the received signal to the recloser control or relay via MIRRORED BITS communications in as little as 6 ms. The recloser control uses the fault information to make protection or relay decisions.

To monitor the health of the system, the SEL-FT50 Fault Transmitters periodically send communication link-check messages to the SEL-FR12 to indicate their status.

Each SEL-RP50 Fault Repeater forwards fault and link messages from one SEL-FT50. Up to five SEL-RP50s can be installed in a row with proper settings, and must be installed on the same phase conductor for proper operation in low current conditions. The SEL-RP50s will usually be installed in sets of three, one per phase.

The SEL-FR12 recognizes messages coming directly from SEL-RP50s and/or indirectly via SEL-RP50s.

System Overview

Figure 2 provides an overview of the SEL-FT50/SEL-FR12 system and illustrates how to apply it across a distribution power system.

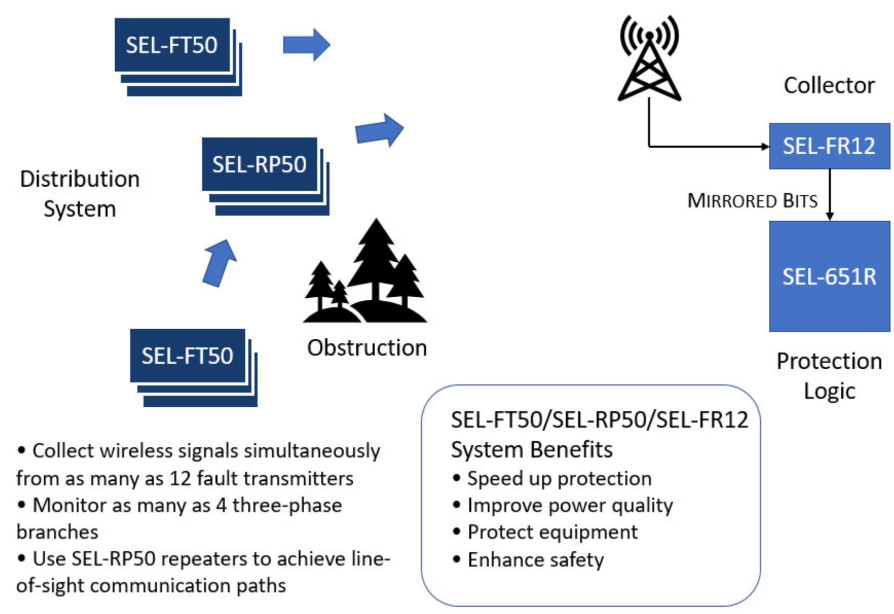


Figure 2 SEL-FT50/SEL-FR12 System -- **need updated drawing**

The SEL-FT50/SEL-FR12 system components are easy to use, and they contain many powerful and innovative features. Use programmable logic in the SEL-651R or in connected relays to incorporate the new protection capabilities and achieve the benefits shown in *Figure 2*.

NOTE: The SEL-RP50 is not available in all markets. See *Table 13*.

Figure 3 depicts the key components of the FT50-0001/FT50-0003/FT50-0005/FT50-0006 models. The other product variants FT50-0004/FT50-0007 have identical interior features and similar exterior features.

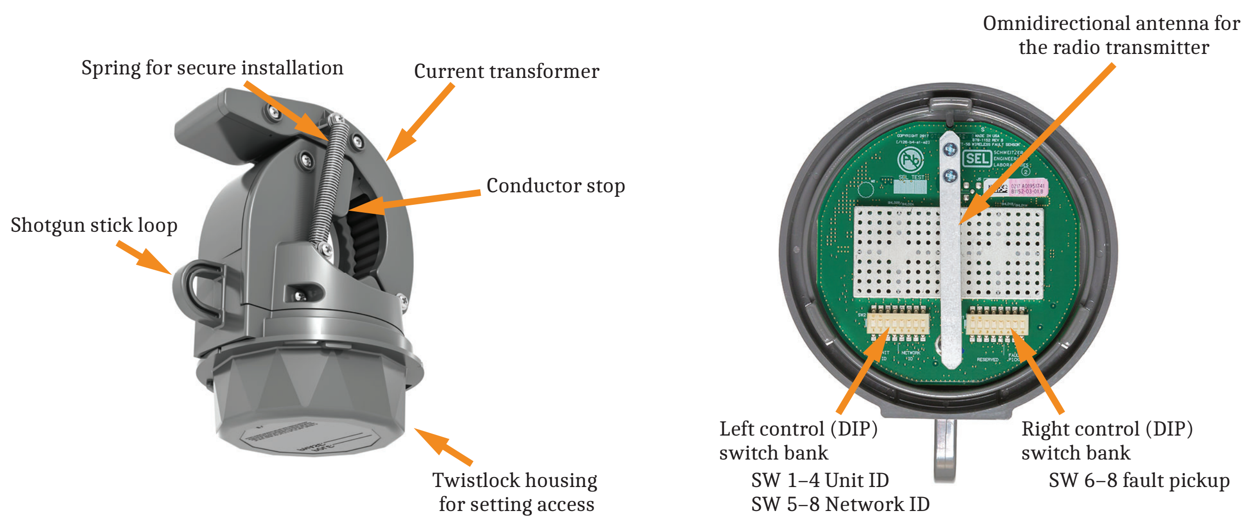
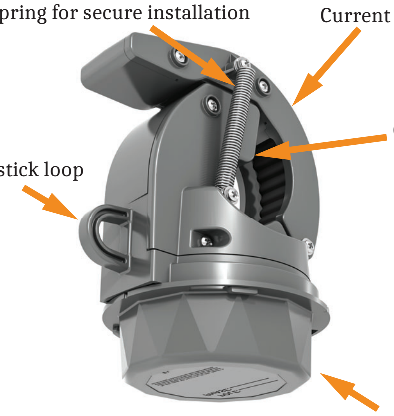


Figure 3 SEL-FT50 Overview

Each SEL-FT50 mounts onto and monitors the line current on one phase. When a fault occurs, the SEL-FT50 transmits a high-speed wireless signal to influence protection decisions. Control (DIP) switches inside the transmitter allow easy selection of unit and Network IDs. No batteries are needed because the SEL-FT50 is powered by line current.

In applications where trees, buildings, or terrain could block the line-of-sight path between the SEL-FT50 and SEL-FR12 antenna, one or more SEL-RP50 Fault Repeaters can be installed to forward signals that might otherwise be blocked. *Figure 4* shows the exterior and interior features of the SEL-RP50.



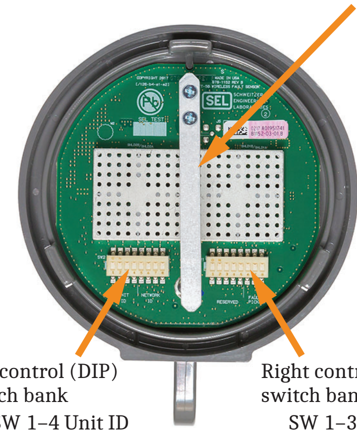


Figure 4 SEL-RP50 Overview

NOTE: The SEL-RP50 is a node in the wireless link between the SEL-FT50 and the SEL-FR12. The SEL-RP50 receives fault and link messages, modifies the message by attaching identifier and diagnostic data, then transmits this message to the next device in the link (e.g., another SEL-RP50 or SEL-FR12).

Each SEL-RP50 mounts onto and harvests energy from one phase. The SEL-RP50 Unit ID and Network ID DIP switch selections must be set the same as the companion SEL-FT50 or SEL-RP50s, and mounted on the same electrical phase. Like the SEL-FT50, for three-phase systems the SEL-RP50s will normally be installed in groups of three. Up to five SEL-RP50 (sites) may be used for each SEL-FT50 with appropriate Repeater ID selections. See *Technical Support on page 57* for details and examples on SEL-RP50 deployment. No batteries are needed because the SEL-RP50 is powered by line current. Each SEL-RP50 site typically adds up to 1 ms to the fault response time as seen by the SEL-FR12.

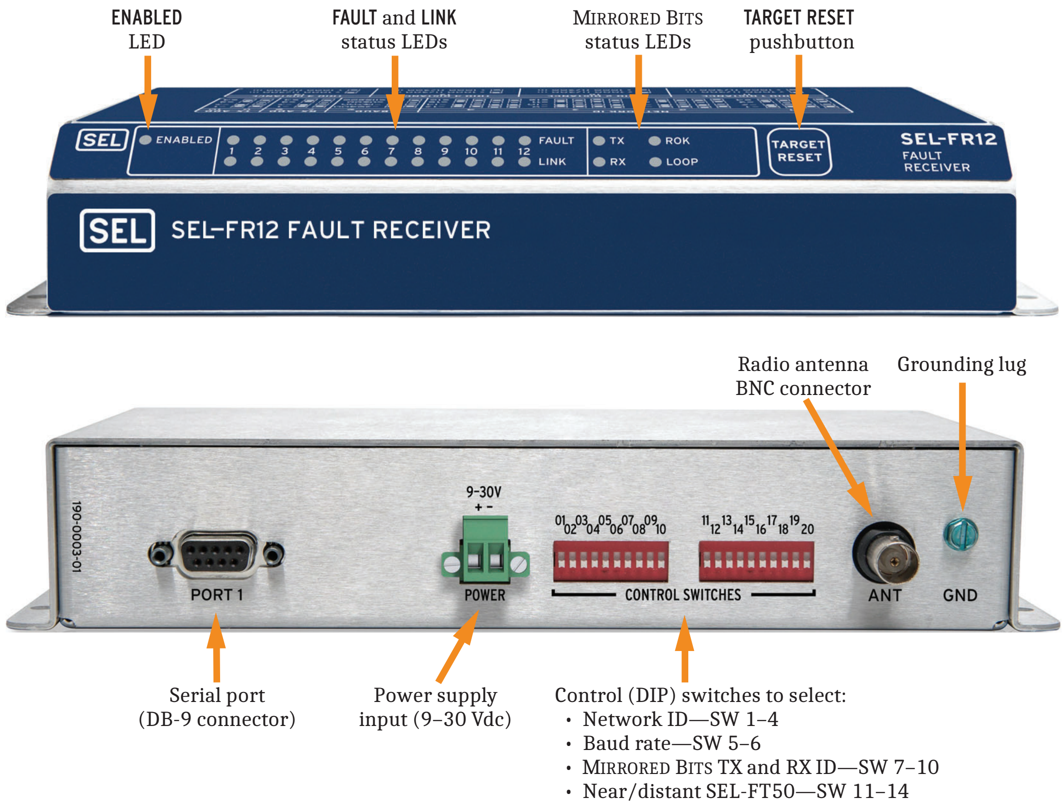


Figure 5 SEL-FR12 Overview

The SEL-FR12 collects wireless signals simultaneously from as many as 12 SEL-FT50 Fault Transmitters (enough for 4 three-phase installations). The SEL-FR12 reports faults to a relay or recloser control in less than 6 ms via MIRRORED BITS. The SEL-FR12 HMI contains 29 LEDs and 1 pushbutton, as shown in *Figure 5*.

NOTE: The **ENABLED** LED operation changes during diagnostic modes (see *Receive Signal Strength Indicator on page 26* and *Read Settings on page 30*).

- The **ENABLED** LED illuminates green when the SEL-FR12 is turned on and operational. The **ENABLED** LED flashes when the SEL-FR12 is in one of the diagnostic modes listed.
- The 12 **FAULT** LEDs (red, one per Unit ID) illuminate after the SEL-FR12 receives a Fault message from the associated SEL-FT50. These LEDs have a latching behavior so that once set, they remain on until reset by the **TARGET RESET** pushbutton or via MIRRORED BITS command.
- The 12 **LINK** LEDs (green, one per Unit ID) have a tristate operation:
  - **LINK** LEDs are initially off when the SEL-FR12 is turned on or after it receives a clear link status command via MIRRORED BITS.
  - **LINK** LEDs illuminate when the SEL-FR12 receives consecutive Link messages or one Fault message from the associated SEL-FT50. These LEDs have a delayed dropout behavior. Once illuminated, they remain illuminated as long as Link signals are periodically received.
  - **LINK** LEDs begin to flash after one minute elapses without receipt of a Link message for the associated Unit ID. When Link or Fault signals resume, the **LINK** LED stops flashing and stays illuminated once again.

NOTE: The SEL-FR12 works identically with systems that include SEL-RP50s.

- ➤ The **ROK**, **TX**, **RX** (green), and **LOOP** (red) LEDs indicate MIRRORED BITS status and activity. The **ROK** LED illuminates when MIRRORED BITS data exchange is successful.
- ➤ The **TARGET RESET** pushbutton resets the **FAULT** LEDs. Press and hold the pushbutton to illuminate all HMI LEDs (lamp test function).

Table 1 Target and Status LED Definitions[a]

LED (Color)	Off	Flashing	On	Reset Methods
FAULT (red) target	No fault signal has been received from the corresponding Unit ID since the last reset.	Not applicable.	The SEL-FR12 received a fault signal from the corresponding Unit ID since the last reset.	Manual—resets via the TARGET RESET pushbutton. Remote—resets via MIRRORED BITS.
LINK (green) status	The SEL-FR12 has not detected an SEL-FT50 with the corresponding Unit ID since initialization. This learning feature keeps unused LINK LEDs turned off.	The SEL-FR12 is not presently receiving signals from the previously learned Unit ID, indicating that an SEL-FT50 is not harvesting energy during low-current conditions or an outage.	The SEL-FR12 has received signals from the corresponding Unit ID within the last minute, indicating that the SEL-FT50 is receiving minimum radio link active current.	Automatic—learning mode resets automatically after the SEL-FR12 turns on. Remote—resets via MIRRORED BITS.

[a] The FAULT and LINK LED operation changes during RSSI measurement mode and Read Settings mode (see *Receive Signal Strength Indicator on page 26* and *Read Settings on page 30*).

Application Examples

Collect Fault Information From Remote Branches

A traditional recloser control or substation circuit breaker must be coordinated with the other protective devices on a distribution feeder, including fuses on downstream line segments. On the sample feeder in *Figure 6*, the recloser control or substation relay cannot distinguish one segment from another.

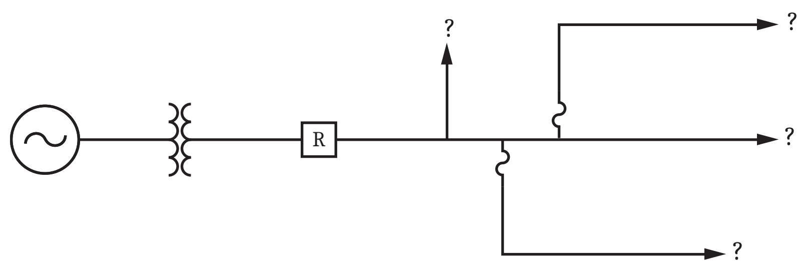


Figure 6 Typical Recloser Visibility

The SEL-FT50/SEL-FR12 system offers increased visibility to a recloser control by providing fault status from locations up to 400 m (0.25 miles) with line-of-sight. *Figure 7* illustrates how this allows the recloser control to see faults on individual branches, including locations where it is not economically feasible to install a relay or recloser. Each SEL-FT50 label in *Figure 7* represents three SEL-FT50 Fault Transmitters, one per phase.

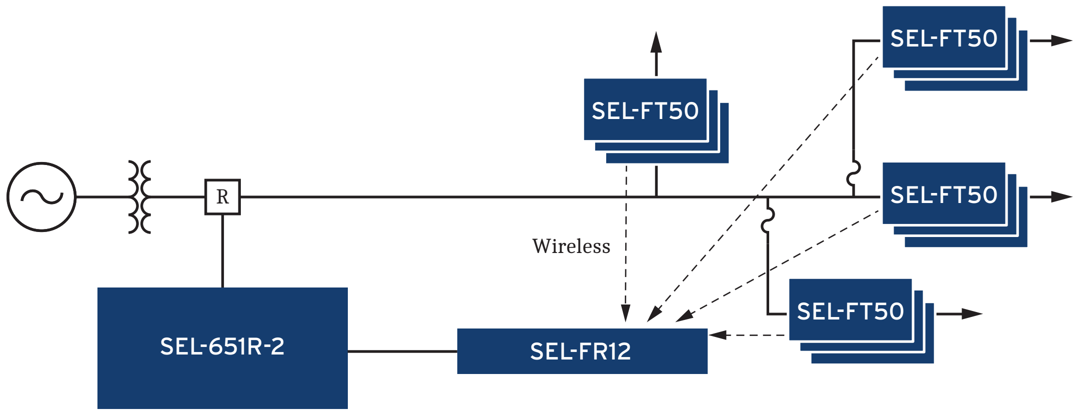


Figure 7 Recloser Communication With Fault Transmitters

Each SEL-FT50 monitors line current and instantly transmits a wireless signal when an overcurrent (fault) condition occurs. The companion SEL-FR12 receives and aggregates fault data from as many as 12 SEL-FT50 Fault Transmitters. Upon detecting a fault indication signal, the SEL-FR12 communicates the fault information to the host SEL-651R recloser control, or other SEL protective relay, by using MIRRORED BITS communications.

The SEL-FT50/SEL-FR12 system allows the protective relay or recloser control to make intelligent decisions by using high-speed fault information from remote locations.

Improve Fuse Coordination

In a radial distribution system, there are two main schemes that control fuse coordination: fuse-saving and fuse-blowing (also called trip-saving). Each of these schemes has shortcomings that you can address with the SEL-FT50/SEL-FR12 system.

Figure 8 gives a representation of a typical time-overcurrent coordination graph.

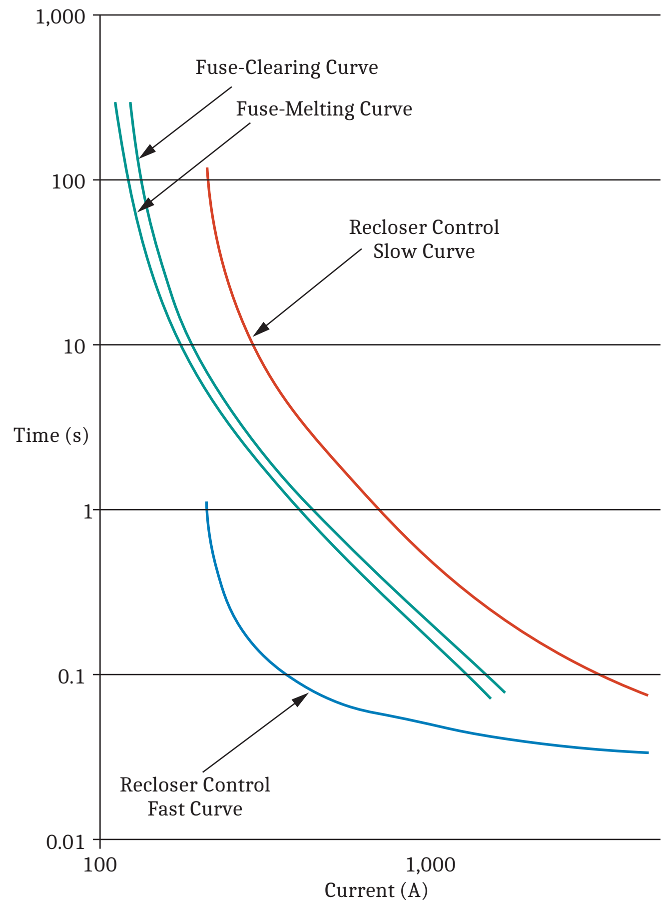


Figure 8 Example Time-Overcurrent Element Coordination

Fuse-Blowing Scheme Shortcomings

For a radial distribution system, the goal of the fuse-blowing scheme is to minimize the number of customers exposed to an interruption. The scheme accomplishes this by allowing a fuse to clear a given fault. The recloser only trips for faults that are not protected by a fuse. This scheme is sometimes called a trip-saving or fuse-blowing scheme because the recloser only trips when absolutely necessary.

Refer to *Figure 8* for the recloser control time-overcurrent element slow curve (shown in red). This curve must coordinate with the highest-rated fuse size present on the system, which is shown in green. An intentional coordination margin allows for prefault load and variances in fuse construction.

For faults on sections of the feeder that are not fuse-protected, the recloser must still implement this intentional coordination margin. The recloser control cannot determine which downstream branch the fault is on and assumes that the fault will be cleared by a fuse. *Figure 9* shows an example of a main line feeder and a fused lateral without a fuse. For a fault on the main line, the recloser control will wait before using the slow curve to clear the fault (see *Figure 8*). For a fault on the main line, the recloser control delays tripping unnecessarily because there is no fuse present.

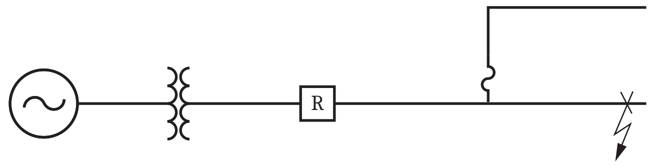
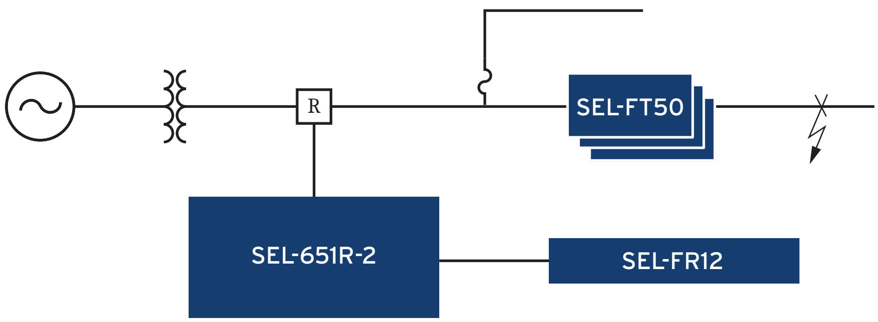


Figure 9 Fault on Unfused Tap

Improve Fuse-Blowing Schemes With the Fault Transmitter and Receiver System

With the SEL-FT50/SEL-FR12 system installed as shown in *Figure 10*, the recloser control receives an indication whenever a fault is on the unfused branch. With this information, if a fault occurs on the unfused line section, the recloser control can trip instantaneously instead of waiting for the fuse delay.

In *Figure 10*, the unfused tap is monitored by a set of SEL-FT50 Fault Transmitters (one for each phase), one SEL-FR12, and one SEL-651R. The SEL-FR12 is connected to the SEL-651R via a serial port.



When the fault is on the unfused branch, the recloser trips without fuse-coordination delay.

Figure 10 SEL-FT50 on Unfused Tap

When using the SEL-FT50/SEL-FR12 system, the SEL-651R knows when a fault occurs on the unfused tap because one or more of the SEL-FT50 Fault Transmitters detect the fault current and send the fault status to the SEL-FR12, which then conveys the information to the recloser control.

The SEL-651R settings replace or modify the curve behavior while the fault is happening. In the example fault shown in *Figure 10*, the recloser control enables the recloser control fast curve (see *Figure 8*). Compare this to when a fault is on the same unfused line section but the recloser control does not know it. The recloser trips after a delay. Based on the coordination curves in *Figure 8*, for a 1000 A fault, using the SEL-FT50/SEL-FR12 system to trip on the fast curve instead of the slow curve reduces the fault clearing time by 400 ms.

Fuse-Saving Combined With Fuse-Blowing Schemes

The fundamental choice in distribution-line protection is between fuse-saving and fuse-blowing. For a given fault, designers either favor blowing fuses and disrupting as few customers as possible, or tripping the recloser and interrupting the fault without blowing any fuses. Each method has its advantages, but the protection planner has to pick one or the other.

Using the SEL-FT50/SEL-FR12 system, design smart protection that switches from fuse-saving to fuse-blowing, or vice versa without interruption. You get the fuse-saving or fuse-blowing benefits you want while eliminating any drawbacks.

The following two example applications show how a single protective zone using the SEL-FT50/SEL-FR12 system allows both fuse-saving and fuse-blowing schemes in service.

Example 1: Switchover Without Interruption From a Fuse-Blowing Scheme to a Fuse-Saving Scheme

In this switchover scheme, utilities have the option to tailor protection for specific line segments with different characteristics. If the SEL-FT50 declares that a fault is present on a candidate line section, the scheme enables fuse-saving while the fault is in progress. For other faulted line segments, the fuse-blowing scheme works as intended.

Example 2: Switchover Without Interruption From a Fuse-Saving Scheme to a Fuse-Blowing Scheme

In this switchover scheme, the SEL-FT50/SEL-FR12 system is used to indicate which line section contains a fault. However, the fuse-saving scheme is the default operating mode. When the SEL-FT50 declares that a fault is present on a candidate line section, the scheme enables fuse-blowing while the fault is in progress. For other faulted line segments, the fuse-saving scheme works as intended.

Improve Feeder Cable First-Span Protection

The SEL-FT50/SEL-FR12 system improves first-span feeder cable protection. Feeder cables are often used for substation egress, eliminating overhead line clutter and improving working safety. These feeder cables radiate from a substation, continuing for a few feet to one mile. These cables are usually terminated on a riser pole and then connected to the overhead conductors.

To protect cable sections, some utilities use instantaneous overcurrent elements with pickup levels set to cover the entire cable length, plus some margin that overreaches onto a portion of the overhead line. In these applications, a high-current fault causes an instantaneous trip with no reclosing permitted.

While this approach protects equipment, it also often causes an unnecessary permanent outage when the fault is on the portion of the overhead line where available fault levels are still very high. The majority of overhead faults are caused by temporary events and are far more likely to occur than underground faults. By not reclosing for close-in overhead faults, the entire feeder suffers a permanent outage that could have been avoided.

To improve the first-span feeder cable protection, use a set of three SEL-FT50 Fault Transmitters to monitor the first span of overhead line, as shown in *Figure 11*. When an overhead fault occurs, the relay instantaneous element trips the recloser or feeder breaker, but reclosing is allowed when the SEL-FT50 signals that the fault is on the overhead portion of the feeder. This simple modification of an existing scheme improves system availability. This application extends to any line that transitions between overhead and underground lines. Knowing whether a fault is on an overhead or underground section of a feeder helps when coordinating reclosing and protection schemes.

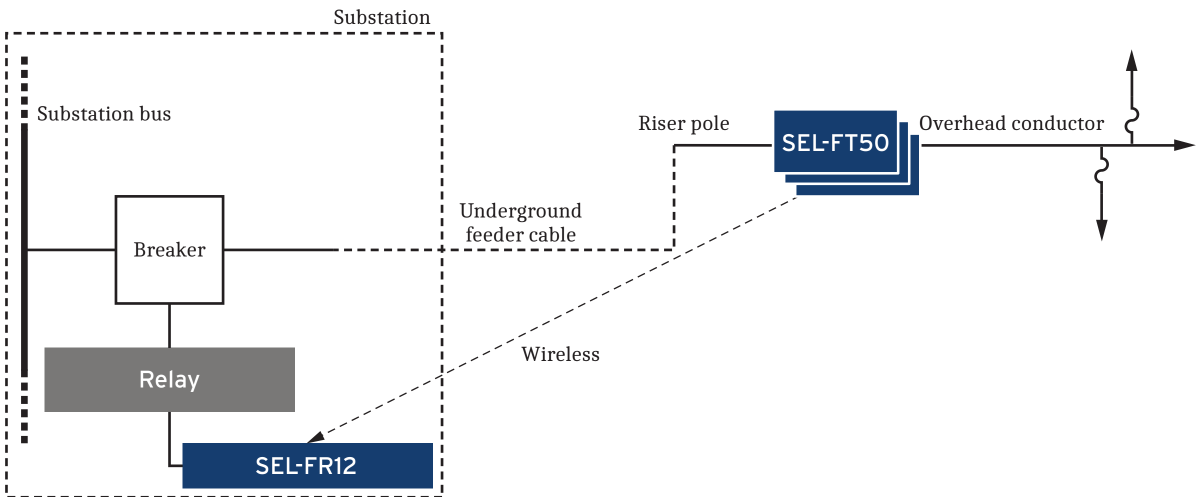


Figure 11 Feeder Cable Egress Protection With Enhancements

Implement a Low-Cost Fast Bus-Tripping Scheme

A fast bus-tripping scheme uses a short-time delayed overcurrent element in the bus relay to provide a quick response to bus faults. To maintain coordination for feeder faults, the scheme must block this fast element operation whenever a feeder relay or recloser control is picked up and timing. Traditional fast bus-trip schemes use a hardwired control circuit or communications link to allow each feeder relay to drive a bus relay block signal when a fault occurs on a distribution line outside the substation.

In stations without bus differential or a fast bus-tripping scheme, a bus fault has a long duration because the bus relay only uses a time-overcurrent element coordinated with the feeder protection.

In some substations, installing a fast bus-trip scheme is not feasible because the feeder pickup-based block signal cannot be created or transmitted through normal means. For example, some feeder protection devices (reclosers or relays) may not be able to provide a block signal, or the device may be located far across a substation yard, requiring a costly cable or fiber run to bring a block signal back to the bus relay panel. *Figure 12* shows a substation one-line diagram with a recloser on each feeder. Retrofitting a traditional fast bus-tripping scheme to this type of substation might be expensive.

Instead of installing wiring or upgrading equipment, use the SEL-FT50/ SEL-FR12 Fault Transmitter and Receiver System to bring in the required feeder pickup signal without making changes to the medium voltage system.

In *Figure 12*, each feeder (A through D) is equipped with SEL-FT50 transmitters. An example fault F1 on Feeder D triggers one or more of the SEL-FT50 transmitters to transmit. The SEL-FR12 receives the transmission and immediately sends the fault status to the bus relay. At the same time, the bus relay is also picked-up and timing the respective definite-time overcurrent element. As soon as the SEL-FR12 fault signal arrives, the bus relay blocks the respective definite-time overcurrent element and maintains the block state until the overcurrent element has completely reset. The Feeder Recloser D operates as needed to clear the fault or lockout the line.

For a bus fault F2, none of the SEL-FT50 transmitters trigger for fault current, and the bus relay receives no fault signal from the SEL-FR12. In this situation, the bus relay fast-acting definite-time overcurrent element times out and trips the bus breaker after a brief coordination delay.

You can find further details in *Low-Cost Fast Bus Tripping Scheme Using High-Speed Wireless Protection Sensors* (presented at WPRC, October 2018) and SEL application guide *Using the SEL-FT50/SEL-FR12 System to Selectively Block Fuse-Saving and Accelerated Tripping in the SEL-351R Recloser Control* (AG2018-14), both available at selinc.com.

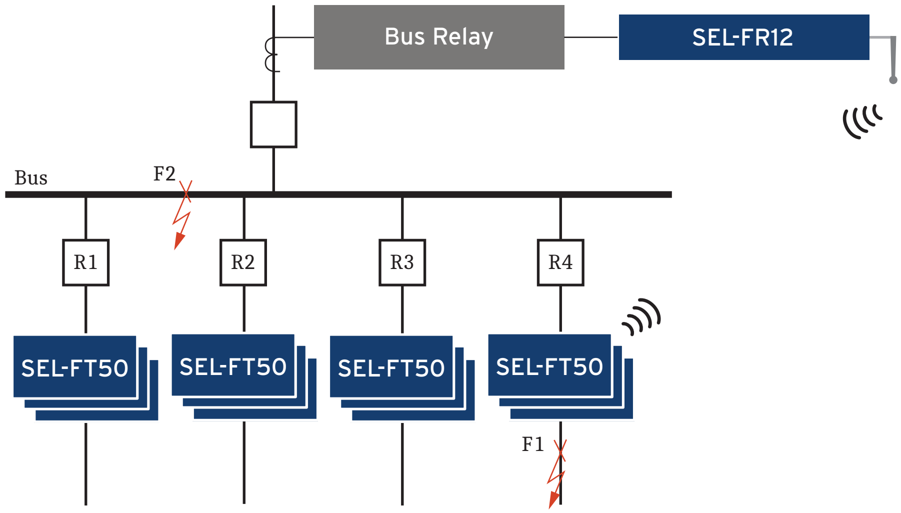


Figure 12 Wireless Fast Bus-Tripping Scheme

Tripping the Right Recloser Faster

You can protect a distribution feeder with multiple reclosers. In a radial system, to optimize selectivity, users want the recloser closest to the fault to operate for that fault. For this reason, reclosers at the end of the distribution line are set to trip first and the close-in reclosers are set to delay their tripping.

Figure 13 shows a fault in Zone R1. In a conventional protection design, assuming the reclosers use a fuse-blowing scheme, R1 clears this fault, but only after it gives Zones R2, R3, and R4 a chance to operate. This situation results in a long fault duration that stresses the system and impacts the power quality on other substation loads.

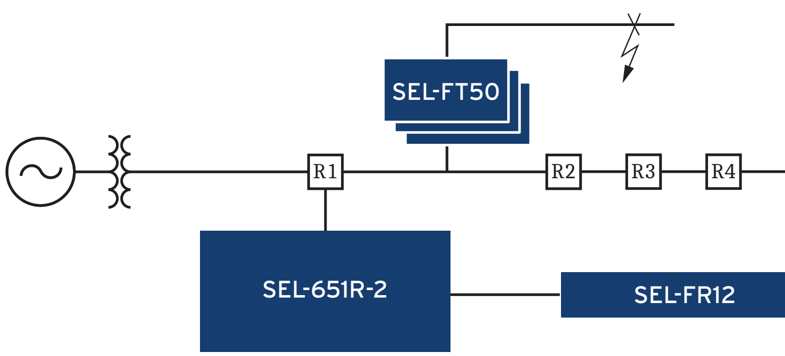


Figure 13 Radial Distribution Line With Multiple Reclosers

Fix this problem by using an SEL-FT50/SEL-FR12 system. In *Figure 13*, the SEL-FT50 detects the fault and immediately transmits the information to the SEL-FR12, which then sends this information to the recloser control at R1. Because R1 knows that the fault is in its zone, it trips without waiting for the downstream reclosers, avoiding the unnecessary coordination delay.

Safety Information

Regulatory Information

⚠DANGER
Install fault transmitters and sensors in accordance with normal safe operating procedures. These instructions are not intended to replace or supersede existing safety or operating requirements. Only trained qualified personnel with knowledge of high voltage safety should install or operate fault transmitters.

⚠CAUTION
Although the power level is low, concentrated energy from a directional antenna may pose a health hazard. Do not allow users to come closer than 23 cm (9 in) to the transmitter when it is operating.

⚠DANGER
To ensure proper safety and operation, the equipment ratings, installation instructions, and operating instructions must be checked before commissioning or maintenance of the equipment. The integrity of any protective conductor connection must be checked before carrying out any other actions. It is the responsibility of the user to ensure that the equipment is installed, operated, and used for its intended function in the manner specified in this manual. If misused, any safety protection provided by the equipment may be impaired.

The SEL-FT50 and SEL-RP50 are approved for use only with specific output power configurations that have been tested and approved. Changes or modifications to the SEL-FT50, SEL-RP50, SEL-FR12, or the antenna system, and the power output not expressly approved by the manufacturer could void the user's authority to operate the equipment.r The radio equipment described in this manual emits radio frequency energy. Professional installation is required.

United States (FCC)

This equipment has been tested and found to comply with the limits for Class A digital devices, pursuant to FCC Part 15 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. 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 radiates radio frequency energy, and if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communication. Operation of this equipment in a residential environment is likely to cause harmful interference, in which case the user will be required to correct the interference at his/her own expense.

Brazil

Este equipamento não tem direito à proteção contra interferência prejudicial e não pode causar interferência em sistemas devidamente autorizados.

Este produto não é apropriado para uso em ambientes domésticos, pois poderá causar interferências eletromagnéticas que obrigam o usuário a tomar medidas necessárias para minimizar estas interferências.

Canada

This device complies with Industry Canada license-exempt RSS standard(s). 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. Radio apparatus shall comply with the requirements to include required notices or statements to the user of equipment with each unit of equipment model offered for sale.	Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage ; (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement. Les appareils radio doivent inclure les avis ou les déclarations à l'utilisateur de l'équipement avec chaque unité mise en vente.

Dangers, Warnings, and Cautions

This manual uses three kinds of hazard statements, defined as follows:

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, **may** result in minor or moderate injury or equipment damage.

Safety Symbols

The following symbols apply to this device.

⚠	**⚠CAUTION** Refer to accompanying documents.	**⚠ATTENTION** Se reporter à la documentation.
⏚	Protective earth (ground)	Terre de protection
⎓	Direct current	Courant continu
🕮	Instruction manual	Manuel d'instructions

Safety Marks

The following statements apply to this device.

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	**⚠DANGER** Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	**⚠DANGER** Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	**⚠AVERTISSEMENT** L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	**⚠AVERTISSEMENT** Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.

⚠WARNING	⚠AVERTISSEMENT
Do not perform any procedures or adjustments that this instruction manual does not describe.	Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠**CAUTION**	⚠**ATTENTION**
Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.

Network Deployment Overview

The deployment process for the SEL-FT50 and SEL-FR12 networks consists of the following three phases:

- Research
  - Installation site candidate selection
  - Antenna selection
  - Link budget estimation
- Planning
  - Path study
  - Area coverage study
  - Channel selection
- Installation
  - SEL-FR12 installation
  - SEL-FR12 commissioning
  - SEL-FT50 installation
  - SEL-FT50 commissioning
  - Optional SEL-RP50 installation
  - Optional SEL-RP50 commissioning

Begin the network deployment process with the research and planning phases to determine whether a reliable link can be established. If so, install and set up the SEL-FR12 first so the SEL-FT50 devices join the SEL-FR12 network upon installation. Consider the following guidelines before deploying an SEL-FT50/SEL-FR12 system:

- Select SEL-FR12 and SEL-FT50 installation locations with a clear line of sight (i.e., minimal path obstructions) for best network performance.
- When obstructions limit line-of-sight, consider including SEL-RP50s in the design. See *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54*.
- Perform a separate link budget estimation for every unique link on the network (i.e., between the SEL-FR12 and each trio of collocated SEL-FT50 devices, the link between SEL-FT50s and corresponding SEL-RP50s, between sequential SEL-RP50 installations, and between the SEL-RP50 and SEL-FR12.). See *Appendix C: Link Budget Analysis on page 48* for more information. See *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54* when considering the use of SEL-RP50 Fault Repeaters.

Research

The first step in the deployment process is to identify possible installation sites for both the SEL-FR12 and SEL-FT50 devices, and then determine if a reliable link can be established.

Short-Range Network

A short-range network will have the SEL-FT50 devices deployed within a short distance of the SEL-FR12. A deployment is considered to be a short-range network when the installed SEL-FT50 devices are visible from the SEL-FR12 antenna and there are no obstructions between the two devices.

Short-range networks do not require extensive system planning, but a simple link budget estimation should still be performed to determine if the link margin is acceptable (see *Appendix C: Link Budget Analysis on page 48* for details). Select an SEL-FR12 antenna and feeder cable from the list shown in *Table 2* and *Table 3* and include the gain and loss information for these components in the link budget analysis.

When the distance between the SEL-FR12 and the SEL-FT50 devices is short, you can leave the device in low-gain mode. See *Setting SEL-FR12 Receiver Gain on page 25* for instructions on when to use low gain vs. high gain. Low-gain mode will limit the range of the SEL-FR12 but will reduce RF interference from other devices.

SEL-RP50 Fault Repeaters can also be used on short range networks without extensive planning, provided they are properly configured and installed as described in Appanedix D.

Perform an Area Study

Most SEL-FT50/SEL-FR12 links require that you are able to see the SEL-FT50 from the SEL-FR12 antenna. If you cannot see the SEL-FT50 from the SEL-FR12 antenna, perform an area study to determine if the link will work properly. Perform an area study starting at the proposed SEL-FR12 site to determine if the site provides effective coverage. The area study determines the expected receive power levels in the area around the SEL-FR12 site. The area study combines the RF characteristics of the system (e.g., system TX power, cabling losses, antenna gain, etc.), local geography, and ground cover to determine expected received power levels in the area around the SEL-FR12 sites. Effective links require 15 dB of fade margin (how much the received power level exceeds the received sensitivity). If the area study says that the link has less than 15 dB of margin, you should try raising the receiver antenna higher above ground, using a receiver antenna with higher gain, or using a different receiver site entirely.

NOTE: Only one repeater may be used with SEL-FT50s manufactured prior to May 2021.

In situations where obstacles such as trees, terrain, or buildings are blocking line-of-sight from one or more SEL-FT50s, consider installing one or more SEL-RP50 Fault Repeaters per SEL-FT50 on the same feeder as the obscured SEL-FT50s. The repeaters will generally be installed in sets of three. For longer obstruction zones, multiple repeater sites can be used (up to five). The suitability of each segment (between the SEL-FT50 site and the SEL-RP50 site, between successive SEL-RP50 sites, or between the SEL-RP50 site and the SEL-FR12) can be determined by using the simple the Short-Range Network method, above. Refer to *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54* when considering the use of SEL-FT50s.

NOTE: SEL-RP50s are not available in all markets. See *Table 13*.

An area study may also be performed for system with proposed repeaters. In this case, the characteristics of each segment must be considered. Use the SEL-RP50 receive sensitivity and EIRP values listed in Specifications.

If you do not have a clear line of sight between the SEL-FT50 and the SEL-FR12, you may wish to set up a repeater at a high point between the transmitter and the receiver, where the SEL-FR12 is at the repeater site along with an SEL-3031, which can be used as a backhaul device. The SEL-3031 repeater solution adds additional latency to the link.

The area study is only a software-based estimate and should always be accompanied by on-site analysis and testing.

Planning

SEL-FT50 Site Survey

Survey the SEL-FT50 installation site to check for local obstructions between the SEL-FT50 and SEL-FR12. If an obstruction does exist, consider whether the SEL-FT50 location could be moved to a nearby span to avoid the obstruction without compromising the application of the device, as shown in *Figure 14*.

NOTE: SEL-RP50 Fault Repeaters are not available in all countries. See *Table 13*.

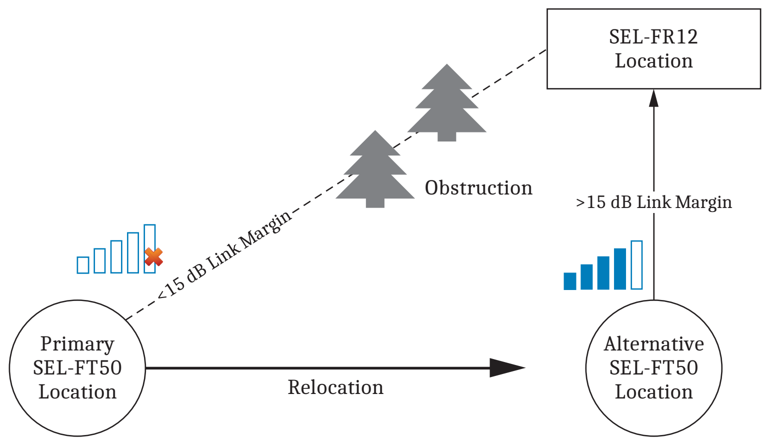


Figure 14 Alternative SEL-FT50 Location

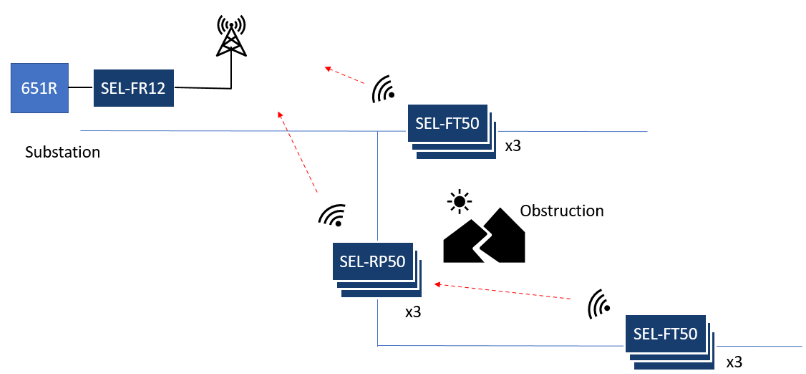


Figure 15 Use SEL-RP50s to Avoid an Obstruction -- need updated drawing

In systems where the line-of-sight cannot be maintained, SEL-RP50 Fault Repeaters can be installed along the distribution feeder to help carry the wireless signals around obstacles. For best results these must be installed on the same feeder as the SEL-RP50s being repeated, one per phase, as shown in *Figure 15*. See *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54* for further examples and implementation details.

If an alternative SEL-FT50 site is not available, consider whether the SEL-FR12 location could be moved to another point with better line of sight. Use the SEL-3031 as a backhaul device to carry the data back to the relay or recloser control that needs the fault information, as shown in *Figure 16*.

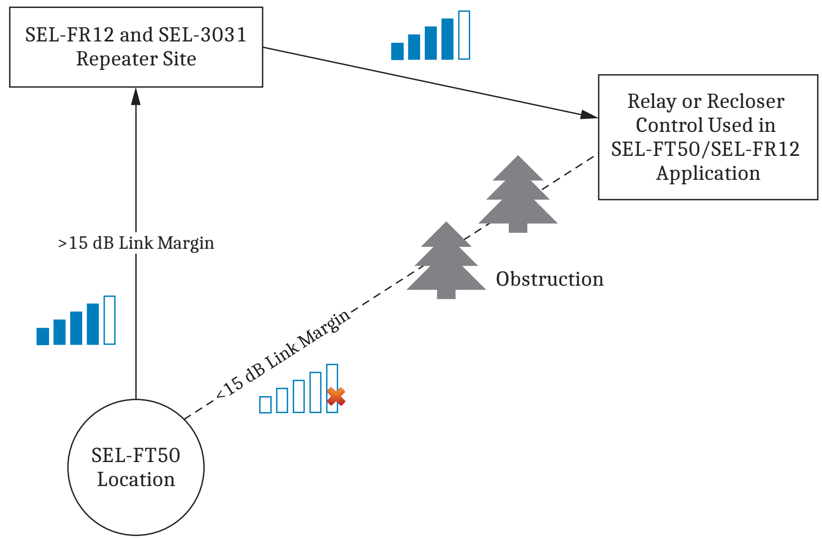


Figure 16 Using the SEL-3031 as a Repeater for Links Without a Clear Line of Sight

Path Study

A path study, rather than an area study, can be performed for networks with only a few SEL-FT50 devices that have either a long link range or have obstructions in the link path. A path study can also complement an area study for specific links in a larger network where received signal level is not optimal. Performing a path study helps you understand the propagation characteristics of the link and whether reliable communication is achievable. SEL provides radio path studies for as many as five SEL-FT50 links at no cost. For larger studies, SEL offers this service, as well as link planning and testing, for a fee through SEL Engineering Services, Inc. (contact SEL for details). Only one path study is needed for each group of collocated SEL-FT50 devices.

On-Site Testing

SEL-FR12 Installation

NOTE: After installing the SEL-FT50 on the Mini Current Loop, press the button on the loop to simulate a fault. You should see a **FAULT** LED on the SEL-FR12 right away. The **LINK** LED will illuminate within 80 s if more than one fault is triggered.

Install the network SEL-FR12 at the identified site or set of sites and enable the radio before installing any SEL-FT50 devices. Follow the procedures in *Physical Installation on page 35* for instructions on the physical installation. Commission the SEL-FR12 as described in *Commissioning the SEL-FR12 on page 23*.

Verify the radio is enabled and functioning with a nearby SEL-FT50 device. For this test, use the SEL-FT50 with a mini current loop to test the link. Simulate a fault by using the mini current loop and verify that the device registers a fault on the SEL-FR12 front-panel LEDs. The RSSI information available will indicate the signal strength, verifying RF connectivity and initial SEL-FR12 setup. See *Receive Signal Strength Indicator on page 26* for details. Now you are ready to install SEL-FT50 devices on the distribution system.

SEL-FT50 Site Installation

At the installation site, activate the SEL-FT50 by using a mini current loop. The mini current loop uses 120 Vac power so bring an inverter and extension cords to the SEL-FT50 installation site. Verify the RF connectivity by using a local SEL-FR12 (a different SEL-FR12, not installed in a cabinet) with an indoor antenna (SEL part number 235-0108). Verify that the local SEL-FR12 registers the local SEL-FT50 by examining the front-panel LEDs.

Set the SEL-FT50 devices according to *Settings and Configuration on page 30*.

Install the SEL-FT50 devices by following the instructions in *Physical Installation on page 35*.

Verify that the installed SEL-FT50 devices can communicate with the SEL-FR12. Check that the LEDs are reporting the correct **LINK** status (solid green LED), and that the RSSI information is similar to the expected signal level determined in the area study.

When SEL-RP50s are part of the system, and the line current during commissioning is less than 40 A, the appearance of LINK status at the SEL-FR12 may be delayed by 30 minutes. When more than one SEL-RP50 site is installed this delay grows by up to 30 minutes per additional site.

The SEL-FT50 only transmits Link messages when it is able to harvest line current greater than 5 A. If the line current is known to be higher than 5 A and the **LINK** LED does not assert after waiting the expected time, the SEL-RP50 Unit ID, Network ID, or Repeater ID setting might be incorrectly configured.

Path or area study modeling of ground cover may not account for specific objects that could impact individual link reliability. A tree or building close to an SEL-FT50 installation could prevent reliable communication. If there is unreliable communication, determine if it is possible to change the SEL-FT50 location to avoid the obstruction without compromising the application of the device.

These steps should be repeated for all collocated SEL-FT50 installations.

Device Installation

SEL-FR12

The SEL-FR12 uses two 10-position control (DIP) switches to set the wireless network identification (Network ID) of the associated SEL-FT50 Fault Transmitters, the baud rate and addresses for the MIRRORED BITS serial communications port, and the separate receiver gain values for the SEL-FT50 Fault Transmitters.

The control (DIP) switch assignments are listed on the SEL-FR12 enclosure. The switch positions are labeled 1 through 20, but only 1 through 14 are used.

Physical Installation

Install the SEL-FR12 first for easier commissioning when you install the SEL-FT50 Fault Transmitters.

For simplest installation, place the SEL-FR12 inside the recloser control cabinet, powered by the 12 Vdc auxiliary power supply of the SEL-651R. However, it can be installed with any device that communicates through MIRRORED BITS communications. The SEL-FR12 must be connected to an antenna that is outside the recloser control cabinet and can connect to a coaxial cable run with proper grounding and lightning protection devices. The antenna is typically mounted higher up on the pole in a safe location. The appropriate antenna type is site-specific. Perform a path study before choosing the antenna.

The SEL-FR12 serial port connects to one of the serial ports of the SEL-651R that are configured for SEL MIRRORED BITS communications. This connection allows the SEL-FR12 to share the received fault with the recloser control. The programmable logic of the recloser control is configured to incorporate the received data as part of the protection or control decisions.

Installation details differ slightly for SEL-FR12 Fault Receivers placed in substations.

Refer to the *SEL Radio Accessories Guide*, available at selinc.com, for a complete list of radio accessories offered by SEL.

Mounting the SEL-FR12

Use the accessory kit hardware to mount the SEL-FR12 in the recloser control cabinet. When ordered as an accessory to the SEL-651R, the unit comes pre-installed as part of the cabinet.

Chassis Ground and Power Connection

Connect the rear-panel grounding terminal (labeled with the ground symbol) to a rack frame ground or main station ground for proper safety and performance. Use 4 mm^2 (12 AWG) or heavier wire of less than 2 meters (6.6 feet) for this connection. Make the ground connection before making the power connections.

Connect the power harness to a fused 12 V auxiliary power supply terminal on the SEL-651R, paying attention to polarity.

If possible, turn on the SEL-FR12 and verify that the **ENABLED** LED illuminates. Turn it off before continuing.

Connect the Serial Port

Use a short cable, such as the SEL-C272, to connect the serial output of the SEL-FR12 to the recloser control or relay serial port that has been configured for MIRRORED BITS operation.

Turn on the SEL-FR12 and verify that the **ROK** LED illuminates. If **ROK** does not assert, check the SEL-FR12 MIRRORED BITS Speed and Address switches and compare them with the MIRRORED BITS port settings of the host device. Turn it off before continuing.

Antenna

SEL offers directional and omnidirectional antennas of various sizes. Contact SEL support or submit a path study if you need assistance in choosing the correct antenna for your application. If your SEL-FT50 Fault Transmitters are all in one location, you may opt use a directional antenna for greater gain. If you are setting up a point-to-multipoint link, use an omnidirectional antenna.

Table 2 lists antennas that SEL offers as orderable accessories for the SEL-FR12.

Table 2 SEL-FR12 Orderable Antennas

Type	SEL Part Number	Description	Length	Omnidirectional Diameter	Mounting
Omnidirectional	235-0003	Low-profile 3 dBi Gain Omnidirectional Antenna, 698–960 MHz, 1710–2700 MHz, N Female Connector	90 mm (3.5 in)	37 mm (1.4 in)	915900494
	235-0232	7.15 dBi Gain Omnidirectional Antenna, 902–928 MHz, N Female Connector	1358.9 mm (53.5 in)	33.3 mm (1.3 in)	240-0106 (for mounting to existing mast)
	235-0233	9.15 dBi Gain Omnidirectional Antenna, 902–928 MHz, N Female Connector	2476.5 mm (97.5 in)	33.3 mm (1.3 in)	240-0106 (for mounting to existing mast)
	235-0257	5.15 dBi Gain Omnidirectional Antenna, 843–873 MHz, N Female Connector	711.2 mm (28 in)	33.3 mm (1.3 in)	240-0106 (for mounting to existing mast)
Yagi, Directional	235-0009	3-Element, 8.15 dBi Gain Yagi Antenna 896–970 MHz, N Female Connector	426.75 mm (16.8 in)	N/A	Mast mount included
	235-0220	5-Element, 11.1 dBi Gain Yagi Antenna, 902–928 MHz, N Female Connector	548.6 mm (21.6 in)	N/A	Mast mount included
	235-0222	11-Element, 14.15 dBi Gain Yagi Antenna, 902–928 MHz, N Female Connector	914.4 mm (36 in)	N/A	Mast mount included
	235-0258	3-Element, 8.65 dBi Gain Yagi Antenna, 806–896 MHz, N Female Connector	330.2 mm (13 in)	N/A	Mast mount included
	235-0259	11-Element, 14.15 dBi Gain Yagi Antenna, 806–896 MHz, N Female Connector	939.8 mm (37 in)	N/A	Mast mount included
Indoor	235-0108	Indoor Antenna, TNC Male Connector	203.2 mm (8 in)	N/A	N/A

Feed Lines

The feed line used with the antenna is important. Use coaxial cables that have low attenuation and are rated for outdoor use. Keep the feed line as short as possible to minimize signal loss between the radio and antenna. RG-8X or LMR-400 coaxial cables are preferred. If longer lengths or less cable loss is desired for the radio link, then you can use a larger cable, such as a 7/8" HELIAX. *Table 3* lists the signal losses for the indicated lengths of each cable type.

Table 3 Estimated Length vs. Loss in Coaxial Cables

Cable Type	Characteristic Impedance	3.05 Meters (10 Feet)	12.24 Meters (50 Feet)	30.48 Meters (100 Feet)	91.44 Meters (300 Feet)
RG-8X (SEL-C964, SEL-C975)	50 Ω	0.70 dB	3.50 dB	7.0 dB	Unacceptable loss
LMR-400 (SEL-C966, SEL-C968)	50 Ω	0.39 dB	1.95 dB	3.90 dB	Unacceptable loss
7/8" HELIAX (SEL-C978)	50 Ω	Do not use	0.64 dB	1.28 dB	3.84 dB

To avoid water intrusion, seal all connections with coax sealing tape and ensure that the lowest point on the feed line is not a connector into which water could ingress.

Antenna System Ground

Antenna system grounding is not included in the scope of this manual. Please consult a radio systems engineer or other professional for advice on ground-system design, and read SEL application guide *Radio System Lightning Protection Best Practices* (AG2014-36), which can be found on the SEL website. A well-designed system will minimize equipment damage and risk of electric shock to personnel. SEL recommends that all installations include a properly grounded external surge protector. SEL offers a Radio Surge Protector With N Female Connectors (part number 200-2004) as an accessory to the SEL-FR12.

Commissioning the SEL-FR12

Setting Network ID

To enable multiple wireless fault transmitter and fault receiver systems to operate in close proximity, both the SEL-FT50 and SEL-FR12 feature a Network ID selection (1–16). See *Figure 17* for an example of two networks.

Each SEL-FT50 contain configuration switches to select one of 16 network identification numbers. The SEL-FR12 also has Network ID configuration switches and will only accept received SEL-FT50 messages that have a matching Network ID.

For example, if three distribution feeders emanate from one substation, each with their own SEL-FT50/SEL-FR12 system, these systems operate independently if they have unique Network IDs.

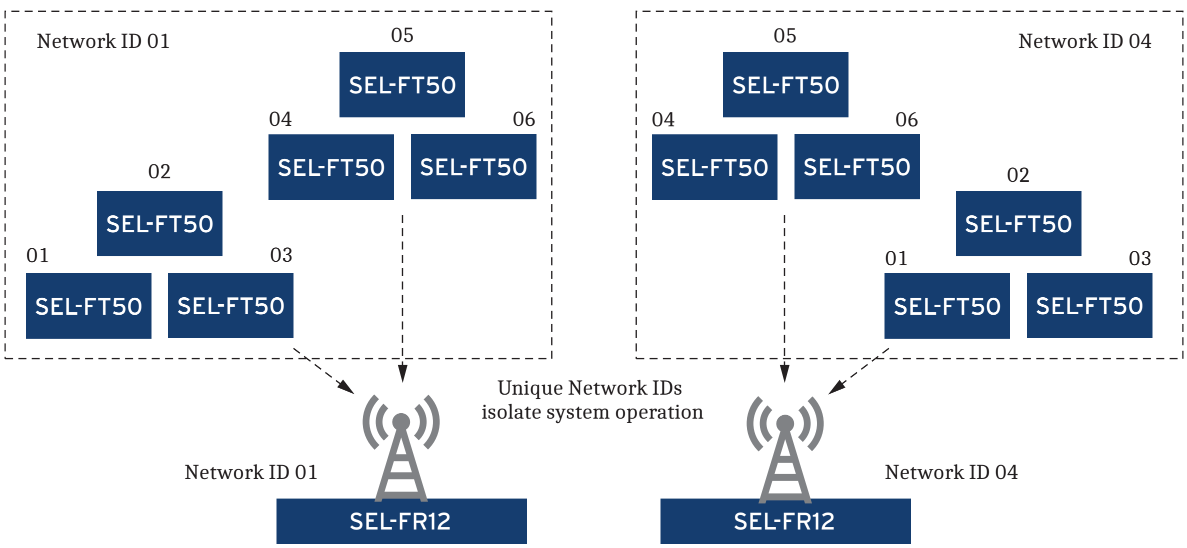


Figure 17 Two-Network Example

Once you have determined the Network ID to be used, set control switches to the appropriate positions, as shown in *Figure 18*.

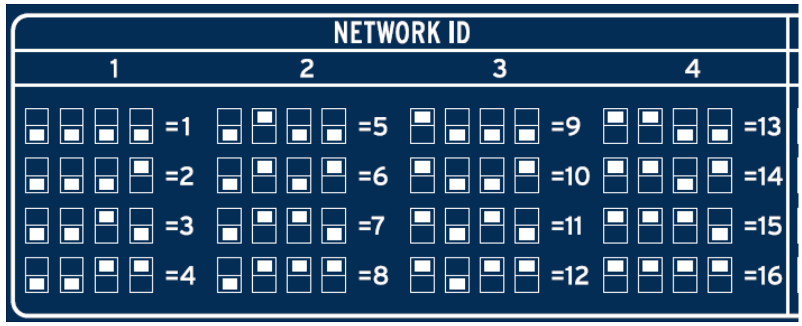


Figure 18 Network ID Switch Selection

Avoiding Radio Interference From Adjacent Networks

The Network ID encoded in each message allows only SEL-FR12 Fault Receivers configured with the same Network ID to recognize that message. However, the broadcast radio frequency (channel) selection is controlled by the Unit ID setting in each SEL-FT50. The Network ID selection does *not* affect the radio channel.

In the example system shown in *Figure 17*, the Unit ID selections 01 through 06 are duplicated on each network. This channel sharing poses no problem when the networks are monitoring separate distribution feeders and faults are isolated to one network at a time.

In cases where two networks are on the same feeder, and some SEL-FT50 Fault Transmitters on each network may simultaneously detect a fault, the Unit ID assignments for those SEL-FT50 Fault Transmitters should be unique. This avoids situations in which SEL-FT50 Fault Transmitters with a shared Unit ID broadcast fault messages at the same time (on the same channel) and interfere with one another.

Serial Port Settings

Configure the desired serial port baud rate through use of the control switch positions.

For best performance, choose the highest speed that matches the available MIRRORED BITS speed on the connected device.

Set the transmit address (**TX_ADD**) of the SEL-FR12 to match the receive address of the connected device. Set the receive address (**RX_ADD**) of the SEL-FR12 to match the receive transmit of the connected device. *Figure 19* outlines the control switch settings. Do not set the TX and RX addresses of each device to the same number because the SEL-FR12 detects a loopback condition when it receives its own transmit address in the MIRRORED BITS message. When the SEL-FR12 detects loopback, the **LOOP** LED illuminates and the **ROK** LED extinguishes.

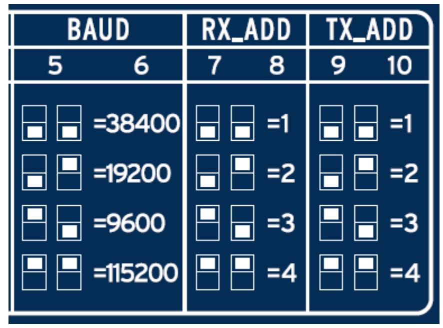


Figure 19 Serial Port Settings Selection

Setting SEL-FR12 Receiver Gain

The SEL-FR12 allows you to set the internal gain of the device. The device can be set to either Low Gain or High Gain for each trio of SEL-FT50 devices. The purpose of Low Gain mode is to ensure that you do not overdrive the receiver (which would decrease point link reliability).

For three-phase installations, the SEL-FT50 Fault Transmitters are installed in groups of three, and the received signal strength from all members of a trio is identical. The received signal strength between multiple trios is usually different because of path differences. To accommodate the range of reception signal strengths, an attenuation setting is provided for each trio. See *Table 4* for trio assignments.

The SEL-FR12 works equally well with messages received directly from an SEL-FT50, and one or more SEL-RP50. In bench test situations, stay below the SEL-RP50 maximum received signal strength specification by spacing the SEL-RP50 at least 50 feet (15 m) from the SEL-FT50, and more than 25 feet (7 meters) from another SEL-RP50 with the same Unit ID.

Table 4 Trio Assignments

Node (Three-Phase)	Unit ID Assignments at Each Location	Trio Number
1	1, 2, 3	1
2	4, 5, 6	2
3	7, 8, 9	3
4	10, 11, 12	4

NOTE: There is no transmitter power adjustment selection in the SEL-FT50 nor the SEL-RP50.

When you first install the SEL-FT50, set Control Switches 11–14 to the Low Gain position and use the RSSI feature (see *Receive Signal Strength Indicator on page 26*) to measure the receive signal strength for each trio. If the receive signal strength shows 12 LEDs, leave the trio in Low Gain mode. If RSSI mode is showing less than 12 LEDs illuminated, switch to High Gain mode. Switching to High Gain should illuminate more LEDs, corresponding to a higher RSSI.

The RSSI feature also indicates signal strength from an SEL-RP50. Generally the RSSI reading will be highest from the SEL-RP50 located closest to the SEL-FR12 (with the largest Repeater ID number). When the SEL-FR12 can receive messages from multiple SEL-RP50s with the same unit ID, it displays the RSSI from the last message received, which will usually be from the nearest SEL-RP50, with the largest Repeater ID.

During low line current conditions (less than 40 A), the SEL-RP50s take up to 30 minutes to start repeating Link messages. For a newly energized or newly-installed system, this delay is repeated for each increasing Repeater ID. If the RSSI reading is examined during this time, low readings may be initially displayed if weak signals are arriving from distant devices. As each SEL-RP50 starts repeating the Link messages the RSSI reading might jump to a higher value. If you set the Gain switch to the High position based on these early readings, the signals from the closest SEL-RP50s might be too strong to be received. This is unlikely if the SEL-RP50s are installed according to the guidelines in *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54*.

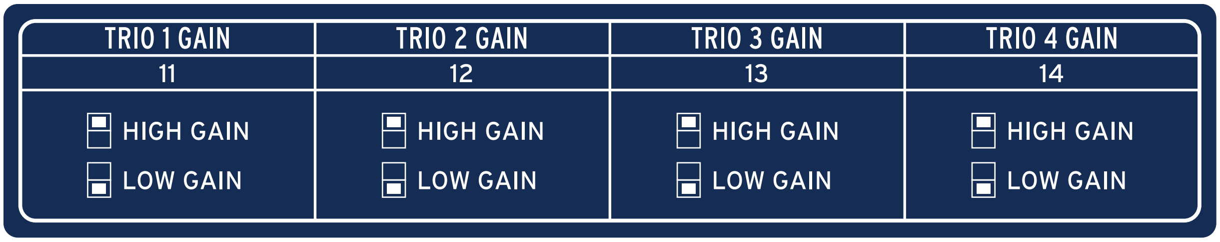


Figure 20 Trio Attenuation Switch Selection

Receive Signal Strength Indicator

NOTE: The RSSI feature was introduced in March 2018. Devices with prior serial numbers will not support the receive signal strength feature.

NOTE: The SEL-FR12 still supports its normal MIRRORED BITS communications operation even when it is not in Normal mode (i.e., your scheme will remain active).

NOTE: RSSI readings are only available by reading the front-panel LEDs. They cannot be accessed remotely.

The SEL-FR12 has a built-in feature to determine the link quality for each of its 12 SEL-FT50/SEL-FR12 links called Receive Signal Strength Indicator (RSSI) mode. While in Normal mode, press and hold the TARGET RESET pushbutton for at least four seconds (until the ENABLED LED begins flashing) to enter RSSI mode. The SEL-FR12 will display the receive signal strength of each link as follows:

- The ENABLED LED blinks once per second to indicate that the device is in RSSI mode.
- FAULT LED 1 illuminates to indicate that you are reading the RSSI for the link between the SEL-FR12 and the SEL-FT50 with Unit ID 1. Press the TARGET RESET pushbutton to sequence through Unit IDs 1–12.
- The LINK LEDs report the RSSI as shown in *Table 5* and *Table 6*. The SEL-FR12 receive sensitivity is specified with one percent packet error. If the SEL-FR12 is receiving at or below its receive sensitivity, no LEDs are illuminated. Each LED corresponds to a 2 dB increase in signal strength above the threshold.

Table 5 RSSI Specifications for FR12-0001/FR12-0003/FR12-0006 (U.S.A., Canada, Mexico, Peru, and Brazil)

Number of LINK LEDs Illuminated	RSSI (High Gain Mode)[a]
0	–97 dBm or worse
1	–95 dBm
2	–93 dBm
3	–91 dBm
4	–89 dBm
5	–87 dBm
6	–85 dBm
7	–83 dBm
8	–81 dBm
9	–79 dBm
10	–77 dBm
11	–75 dBm
12	–73 dBm or better

[a] For RSSI values in Low Gain mode, add 16 dB to each value.

Table 6 RSSI Specifications for FR12-0004/FR12-0005 (Europe, Australia, and New Zealand)

Number of LINK LEDs Illuminated	RSSI (High Gain Mode)[a]
0	–105 dBm or worse
1	–103 dBm
2	–101 dBm
3	–99 dBm
4	–97 dBm
5	–95 dBm
6	–93 dBm
7	–91 dBm
8	–89 dBm
9	–87 dBm
10	–85 dBm
11	–83 dBm
12	–81 dBm or better

[a] For RSSI values in Low Gain mode, add 16 dB to each value.

For critical links, the best practice is to have at least 15 dB of fade margin above your receive sensitivity (which corresponds to at least eight illuminated LEDs) for a reliable link. At lower RSSI values, the device is more susceptible to unwanted interference from other radio systems.

When the SEL-FR12 is receiving link messages, the RSSI indicated by the **LINK** LEDs updates every 15 seconds. If the SEL-FR12 misses a link message, the **LINK** LEDs that represent the RSSI will flash at the last measured value of a successful message. This will persist until another successful message is received or the SEL-FR12 is turned off.

Press and hold the **TARGET RESET** pushbutton for two more seconds to enter Read Settings mode (see *Read Settings on page 30* for details), and then for two seconds longer to get back to Normal mode. The SEL-FR12 will default to Normal mode automatically after 30 minutes.

Connecting the SEL-FR12 to Other SEL Devices

The SEL-FR12 uses the MB8 MIRRORED BITS protocol. The following examples give sample configurations for SEL devices that operate with the SEL-FR12. For each of these examples, select BAUD = 38400, RX_ADD = 2, and TX_ADD = 1 on the SEL-FR12. Only the minimum settings required are shown. Consult the appropriate instruction manual to ensure proper settings for your particular MIRRORED BITS application.

SEL-351, SEL-751 Relays, SEL-351R, and SEL-651R Recloser Controls

PROTO = MB8A*
SPEED = 38400
TXID = 2
RXID = 1

* = MB8A or MB8B may be used

SEL-451 Relay

PROTO= MBA*
SPEED = 38400
MBT = N
TX_ID = 2
TX MODE = P
STOPBIT = 2
RX_ID = 1
MBNUM = 8

* = MBA or MBB may be used

SEL-2505/SEL-2506 Remote I/O Module

SPEED = 38400
RX_ADD = 1
TX_ADD = 2

MIRRORED BITS Interface and Messages

The SEL-FR12 communicates with a host device (protective relay or recloser control) through use of SEL MIRRORED BITS communications. The connection requires one serial port on the host device. The SEL-FR12 supports four port speeds: 9.6, 19.2, 38.4, and 115.2 kbps. By default, the messages have the formats listed in *Table 7*.

Table 7 Default Command Set—SEL-FR12 MIRRORED BITS Data Message Contents

Required SEL-651R Transmit MIRRORED BITS (SELOGIC Equations) for Default Mode							
TMB1	TMB2	TMB3	TMB4	TMB5	TMB6	TMB7	TMB8
0	0	0	0	0	0	Clear link state in SEL-FR12	Target reset on SEL-FR12 HMI
SEL-651R Received MIRRORED BITS (Relay Word bits)							
RMB1	RMB2	RMB3	RMB4	RMB5	RMB6	RMB	RMB8
Trio 1 FAULT	Trio 2 FAULT	Trio 3 FAULT	Trio 4 FAULT	Trio 1 LINK	Trio 2 LINK	Trio 3 LINK	Trio 4 LINK

The default command set is ideal for applications where SEL-FT50 Fault Transmitters are installed in trios and individual unit information is not needed. For other applications, the SEL-FR12 supports two additional MIRRORED BITS command sets.

The command sets listed in *Table 9* and *Table 10* provide conditional responses. Program the SEL-651R logic to evaluate the expression RMB1 OR RMB2. When true, the remaining bits RMB3–RMB8 contain FAULT data; otherwise, they contain LINK data.

Table 8 defines the Trio FAULT and Trio LINK bits.

The TMB1–TMB6 entries in *Table 9* and *Table 10* indicate the required TMB states to select the Default Set or Command Set 2 or 3. Any other bit combinations force the SEL-FR12 to return all zeros and cause it to ignore TMB7 and TMB8 commands.

Table 8 Definition of FAULT and LINK Bits

Bit Label	Definition
LINK *u*	*u* = Unit ID 1–12 SEL-FR12 is receiving messages from SEL-FT50 Fault Transmitters. Asserts whenever SEL-FR12 **LINK** LED *u* is solidly illuminated.
Trio 1 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 1, 2, and 3
Trio 2 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 4, 5, and 6
Trio 3 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 7, 8, and 9
Trio 4 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 10, 11, and 12
FAULT *u*	*u* = Unit ID 1–12 Asserts for at least 116 ms when the SEL-FR12 receives a fault message from the SEL-FT50 and deasserts thereafter; this bit is not latched (this differs from the SEL-FR12 **FAULT** LEDs, which are latched until reset).
Trio 1 FAULT	Logical OR of the fault state from Unit IDs 1, 2, and 3
Trio 2 FAULT	Logical OR of the fault state from Unit IDs 4, 5, and 6
Trio 3 FAULT	Logical OR of the fault state from Unit IDs 7, 8, and 9
Trio 4 FAULT	Logical OR of the fault state from Unit IDs 10, 11, and 12

The Trio 1 LINK, Trio 2 LINK, Trio 3 LINK, and Trip 4 LINK bit logic ignores SEL-FT50 Fault Transmitters that have not been installed or detected. For example, if SEL-FT50 Fault Transmitters with Unit IDs 4 and 5 are installed, but there is no Unit ID 6, LINK 6 never asserts. The equation for the Trio 2 LINK is reduced to LINK 4 AND LINK 5.

Table 9 Detailed Command Set 2—SEL-FR12 Mirrored Bits Data Message Contents

Required SEL-651R Transmit Mirrored Bits (SELogic Equations) for Detailed Command Set (2)							
TMB1	TMB2	TMB3	TMB4	TMB5	TMB6	TMB7	TMB8
0	0	1	0	0	0	Clear link state in SEL-FR12	Target reset on SEL-FR12 HMI
SEL-651R Received Mirrored Bits (Relay Word bits)							
RMB1	RMB2	RMB3	RMB4	RMB5	RMB6	RMB7	RMB8
Response During Normal Conditions (No Fault on Trio 1 or Trio 2)							
Trio 1 FAULT = 0	Trio 2 FAULT = 0	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6
Response During FAULT Indication (One or Both Trio 1 FAULT, Trio 2 FAULT Asserted)							
Trio 1 FAULT	Trio 2 FAULT	FAULT 1	FAULT 2	FAULT 3	FAULT 4	FAULT 5	FAULT 6

Table 10 Detailed Command Set 3—SSEL-FR12 Mirrored Bits Data Message Contents (Sheet 1 of 2)

Required SEL-651R Transmit Mirrored Bits (SELogic Equations) for Detailed Command Set (2)							
TMB1	TMB2	TMB3	TMB4	TMB5	TMB6	TMB7	TMB8
0	0	1	1	0	0	Clear link state in SEL-FR12	Target reset on SEL-FR12 HMI

Table 10 Detailed Command Set 3—SSEL-FR12 MIRRORED BITS Data Message Contents (Sheet 2 of 2)

Required SEL-651R Transmit MIRRORED BITS (SELOGIC Equations) for Detailed Command Set (2)							
SEL-651R Received MIRRORED BITS (Relay Word bits)							
RMB1	RMB2	RMB3	RMB4	RMB5	RMB6	RMB7	RMB8
Response During Normal Conditions (No Fault on Trio 3 or Trio 4)							
Trio 3 FAULT = 0	Trio 4 FAULT = 0	LINK 7	LINK 8	LINK 9	LINK 10	LINK 11	LINK 12
Response During FAULT Indication (One or Both Trio 3 FAULT, Trio 4 FAULT Asserted)							
Trio 3 FAULT	Trio 4 FAULT	FAULT 7	FAULT 8	FAULT 9	FAULT 10	FAULT 11	FAULT 12

Access 12 Individual LINK and FAULT Bits

Command Set 2 provides the individual status of Unit IDs 1–6 and Command Set 3 provides it for Unit IDs 7–12. However, there is no command set that provides all 12 individual status points at one time.

For applications that require more than six individual LINK *u* or FAULT *u* bits, set the SEL-651R to alternately request Command Set 2 and Command Set 3. Achieve this by operating TMB4 from a SELOGIC timer, changing state automatically (refer to the top sections of *Table 9* and *Table 10*). Configure further SELOGIC to qualify and decode the RMB data, and store the result in the appropriate SELOGIC variables for use in control functions or for system logging in the Sequential Events Recorder.

Temporarily Disable SEL-FR12 MIRRORED BITS Responses

For commissioning purposes, it may be necessary to disable the MIRRORED BITS data that the SEL-FR12 is transmitting. In the SEL-651R, set TMB1–TMB8 = 0, with the exception of setting TMB4 = 1. This has no effect on the SEL-FR12 front-panel LED operation.

Read Settings

NOTE: The SEL-FR12 automatically exits Read Settings mode after 30 minutes. To manually exit, press and hold the **TARGET RESET** pushbutton until the **ENABLED** LED stays illuminated.

NOTE: The Read Settings function is only available using the front-panel LEDs. The settings cannot be accessed remotely.

Because the SEL-FR12 is set via control (DIP) switches on the rear of the device, it may be difficult to read settings on the SEL-FR12 while it is installed in a cabinet. The SEL-FR12 includes a Read Settings mode that allows you to see the switch positions of the device. To enter Read Settings mode, press and hold the **TARGET RESET** pushbutton two times (the first press cycles through RSSI mode). The control (DIP) switch settings are displayed as follows:

- ➤ The **ENABLED** LED blinks three times per second to indicate that the device is in Read Settings mode.
- ➤ LEDs 1–10 on the **FAULT** row of LEDs indicate the position of Switches 1–10. If an LED is illuminated, that control (DIP) switch is in the UP (or ON) position.
- ➤ LEDs 1–10 on the **LINK** row of LEDs indicate the position of Switches 11–20.

SEL-FT50

Settings and Configuration

The SEL-FT50 uses two internal eight-position switch banks to configure the Unit ID, the Network ID, and the Fault Pickup current level.

The SEL-FT50 only reads settings during startup; changing settings while the unit is turned on has no effect. Changing settings requires removal of device power. The SEL-FT50 retains some energy in storage and may take a couple of minutes to fully turn off. For an SEL-FT50 connected to an SEL-FR12, the device is fully turned off when the LINK LED for that unit starts blinking, indicating that the receiver has stopped receiving link messages from the SEL-FT50 transmitter.

⚠CAUTION
To avoid damaging the SEL-FT50, do not use the CT and clamping mechanism as a handle when removing the bottom.

To begin, open the SEL-FT50 by twisting the bottom counter-clockwise. On the inside of the device, you will see the two banks of switches. The switch positions are labeled 1 through 8 on each of the two switch banks. The switch selections are outlined on a label on the interior of the device, as shown in *Figure 21*.

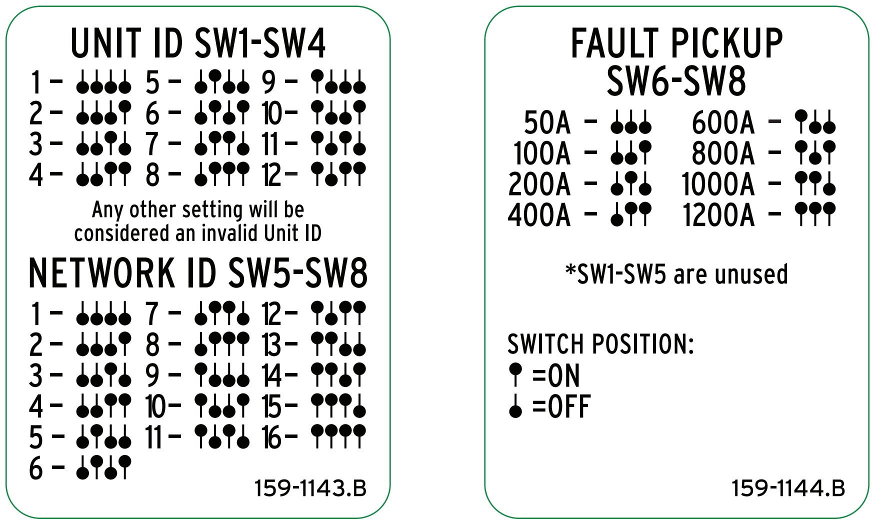


Figure 21 SEL-FT50 Switch Selections Labels

Setting the Unit ID

NOTE: Each SEL-FT50 transmits faults on a specific frequency based on its Unit ID, and the frequencies for each Unit ID are the same across different networks. To avoid collisions, select the Unit ID such that a single fault is not likely to trip two SEL-FT50 Fault Transmitters (with the same Unit ID) on separate networks.

For example, consider an SEL-FT50 with Unit ID 1 on Phase A of a given feeder. If you have a separate network downstream, assigning Unit ID 1 to an SEL-FT50 on Phase A on that separate network would result in a Phase-A line fault tripping both SEL-FT50 Fault Transmitters simultaneously.

The SEL-FR12 Fault Receiver receives wireless signals from as many as 12 SEL-FT50 Fault Transmitters on the same network, defined by the Network ID selection in the SEL-FT50/SEL-FR12 system.

To allow the SEL-FR12 to distinguish which fault transmitter has sent a message, each SEL-FT50 transmits a Unit ID field as part of the message (the Unit ID is a number from 1 to 12).

The following lists the requirements when planning the Unit IDs to use in a system:

- Unit IDs cannot be duplicated on the network.
- Not all Unit IDs need to be present.
- Unit IDs should be grouped in three-phase locations as trios (see *Table 4*).
- Single-phase and two-phase applications are possible in specific situations.
- Unit IDs should be marked on the system record for later installation and commissioning work.
- Each SEL-FT50 Unit ID is configurable and is selected by the Unit ID control switches inside the housing.

➤ Use different Unit IDs for any SEL-FT50 trios that may experience simultaneous through-fault current, even if those SEL-FT50 Fault Transmitters are on different networks. See *Avoiding Radio Interference From Adjacent Networks on page 24* for details.

Setting the Network ID

Configure your SEL-FT50 Fault Transmitters to communicate on the same network as your SEL-FR12 by giving both devices the same Network ID. Devices with different Network IDs cannot communicate.

Setting Fault Pickup

The topic of power system coordination is outside the scope of this guide. An overcurrent element must supervise SEL-FT50 data when used in trip decisions or other operations affecting protection. Choose an SEL-FT50 Fault Pickup to be at or below the upstream protective device (e.g., recloser control) supervising the overcurrent pickup setting (expressed in primary amperes).

Because the SEL-FT50 measurement accuracy is not as accurate as a relay, take care when choosing your fault pickup settings. The measurement accuracy for each trip threshold is spelled out in the specifications section. Follow the guidelines in the following table to ensure the right pickup levels while avoiding false pickups.

Table 11 and *Table 12* provide the recommended pickup settings based on the expected load and fault currents. These tables take into account the different pickup specifications for each product family (two styles of CTs).

NOTE: The SEL-FT50 current measurement circuitry is not as precise as a protective relay overcurrent element. Refer to *Specifications on page 41* for fault pickup accuracy, response characteristics, and device ratings.

Table 11 Fault Pickup Accuracy Considerations for FT50-0001/FT50-0003/FT50-0005/FT50-0006 (U.S.A., Canada, Peru, Australia, New Zealand, and Brazil)

Fault Pickup Level (rms)	Host Relay Pickup Setting (rms)	Load Behind FT50 (rms)
50 A	> 60 A	< 40 A
100 A	> 120 A	< 85 A
200 A	> 240 A	< 170 A
400 A	> 480 A	< 360 A
600 A	> 720 A	< 540 A
800 A	> 960 A	< 720 A
1000 A	> 1200 A	< 900 A
1200 A	> 1440 A	< 1080 A

Table 12 Fault Pickup Accuracy Considerations for FT50-0004/FT50-0007 (Europe and Mexico)

Fault Pickup Level (rms)	Host Relay Pickup Setting (rms)	Load Behind FT50 (rms)
50 A	> 75 A	< 25 A
100 A	> 130 A	< 70 A
200 A	> 260 A	< 140 A
400 A	> 480 A	< 320 A
600 A	> 720 A	< 480 A
800 A	> 960 A	< 640 A
1000 A	> 1200 A	< 800 A
1200 A	> 1440 A	< 960 A

This selection method guarantees that the SEL-FT50 picks up for any fault that the protective device element can see. This setting method will perform well in locations where fault current is much higher than load current.

The protection planner must consider the load current range on the distribution system at each node, combined with the SEL-FT50 accuracy rating at currents below the fault pickup. High load current levels may result in false assertion of the SEL-FT50 fault detector. In most cases, this is acceptable because the supervising overcurrent element will not assert. However, the more frequent a load condition is mistaken for a fault, and the longer each instance persists, the higher the chance of the SEL-FT50 missing an actual fault. To avoid this situation, consider selecting the SEL-FT50 Fault Pickup setting to be one step higher.

SEL-RP50 Settings and Configuration

The SEL-RP50 uses two internal eight-position switch banks to configure the Unit ID, Network ID, and the Repeater ID.

The SEL-RP50 only reads settings during startup; changing settings while the unit is turned on has no effect. Changing settings requires removal of device power. The SEL-RP50 retains some energy in storage and may take a couple of minutes to fully turn off. For an SEL-RP50 as part of the LINK to an SEL-FR12, the device is fully turned off when the LINK LED for that unit starts blinking. During bench testing, however, other device Link messages may keep the SEL-FR12 LINK LED illuminated. Waiting 5 minutes with the SEL-RP50 removed from its test current source will be long enough in these cases.

To begin, open the SEL-FT50 by twisting the bottom counter-clockwise. On the inside of the device, you will see the two banks of switches. The switch positions are labeled 1 through 8 on each of the two switch banks. The switch selections are outlined on a label on the interior of the device, as shown in *Figure 22*.

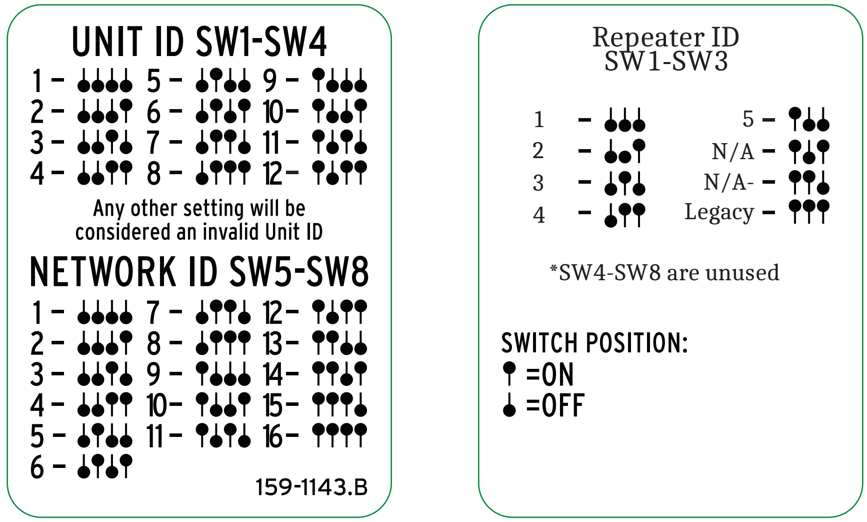


Figure 22 SEL-RP50 Switch Selections Labels

Setting the Unit ID

When configuring one or more SEL-RP50 Fault Repeaters to forward wireless messages from a single SEL-FT50, the Unit ID settings must match.

In a typical three-phase SEL-FT50 installation, the Unit IDs are selected from one of four Trios, as shown in *Table 4*. For example, if the Trio 1 grouping is chosen, the SEL-FT50 Unit IDs would be set to 1, 2, and 3.

If one repeater site is added to this system, the three SEL-RP50s must also be configured for Trio 1. Thus, the internal switches must be set so there is an SEL-RP50 on each unit ID 1, 2, and 3. Additionally, each SEL-RP50 at this repeater site must be mounted on the same electrical phase as the SEL-FT50 that has the same Unit ID.

If a second repeater site is added to this system (that only has the Trio 1 SEL-FT50s), this second set of SEL-RP50s must also be configured to cover Unit IDs 1, 2, and 3, and mounted on the same electrical phase as its Unit ID peer.

If more than one Trio of SEL-FT50s is installed, and SEL-RP50s are needed for the other trios, they too must be set to Unit IDs that match the SEL-FT50 Unit IDs, and mounted on the same electrical phase.

See *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54* for more information on setting the Unit IDs for multiple SEL-RP50 Fault Repeater sites.

Setting the Network ID

Configure your SEL-RP50 Fault Repeaters to communicate on the same network as the SEL-FT50s and SEL-FR12 by making the same Network ID selection on all devices. Devices with different Network IDs cannot communicate.

Setting the Repeater ID

NOTE: Do not install the SEL-RP50s with a reversed Repeater ID sequence. Misconfiguration will delay the wireless message transmission and add latency to the SEL-FR12 fault indication. The Link status signals may also take longer to appear after feeder power is restored.

The Repeater ID selection is a number between 1 and 5. The numeric sequence is important when more than one repeater site is used for a particular Trio. For example, when a Trio uses the maximum of five SEL-RP50 sites, the Repeater IDs must increase from 1 (nearest the SEL-FT50) to 5 (nearest the SEL-FR12).

If only one repeater site is installed for a Trio, any repeater ID can be used. A smaller value provides the lowest latency, so using repeater ID = 1 keeps it simple.

NOTE: Each SEL-RP50 repeater ID adds approximately 1 ms latency to the fault response at the SEL-FR12

A special Repeater ID = Legacy is provided when using SEL-FT50s manufactured before May 2021. These older SEL-FT50s are not compatible with the numeric Repeater ID selections, and only one repeater site can be used. Do not use the Legacy selection with newer SEL-FT50s.

Repeater IDs may be skipped, but cannot be reversed. For example, with three repeater sites, working away from the SEL-FT50 towards the SEL-FR12, it is permissible to use Repeater IDs 2, 4, and 5, but not 2, 5, 4.

See *Appendix D: SEL-RP50 Fault Repeater Detailed Implementation on page 54* for more examples of settings the Repeater ID.

Do not use the Repeater ID switch configurations marked N/A.

SEL-FT50 and SEL-RP50 Field Installation

Physical Installation

Install the SEL-FT50 or SEL-RP50 on a distribution line by using an industry-standard shotgun stick.

Step 1. Use a shotgun stick to grasp the hook eye on the side of the SEL-FT50/SEL-RP50, and place the device on the line so that the opening hangs over the line.

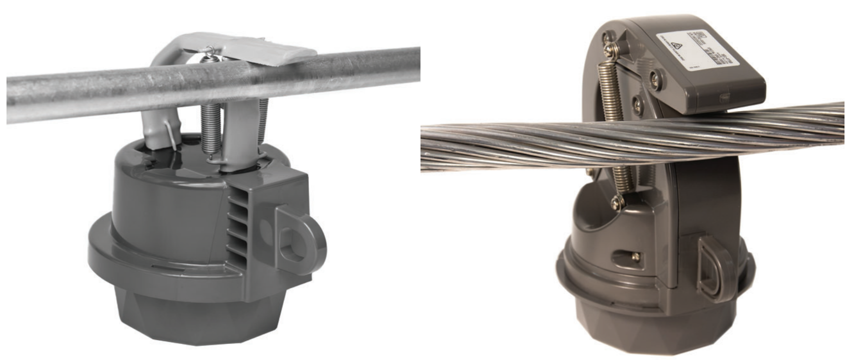


Figure 23 Positioning the SEL-FT50/SEL-RP50

Step 2. Apply slight downward and sideways pressure until the device is closed around the line.

The spring mechanism should be pushed in so that it wraps around the line.

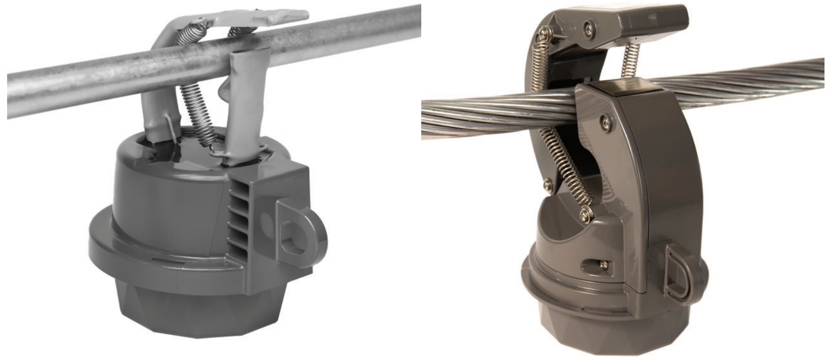


Figure 24 SEL-FT50/SEL-RP50 Installation Position

Step 3. Apply slight upward pressure until the device is secured around the line as shown in *Figure 25*.

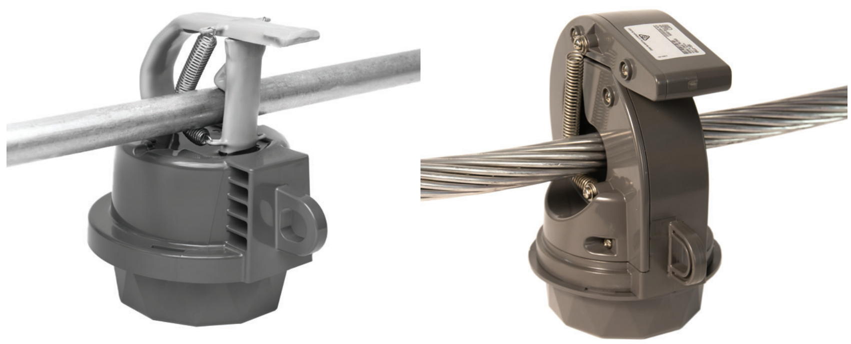


Figure 25 SEL-FT50/SEL-RP50 Secure on the Line

Step 4. Use the shotgun stick to adjust the transmitter orientation so that it is directly vertical. This is important to ensure the best propagation characteristics for the internal antenna.

Dimensions

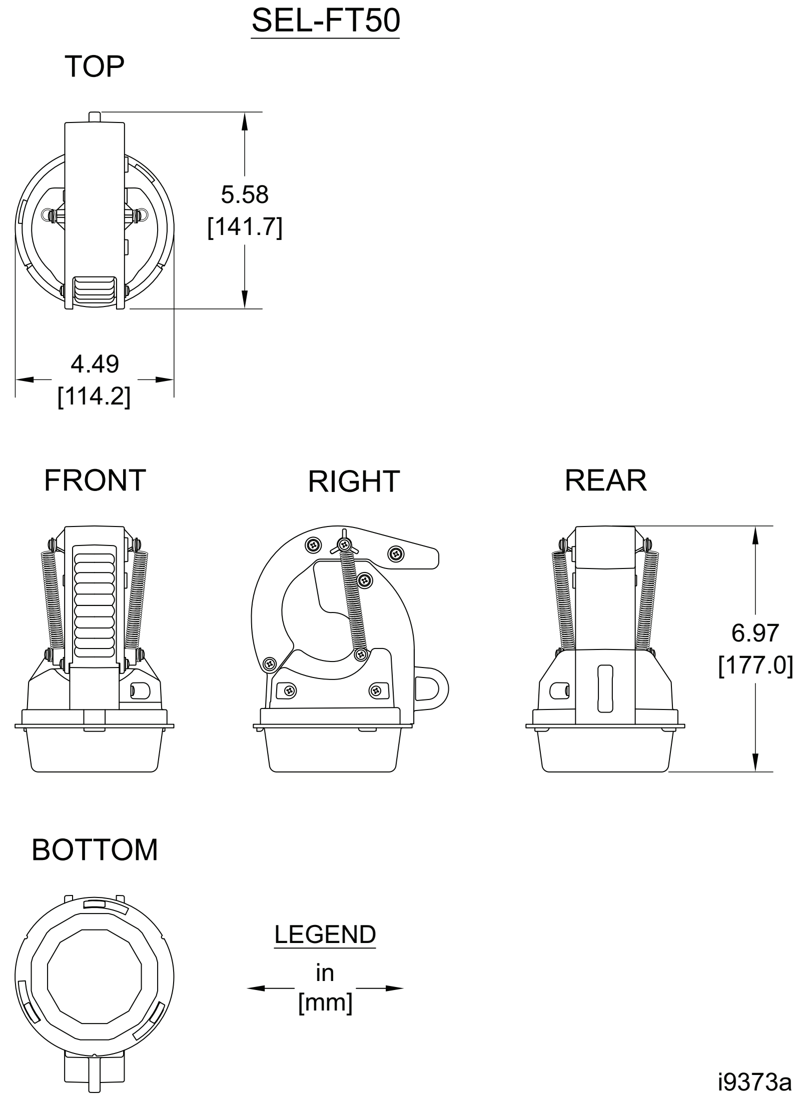


Figure 26 SEL-FT50 Dimensions for FT50-0001/FT50-0003/FT50-0005/ FT50-0006 (U.S.A., Canada, Peru, Australia, New Zealand, and Brazil)

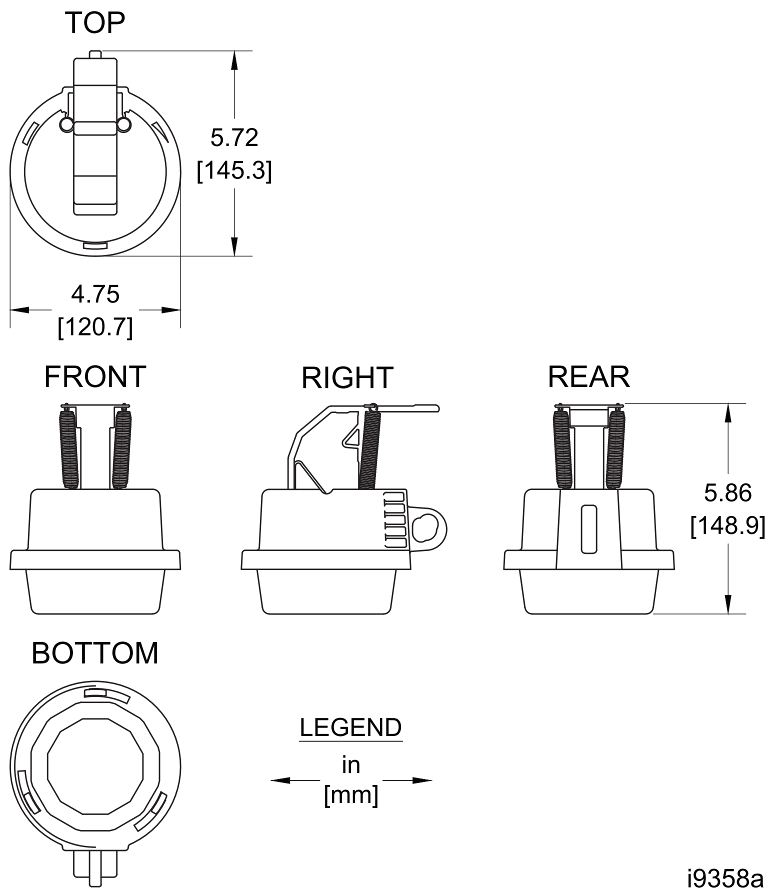


Figure 27 SEL-FT50 Dimensions for FT50-0004/FT50-0007 (Europe and Mexico)

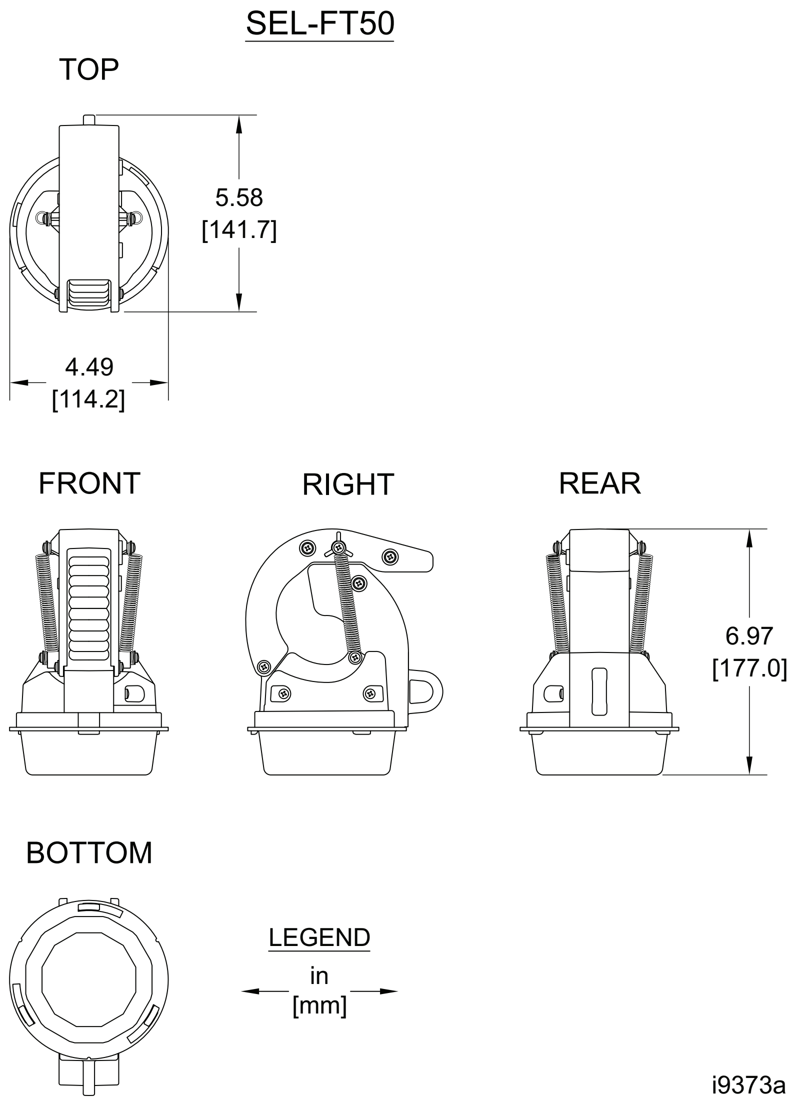


Figure 28 SEL-RP50 Dimensions for RP50-0001 (U.S.A., Canada) -- need updated drawing

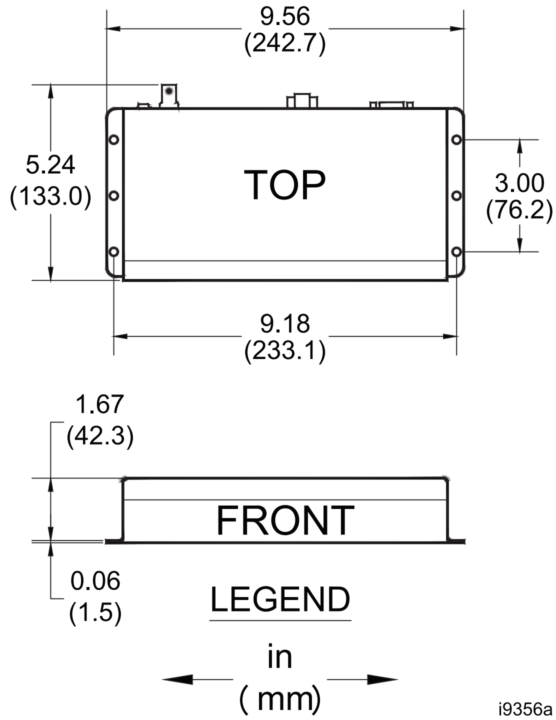


Figure 29 SEL-FR12 Dimensions

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

CE Mark

RoHS compliant

General

Operating Temperature

–40° to +85°C (–40° to +185°F)

Storage Temperature

–40° to +85°C (–40° to +185°F)

Operating Environment

Pollution Degree:	2
Relative Humidity:	5%–95%, noncondensing
Maximum Altitude:	2000 m

Ingress Protection

SEL-FT50, SEL-RP50:	IP67
SEL-FR12:	IP3X

Clamp Range (SEL-FT50)

FT50-0001/FT50-0003/ FT50-0005/FT50-0006:	6.35 mm to 31.75 mm (0.25 in to 1.25 in)
FT50-0004/FT50-0007:	7.6 mm to 27.9 mm (0.3 in to 1.1 in)
RP50-0001:	6.35 mm to 31.75 mm (0.25 in to 1.25 in)

Dimensions

SEL-FT50

FT50-0001/FT50-0003/ FT50-0005/FT50-0006:	141.7 mm diameter x 177.0 mm height (5.58 in. diameter x 6.97 in. height)
FT50-0004/FT50-0007:	145 mm diameter x 148 mm height (5.71 in. diameter x 5.83 in. height)
RP50-0001:	141.7 mm diameter x 177.0 mm heigh (5.58 in. diameter x 6.97 in. height)

SEL-FR12

44 mm x 243 mm x 117 mm (1.73 in x 9.57 in x 4.61 in)

Weight

SEL-FT50

FT50-0001/FT50-0003/ FT50-0005/FT50-0006:	0.85 kg (1.9 lb)
FT50-0004/FT50-0007:	0.6 kg (1.3 lb)
RP50-0001:	0.85 kg (1.9 lb)

SEL-FR12

0.54 kg (1.20 lb)

Connection Cables (SEL-FR12)

Wire Size:	12–24 AWG
Wire Type:	Copper, 60°/75°C solid or stranded
Insulation:	50 V minimum

Torque

Ground Wire	
Minimum:	0.9 Nm (8 in-lb)
Maximum:	1.4 Nm (12 in-lb)
Power Supply Wires	
Minimum:	0.5 Nm (4.4 in-lb)
Maximum:	0.6 Nm (5.3 in-lb)

Overvoltage

Category III (SEL-FT50 and SEL-FR12)

Insulation Class

SEL-FT50, SEL-RP50:	Class III
SEL-FR12:	Class I

System

Power System Frequency Range

45–65 Hz

Current Pickup Level (rms)

Note: Units are individually configurable.

50, 100, 200, 400, 600, 800, 1000, 1200 A

Fault Detection Accuracy (FT50-0001/FT50-0003/FT50-0005/FT50-0006)

All Fault Thresholds:	3% typical, 20% maximum

Fault Detection Accuracy (FT50-0004/FT50-0007)

50 A Threshold:	50%
100 A, 200 A Threshold:	30%
400 A Threshold and Above:	20%

System Latency—Fault Detection to Relay Input for FT50-0001/FT50-0003/FT50-0005/FT50-0006

From Link Active State:	6 ms typical, 16 ms maximum
From SEL-FT50 Sleep State:	<100 ms for fault currents less than 400 A <16 ms for fault currents greater than 400 A

System Latency—Fault Detection to Relay Input for FT50-0004/FT50-0007

From Link Active State:	6 ms typical, 16 ms maximum
From SEL-FT50 Sleep State:	<100 ms for fault currents less than 400 A <30 ms for fault currents between 400 A and 600 A <16 ms for fault currents greater than 600 A

System Latency—Addition Fault Detection Delay from RP50-0001

From SEL-FT50 Fully Awake State (Load Current > 40 A):	+1 ms typical per SEL-RP50 in line
From SEL-RP50 Semi-Awake or Sleep State (Load Current 0–40 A):	+1 ms typical, +6 ms maximum for first SEL-RP50 in line +1 ms typical for 2nd through 5th SEL-RP50 in line

Maximum Voltage

38 kV (L-L)

Maximum Steady-State Load Current

FT50-0001/FT50-0003/ FT50-0005/FT50-0006:	600 A (Thermal Rating)
FT50-0004/FT50-0007:	400 A
RP50-0001:	600 A (Thermal Rating)

Maximum Fault Current

25 kA for 10 cycles

Power

SEL-FT50 Minimum Radio Link Active Current

FT50-0001/FT50-0003/ FT50-0005/FT50-0006:	5 A
FT50-0004/FT50-0007:	15 A

SEL-RP50 Minimum current

Fully Awake:	load current > 40 A
Semi-Awake:	load current > 5 A

SEL-FR12 Power Requirements

Rated Voltage:	12–24 Vdc
Operational Voltage:	9–30 Vdc
Power Consumption:	<2 W

Radio System

Frequency Band

FT50-0001, RP50-0001, FR12-0001: 902–928 MHz ISM band (U.S.A, Canada)

FT50-0007, FR12-0001: 902–928 MHz ISM band (Mexico)

FT50-0003, FR12-0003: 916–928 MHz (Peru)

FT50-0004, FR12-0004: 863-870 MHz (Europe)

FT50-0005, FR12-0005: 915–928 MHz (Australia, New Zealand)

FT50-0006, FR12-0006: 902–907.5 MHz, 915–928 MHz (Brazil)

SEL-FT50 and SEL-RP50

TX Power (Effective Isotropic Radiated Power)

FT50-0001, FT50-0003, FT50-0006, FT50-0007:	1 W (30 dBm) peak, 40 mW (16 dBm) typical
FT50-0004:	40 mW (16 dBm) peak, 1.6 mW (2 dBm) typical
FT50-0005:	125 mW (21 dBm) peak, 5 mW (7 dBm) typical
RP50-0001:	50 mW (17 dBm) peak, 20 mW (13 dBm) typical

RX Sensitivity (1% Error Rate)

RP50-0001:	–92 dBm

Maximum Received Signal Strength

RP50-0001:	–40 dBm

SEL-FR12

Number of Channels:	12
Antenna Connector:	BNC, 50 Ω

RX Sensitivity (1% Error Rate)

FR12-0001, FR12-0003, FR12-0006:	–97 dBm
FR12-0004, FR12-0005:	–105 dBm

Modulation

FSK

Link Range (SEL-FT50 to SEL-FR12)

U.S.A., Canada, Mexico, Peru, Brazil, Australia, New Zealand:	As far as 6.4 km (4 miles) (line-of-sight)
Europe:	As far as 3.2 km (2 miles) (line-of-sight)

Link Range (SEL-RP50)

FT50-0001 to RP50-0001:	As far as 1.6 km (1 mile) (line-of-sight)
RP50-0001 to RP50-0001:	As far as 0.8 km (0.5 miles) (line-of-sight)
RP50-0001 to FR12-0001:	As far as 0.8 km (0.5 miles) (line-of-sight)

Communications Port

EIA-232:	One rear
Port Data Rate Selections:	9600, 19200, 38400, 115200 bps

Type Tests

Electromagnetic Compatibility Emissions

Radiated:	47 CFR Part 15.109 Class A
Conducted:	47 CFR Part 15.107 Class A

Electromagnetic Compatibility Immunity

Electrostatic Discharge:	IEC 61000-4-2:2008 IEEE C37.90.3-2001 Discharges: Indirect: ±8 kV Contact: ±8 kV Air: ±15 kV
Radiated:	IEEE C37.90.2-2004 20 V/m_{rms}; 80 MHz to 1 GHz >35 V/m_{rms} with 80% 1 kHz sine wave modulation
Surge:	IEC 61000-4-5:2005 Zone B: ±0.5; 1.0 kV; line-to-line Zone B: ±0.5; 1.0; 2.0 kV; line-to-earth
Conducted:	IEC 61000-4-6:2008 10 V_{rms}; 150 kHz to 80 MHz 80% 1 kHz sine wave modulation
Power Frequency Magnetic Field:	IEC 61000-4-8:2009 100 A/m; 50/60 Hz; ≥60 s 1000 A/m; 50/60 Hz; 1–3 s
IEEE Surge Withstand Capability:	IEEE C37.90.1-2012 Damped Oscillatory (1 MHz)—(CM & DM) Power Input: ±2.5 kV Communications Ports: ±2.5 kV (CM only) Fast Transient (5 kHz)—(CM & DM) Power Input: ±4.0 kV Communications Ports: ±4.0 kV (CM only)

Environmental

Cold:	IEC 60068-2-1:2007 Cold Profile Ad; –40°C; ≥16 hours; operational
Dry Heat:	IEC 60068-2-2:2007 Dry Heat Profile Bd; +85°C; ≥16 hours; operational
Damp Heat; Cyclic:	IEC 60068-2-30:2005 Damp Heat Profile Db; +25° to +55° C; relative humidity ≥93%; 6 cycles
Vibration:	IEC 60255-21-1:1988 Class 1 Vibration Endurance Class 2 Vibration Response
Shock and Bump:	IEC 60255-21-2:1988 Class 1 Shock Withstand Class 1 Bump Class 2 Shock Response
Seismic:	IEC 60255-21-3:1993 Class 2 Quake Response

Table 13 Certifications by Country

Country	Part Number	Authority	Reference
U.S.A.	FT50-0001	FCC	R34-900FT50
Canada	FT50-0001	IC	4468A-900FT50
Peru	FT50-0003	MTC	TRSS39617
Europe[a]	FT50-0004	European Union	CE Mark
Australia and New Zealand	FT50-0005	ACMA	RCM
Brazil	FT50-0006	Anatel	05386-20-12987
Mexico	FT50-0007	IFETEL	RCPSCSE17-1114-A1

[a] Includes Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

Table 14 Frequency Mapping by Country

Unit ID	Frequency (MHz)			
	U.S.A., Canada, Mexico[a], Brazil[a]	Peru	EU	Australia, New Zealand
	FT50-0001/-0006/-0007 FR12-0001/-0006 RP50-0001	FT50-0003 FR12-0003	FT50-0004 FR12-0004	FT50-0005 FR12-0005
1	904	918.82	863.175	923.175
2	905	917.91	863.500	923.475
3	917	917.00	863.825	923.775
4	918	919.73	864.175	924.075
5	919	920.64	864.500	924.375
6	920	921.55	864.825	924.675
7	921	922.46	868.150	924.975
8	922	923.37	868.450	925.275
9	923	924.28	868.825	925.575
10	924	925.19	869.075	925.875
11	925	926.10	869.525	926.175
12	926	927.01	869.850	926.475

[a] SEL-RP50 not available for Mexico and Brazil.

Appendix A: Manual Versions

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table 15 lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table 15 Instruction Manual Revision History (Sheet 1 of 2)

Date Code	Summary of Revisions
20210501	Globally ➤ Added new product SEL-RP50 Fault Repeater. ➤ New *Appendix D: SEL-RP50 Fault Repeater Application Instruction*s. Regulatory Information ➤ Added SEL-RP50. Specifications ➤ Added *Table 14: Frequency Mapping by Country.*
20201230	➤ Added FT50-0005 (Australia/New Zealand) to *Table 11: Fault Pickup Accuracy Considerations for FT50-0001/FT50-0003/FT50-0005/FT50-0006 (U.S.A., Canada, Peru, Australia, New Zealand, and Brazil).* ➤ Updated *Figure 23: SEL-FT50 Dimensions for FT50-0001/FT50-0003/FT50-0005/FT50-0006 (U.S.A., Canada, Peru, Australia, New Zealand, and Brazil)* to indicate the revised upper housing, clamp, and revised current transformer for FT50-0005 (Australia/New Zealand). ➤ Updated *Clamp Range (SEL-FT50)*, *Dimensions*, and *Weight* in *Specifications* for FT50-0005 (Australia/New Zealand). ➤ Updated *Fault Detection Accuracy (FT50-0001/FT50-0003/FT50-0005/FT50-0006)*, *System Latency—Fault Detection to Relay Input for FT50-0001/FT50-0003/FT50-0005/FT50-0006*, and *Maximum Steady-State Load Current* in *Specifications* for FT50-0005 (Australia/New Zealand). ➤ Updated *SEL-FT50 Minimum Radio Link Active Current* in *Specifications* for FT50-0005 (Australia/New Zealand).
20200529	➤ Updated regulatory information for Brazil in *Safety Information*. ➤ Added FT50-0006 (Brazil) to *Table 11: Fault Pickup Accuracy Considerations for FT50-0001/FT50-0003/FT50-0006 (U.S.A., Canada, Peru, and Brazil).* ➤ Updated *Figure 23: SEL-FT50 Dimensions for FT50-0001/FT50-0003/FT50-0006 (U.S.A., Canada, Peru, and Brazil)* to indicate the revised upper housing, clamp, and revised current transformer for FT50-0006 (Brazil). ➤ Updated *Clamp Range (SEL-FT50)*, *Dimensions*, and *Weight* in *Specifications* for FT50-0006 (Brazil). ➤ Updated *Fault Detection Accuracy (FT50-0001/FT50-0003/FT50-0006)*, *System Latency—Fault Detection to Relay Input for FT50-0001/FT50-0003/FT50-0006*, and *Maximum Steady-State Load Current* in *Specifications* for FT50-0006 (Brazil). ➤ Updated *SEL-FT50 Minimum Radio Link Active Current* in *Specifications* for FT50-0006 (Brazil). ➤ Updated *Table 13: Certifications by Country* for FT50-0006 (Brazil).
20190214	➤ Updated *Table 2: SEL-FR12 Orderable Antennas.*
20181213	➤ Updated SEL-FT50 graphics to show the revised upper housing and clamp and revised current transformer for FT50-0001/FT50-0003. ➤ Added *Implement a Low-Cost Fast Bus-Tripping Scheme* to *Application Examples*. ➤ Added FT50-0007 part number (new designation for Mexico). ➤ Added *Table 11: Fault Pickup Accuracy Considerations for FT50-0001/FT50-0003 (U.S.A., Canada, and Peru)* for updated FT50-0001 and FT50-0003. ➤ Updated hot stick terminology with shotgun stick in *SEL-FT50 Field Installation*. ➤ Updated *Weight*, *Maximum Steady-State Load Current*, *SEL-FT50 Minimum Radio Link Active Current, Frequency Band,* and *Link Range* in *Specifications.* ➤ Added *Fault Detection Accuracy (FT50-0001/FT50-0003)*, *Fault Detection Accuracy (FT50-0004/FT50-0005/FT50-0006/FT50-0007)*, *System Latency—Fault Detection to Relay Input for FT50-0001/FT50-0003*, and *System Latency—Fault Detection to Relay Input for FT50-0004/FT50-0005/FT50-0006/FT50-0007* to *Specifications*.
20180731	➤ Updated *Table 2: SEL-FR12 Orderable Antennas*.

Table 15 Instruction Manual Revision History (Sheet 2 of 2)

Date Code	Summary of Revisions
20180613	➤ Added *Network Deployment Overview.* ➤ Updated *Table 2: SEL-FR12 Orderable Antennas*. ➤ Added *Commissioning the SEL-FR12* heading. ➤ Updated *Table 12: Fresnel Zone Radius (900 MHz)*. ➤ Updated *Specifications*. ➤ Added *Appendix C: Link Budget Analysis*.
20180308	➤ Updated *Table 2: SEL-FR12 Orderable Antennas*. ➤ Added Caution note to *Settings and Configuration* in *System Installation > SEL-FT50*. ➤ Updated *Compliance* and *Radio System* in *Specifications*. ➤ Added EU to *Table 13: Certifications by Country.*
20180206	➤ Added *Avoiding Radio Interference From Adjacent Networks*, *Receive Signal Strength Indicator*, and *Read Settings to SEL-FR12 in System Installation*. ➤ Updated *General* and *Radio System* in *Specifications*. ➤ Added Peru, Australia, and New Zealand to *Table 13: Certifications by Country.*
20171130	➤ Added *Antenna* to *SEL-FR12* in *System Installation*. ➤ Added Brazil to *Table 11: Certifications by Country.*
20170828	➤ Updated *Table 10: Certifications by Country.*
20170622	➤ Updated *System* in *Specifications*. ➤ Added *Type Tests* to *Specifications*.
20170410	➤ Clarified that pickups listed in *Table 8: Fault Pickup Accuracy Considerations* are root-mean-square (rms) values. ➤ Clarified that System Current Pickup Level in *Specifications* is a root-mean-square (rms) value.
20170317	➤ Initial version.

Appendix B: Two-Branch Application

This application has two three-phase branches, A and B, as shown in *Figure 30*. Branch B has a fuse and uses a fuse-blowing scheme, while Branch A does not. When a fault occurs on Branch A, the recloser operates to clear the fault. In traditional protection schemes, those without the SEL-FT50/SEL-FR12 system, the time-inverse overcurrent curves of the SEL-651R recloser control are set above the fuse-clearing curve, resulting in longer tripping times for faults on Branch A. Use the SEL-FT50/SEL-FR12 system to improve this protection scheme.

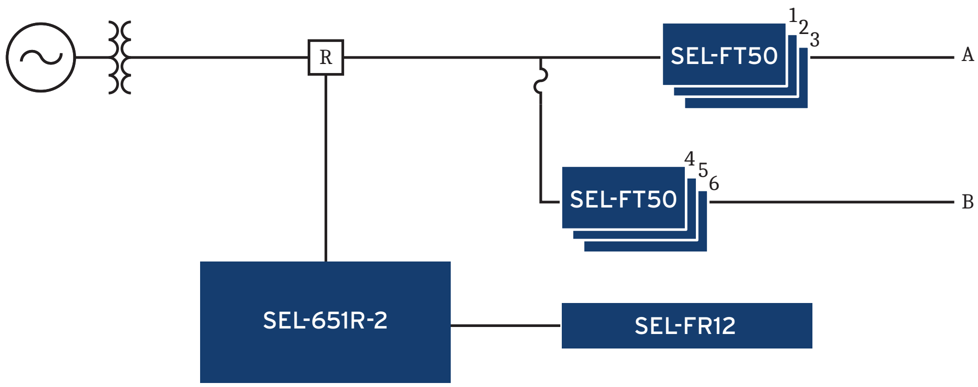


Figure 30 SEL-FT50/SEL-FR12 System Protection Scheme

Insert a set of three SEL-FT50 Fault Transmitters on each branch, one per phase. The SEL-FR12 connects to the SEL-651R with an SEL-C272 serial cable. In this example, the load current of Branch A is 200 A, and the load current of Branch B is 100 A. The 51 element pickup of the SEL-651R is set above 200 percent of the load current. In this example, the fuse size is 140 T, the SEL-651R 51 element pickup is 550 A, and the settings from *Table 16* apply.

Table 16 Settings for the SEL-FT50 Fault Transmitters

SEL-FT50	Branch	Unit ID Control (DIP) Switch Positions	Network ID Control (DIP) Switch Positions	Pickup Threshold Control (DIP) Switch Positions
1	A	1—(DDDD)	3—(DDUD)	400 A—(DUU)
2	A	2—(DDDU)	3—(DDUD)	400 A—(DUU)
3	A	3—(DDUD)	3—(DDUD)	400 A—(DUU)
4	B	4—(DDUU)	3—(DDUD)	200 A—(DUD)
5	B	5—(DUDD)	3—(DDUD)	200 A—(DUD)
6	B	6—(DUDU)	3—(DDUD)	200 A—(DUD)

D = switch is in the DOWN or OFF position.
U = switch is in the UP or ON position.

This settings example uses Network ID = 3, and the fault current pickup threshold is set above the load current and below the pickup.

The Network ID of the SEL-FR12 matches the Network ID of the SEL-FT50 Fault Transmitters. *Table 17* assumes that the SEL-FT50 Fault Transmitters require High Gain mode selections (see *Receive Signal Strength Indicator on page 26* for details). See *Table 18* for the settings of the SEL-651R and *Table 19* for the SEL-651R transmit MIRRORED BITS settings.

Table 17 Settings for the SEL-FR12

Network ID	BAUD	RX_ADD	TX_ADD	Trio 1 Gain	Trio 2 Gain	Trio 3 Gain	Trio 4 Gain
3—(0010)	38400	1	2	High Gain	High Gain	High Gain	High Gain

Table 18 SEL-651R Settings

PROTO	SPEED	TXID	RXID
MB8A or MB8B	38400	1	2

Table 19 SEL-651R Transmit MIRRORED BITS Settings

TMB1A	TMB2A	TMB3A	TMB4A	TMB5A	TMB6A	TMB7A	TMB8A	Comments
0	0	0	0	0	0	0	TRGTR	The **TARGET RESET** pushbutton of the SEL-651R resets the latched **FAULT** LEDs of the SEL-FR12.

With these settings, Branch B operates using a fuse-blowing scheme where the fuse clears faults on the branch, while Branch A operates separately, tripping much faster because the protection does not wait for a fuse-coordination delay.

The required modifications for the SEL-651R Protection settings are not included in this instruction manual. See SEL application guide *Using the SEL-FT50/ SEL-FR12 System to Selectively Permit Accelerated Tripping in the SEL-651R Recloser* (AG2017-30), available at selinc.com.

Appendix C: Link Budget Analysis

Overview

A radio link budget accounts for all losses and gains in a radio link from the transmitter to the receiver. Link budget calculations are used to determine the amount of link margin available for a given radio link. The link budget includes five components: radio transmit power, antenna gains, cable and path losses, interference margin, and radio receiver sensitivity. For a reliable link, the receive power must be greater than the effective receive sensitivity. The link margin is the difference between received power and effective receive sensitivity. The goal of link budget calculation is to account for all of the system and path gains and losses to determine if an adequate link margin is available (see *Figure 31*).

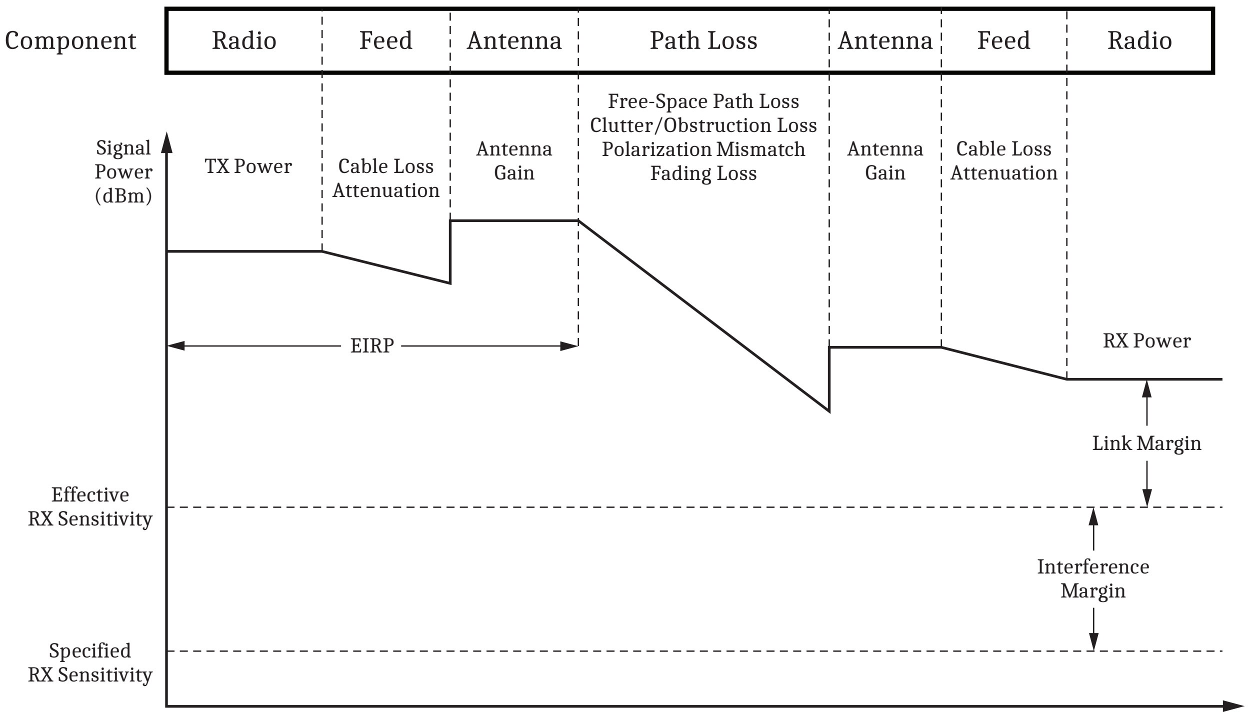


Figure 31 Sample Link Budget

Transmitted and Radiated Power Requirements

FCC and IC regulations for 900 MHz ISM (industrial, scientific, and medical) band radios such as those used by the SEL-FT50 place limits of +30 dBm on maximum radio transmit power and +36 dBm on maximum Effective Isotropic Radiated Power (EIRP). EIRP is a measure of the amount of power radiated from the main lobe of the transmitter antenna, and is calculated by using *Equation 1*.

$$\text{EIRP (dBm)} = \text{TX Power (dBm)} - \text{Line Loss (dB)} - \text{Attenuation (dB)} + \text{Antenna Gain (dBi)}$$

Equation 1

The specified transmit power for radio embedded in the SEL-FT50 includes the antenna gain. Because there is no method of connecting an SEL-FT50 to an external antenna, you do not need to be concerned with violating EIRP requirements if you do not modify the device.

The SEL-FR12 must be connected to an external antenna, but because the SEL-FR12 is not a transmitter, you may attach any size antenna to the device. Keep in mind that larger antennas will amplify the desired signal, but also interference in the band.

Path Loss

Path loss is attenuation of the transmitted signal as it propagates between the transmitter and the receiver. There can be multiple contributors to total path loss, including free-space path loss (FSPL), loss because of obstructions within the path of the radio signal, polarization mismatch between the transmitting and receiving antennas, and multi-path fading. Total path loss is calculated by using *Equation 2*. Loss because of obstructions, antenna polarization mismatch, and fading generally need to be estimated. All potential path loss factors should be included in the link budget calculation when determining link margin.

$$\text{Path Loss (dB)} = \text{FSPL (dB)} - \text{Obstruction Loss (dB)} + \text{Polarization Loss (dB)} - \text{Fading Loss (dB)}$$

Equation 2

Free-Space Path Loss

FSPL is calculated through use of *Equation 3*. *Table 20* shows the 915 MHz FSPL for some typical path distances.

$$\text{FSPL (dB)} = 32.45 + 20\log f\text{ (MHz)} + 20\log d\text{ (km)}$$

Equation 3

where:

f = frequency in MHz
d = distance in km

Table 20 915 MHz[a] Free-Space Path Loss Examples

Distance Between Antennas (d)	Free-Space Loss (dB) (Without Obstructions)
300.0 m (984.3 ft)	81
1.6 km (1.0 mi)	96
6.4 km (4.0 mi)	108

[a] The free-space path loss will decrease slightly for radios in the 860 MHz band.

Obstruction Loss

Path loss caused by obstructions needs to be factored into link budget calculations when there are obstructions within the first Fresnel zone of the radio link. The first Fresnel zone is an elliptical space surrounding the direct path between the transmitter and the receiver antennas, the perimeter of which is described by a total chord distance (d1 + d2) that is half a wavelength greater than the length of the direct path (d) between the transmitter and receiver antennas.

The maximum radius of the first Fresnel zone occurs at a point midway between the transmitting and receiving antennas, as shown in *Figure 32*. *Equation 4* shows how to calculate the radius of the Fresnel zone. For example, at 915 MHz with a distance of 300 m (1000 ft) between antennas, the Fresnel zone has a radius of 4.96 m (16.27 ft). For a distance of 16 km (10 mi) between antennas, the Fresnel zone radius is 36.21 m (118.8 ft). *Table 21* provides the Fresnel zone radius for some typical path distances.

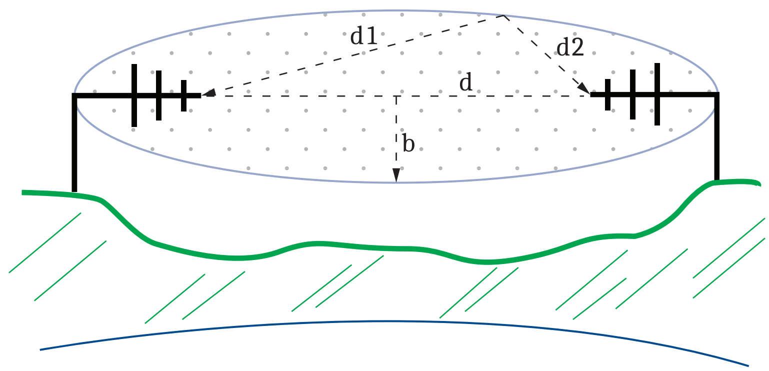


Figure 32 Fresnel Zone

$$b = 547.7\sqrt{\frac{d}{4f}}$$

Equation 4

where:

b = radius of the Fresnel zone in meters
d = distance between transmitter and receiver in kilometers
f = frequency transmitted in MHz

Table 21 915 MHz Fresnel Zone Radius

Distance Between Antennas (d)	Fresnel Zone Radius (b)[a]
300.0 m (984.3 ft)	5.0 m (16.4 ft)
1.6 km (1.0 mi)	11.5 m (37.7 ft)
6.4 km (4.0 mi)	22.9 m (75.1 ft)

[a] The Fresnel zone will be slightly larger for radios in the 860 MHz band.

When you have a clear line of sight, with no obstructions within the first Fresnel zone of the radio link, no obstruction loss value is needed in the link budget calculation. Anything within the Fresnel zone (the ground, buildings, vegetation, etc.) will add obstruction loss to the link budget calculation. When more than 80 percent of the Fresnel zone radius is free of obstructions, 0–3 dB of loss can be added to the link budget to account for obstruction loss. When 50–80 percent of the Fresnel zone radius is free from obstructions, 6–12 dB of obstruction loss can be added to the link budget. When less than 50 percent of the Fresnel zone is free from obstruction, 12–20 dB of obstruction loss can be added to the link budget. When obstructions occur on the direct path between the transmitting and receiving antennas, more than 20 dB of obstruction loss may need to be added to the link budget.

Unlike other radios, which are often installed at base stations on mountain tops, the SEL-FT50 and SEL-FR12 usually need to be positioned locally on a line at the transmitter side and near a relay or recloser on the receiver side. Because of this, you will often have obstructions, or the ground itself, in the Fresnel zone, especially for longer links. You must keep in mind the above principles when planning your links. The best rule of thumb is that if you can see the SEL-FT50 from the SEL-FR12 antenna, the link is likely to work.

Antenna Polarization Loss

While hanging on the line, the SEL-FT50 has a vertically polarized antenna. The SEL-FR12 should use a vertically polarized antenna to match. Antenna polarization refers to the orientation of the e-field in the radiated RF signal. The omnidirectional antennas listed in *Table 20* are all vertically polarized. The Yagi antennas are polarized in the direction of the short radiating elements of the antenna (either vertically or horizontally). For proper system operation, the transmitting and receiving antennas should be polarized in the same direction. When a radio signal propagates over long distances, it is possible for the polarization of the signal to rotate (because of interactions with the ground or obstructions in the path). When this occurs, the received signal polarization may not be aligned with the receiving antenna, which results in polarization mismatch loss. A 45-degree rotation of signal polarization results in 3 dB loss of received signal power. It is possible but unlikely for greater polarization loss to occur in an actual radio link.

Fading Loss

Multipath fading occurs when the transmitted signal is reflected off surfaces that are not on the direct path between the transmitter and receiver. These reflected signal images combine with the direct path signal and add constructively or destructively depending on the phase of the reflected signal relative to the direct path signal. When a direct line-of-sight path exists between the transmitter and receiver, multi-path fading will generally be approximately 6–10 dB, in the presence of nearby reflective surfaces. When a direct line-of-sight path does not exist between the transmitter and receiver, multi-path fading can cause 20 dB or more of signal loss.

Interference Margin

The SEL-FT50/SEL-FR12 system shares frequency spectrum with other services and FCC Part 15 (unlicensed) devices in ITU Region 2 (North, Central, and South America). Signals from other devices and services in the 900 MHz ISM band can cause interference at the receiver that degrades the receive sensitivity of the radio. The effective receive sensitivity of the radio is the signal level at which the radio can properly receive the desired signal in the presence of sustained interference.

Interference margin should be included in the link budget to account for the effect of interfering signals. The level of interference at a receiver can vary greatly depending on the number of other nearby devices and services operating in a given area. In isolated locations, there may be very little interference (0–6 dB of interference margin required). In suburban or urban environments, the level of interference can be substantial (6–20 dB of interference margin required).

Link Margin

The result of a link budget calculation is a determination of the link margin available for a given radio link. While it is possible for a radio link to work properly with 0 dB of link margin, it is undesirable to design a system with little or no link margin. Link budget calculations often rely on estimates of loss factors and interference levels and may not be accurate. In addition, over time, the conditions of the link may change, resulting in additional path loss or new sources of interference, which could render the link unreliable. In practice, allowing for 15 dB of link margin should result in a reliable link at installation and provide tolerance for changes over time. Use *Equation 5*, *Equation 6*, and *Equation 7* to calculate link margin.

$$\text{RX Signal Strength (dBm)} = \text{TX Power (dBm)} - \text{Line Loss}_{FLR}\ \text{(dBi)} - \text{Attenuation}_{FLR}\ \text{(dB)} + \text{Antenna Gain}_{FLR}\ \text{(dBi)} - \text{Path Loss (dB)} + \text{Antenna Gain}_{FLT}\ \text{(dBi)} - \text{Line Loss}_{FLT}$$

Equation 5

$$\text{Effective RX Sensitivity (dBm)} = \text{RX Sensitivity (dBm)} - \text{Interference Margin (dBm)}$$

Equation 6

$$\text{Link Margin (dB)} = \text{RX Signal Strength (dBm)} - \text{Effective RX Sensitivity (dBm)}$$

Equation 7

Link Budget Calculation Example

The SEL-FR12 antenna is mounted half-way up a utility pole and the SEL-FT50 is located 1.61 km (1 mi) away. There is approximately 40 percent obstruction within the Fresnel zone. There is also another 900 MHz radio nearby that has moderate interference.

System

SEL-FT50 Average Transmit Power: +16 dBm

SEL-FT50/SEL-FR12 Receive Sensitivity: –97 dBm

SEL-FT50 Antenna Gain: 0 dBi (integrated into transmit power specification)

SEL-FR12 Antenna: +7.15 dBi

3.05 m (10 ft) of LMR-400 Coaxial Cable: –0.39 dB

Radio Surge Protector (SEL part number 200-2004): –0.25 dB

Path

Obstruction Loss: –5 dB

Polarization Loss: 0 dB

Fading Loss: –6 dB

Interference Margin: –6 dB

Free-Space Path Loss (Equation D.3)

FSPL (dB) = 32.51 + 20log915 (MHz) + 20log1.61 (km)

FSPL (dB) = –95.8 (dB)

Path Loss (Equation D.2)

Path Loss (dB) = –95.8 (dB) – 5 (dB) + 0 (dB) – 6 (dB)

Path Loss (dB) = –106.8 (dB)

Receive Signal Strength (Equation D.5)

RX Signal Strength (dBm) = +16 (dBm) – 0.39 (dBi) – 0.25 (dB) + 7.15 (dBi) – 106.8 (dB) – 0 (dBi) + 0 (dB)

Effective RX Sensitivity (dBm) = –84.3 (dBm)

Effective Receive Sensitivity (Equation D.6)

Effective RX Sensitivity (dBm) = –97 (dBm) – (–6 (dB))

Effective RX Sensitivity (dBm) = –91 (dBm)

Link Margin (Equation D.7)

Link Margin (dB) = –84.3 (dBm) + 91 (dBm)

Link Margin (dB) = 6.7 (dB)

A link margin of 6.7 dB is likely to provide insufficient coverage for this application. Consider increasing the SEL-FR12 antenna gain, and changing the location of the SEL-FT50 to avoid obstructions.

Appendix D: SEL-RP50 Fault Repeater Detailed Implementation

The SEL-RP50 Fault repeater provides a method to help break the line-of-sight restrictions for SEL-FT50 to SEL-FR12 wireless communications paths. This appendix provides details on where SEL-RP50s can help, and where they might not. Example system example diagrams explain configuration details.

In situations where obstacles such as trees, terrain, or buildings are blocking line-of-sight from one or more SEL-FT50s, consider installing one or more SEL-RP50 Fault Repeaters per SEL-FT50 on the same feeder as the obscured SEL-FT50s. The repeaters will generally be installed in sets of three. *Figure 33* shows a distribution system with two SEL-FT50 Trios, and one SEL-FR12. The SEL-FT50s nearest the substation have unobstructed line-of-sight back to the SEL-FR12 antenna. The other SEL-FT50 Trio (lower right part of diagram) is obscured by terrain, and there is no line-of-sight path. A set of three SEL-RP50s installed on the same branch in a location with a good line-of-sight to both the SEL-FT50s and the SEL-FR12 antenna will enable the signals from this SEL-FT50 trio to get around the obstacle.

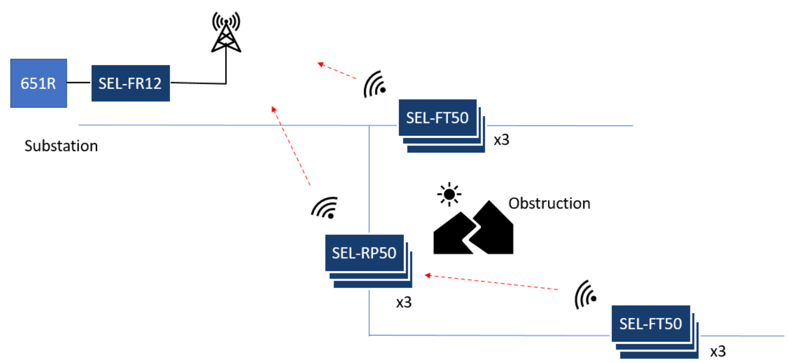


Figure 33 Using SEL-RP50s to get around one obstacle

Some key points to consider:

- SEL-RP50s are not available in all areas. See *Table 13*.
- Each SEL-RP50 only repeats signals from one SEL-FT50, or another SEL-RP50 with matching Unit ID and Network ID. See *Figure 34* and *Figure 35*.
- SEL-FT50s and SEL-RP50s operate using harvested line current, devices with matching Unit IDs must be installed on the same electrical phase
- The SEL-RP50s sharing a Unit ID with an SEL-FT50 must be installed so fault current passes through all devices.
- Each site with three SEL-RP50s can repeat the messages from one SEL-FT50 Trio, or from another SEL-RP50 Trio.
- Up to five sequential SEL-RP50 sites can be installed per SEL-FT50 Trio.
- A maximum (but unlikely) configuration would include one SEL-FR12, twelve SEL-FT50s, and sixty SEL-RP50s.
- When the feeder is deenergized the SEL-RP50s are unable to operate. When a feeder is powered up to a low load condition, the SEL-RP50 wireless repeaters are in a sleep state and do not continually operate. In this state they are still able to wake up and repeat incoming fault messages.

- ➤ When the SEL-RP50 is in sleep mode (see below) a single SEL-RP50 needs up to 30 minutes to synchronize to the link messages coming from the SEL-FT50. If more than one SEL-RP50 is present (with the same Unit ID) the link message synchronization period repeats for each SEL-RP50.
- ➤ The SEL-FT50 and SEL-RP50 are non-directional devices. They operate the same for load or fault current flowing in either direction.
- ➤ In systems that might be supplied by more than one source (during maintenance after automatic restoration) the SEL-RP50s might not be in a radial direction to the SEL-FT50. In this case a fault might trigger an SEL-FT50, but the fault current may not have passed through the SEL-RP50s and the SEL-RP50s might be asleep or off, and be unable to repeat the fault.
- ➤ Multiple SEL-FR12s may be used, since the SEL-FR12 is only a receiver they will not affect each other.
- ➤ Only one SEL-RP50 can be used with any SEL-FT50 manufactured before May 2021 (use he repeater ID = Legacy setting)

Refer to *Figure 34* for a settings example for simple SEL-FT50, SEL-RP50, and SEL-FR12 system. The diagram breaks the feeder one-line to show individual phases, and to provide the important detail on phase and Unit ID matching between each SEL-FT50 and SEL-RP50. In other diagrams the three SEL-FT50s or SEL-RP50s are drawn in a stacked manner to allow the diagram to be less-cluttered. The key information:

- ➤ Each SEL-RP50 only repeats signals with a single Unit ID and matching Network ID
- ➤ Install each SEL-RP50 on the same electrical phase as the SEL-FT50, and configure with the same Unit ID.
- ➤ Configure the SEL-RP50 nearest the SEL-FT50 with Repeater ID = 1
- ➤ Increase the Repeater ID each step towards the SEL-FR12 (2, 3, 4, up to 5)
- ➤ All devices must be set to the same Net ID as the SEL-FR12

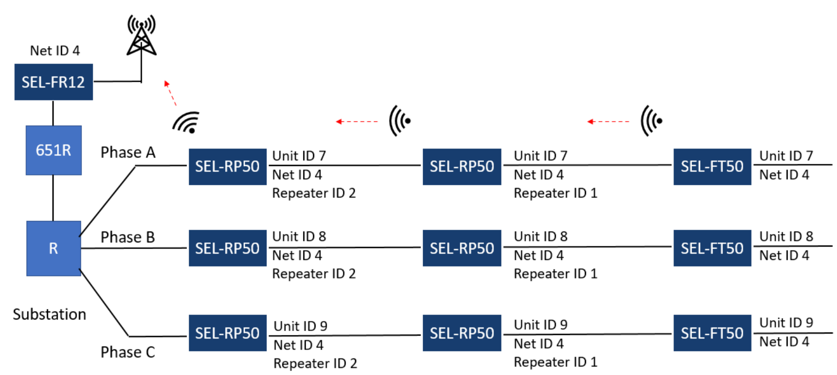


Figure 34 Selection of Unit ID, Net ID, and Repeater ID

Figure 35 shows a feeder one-line diagram on a plan view of an idealized geographic area. There are 4 SEL-FT50 Trios, but three of them do not have line-of-sight back the SEL-FR12 antenna.

In this system there are also twelve SEL-RP50s

- ➤ Trio 1 can directly reach the SEL-FR12

➤ Trio 2 uses two SEL-RP50 sites to reach the SEL-FR12 because of a forested area

➤ Trio 3 uses one SEL-RP50 site to reach the SEL-FR12 because of a forested area

➤ Trio 4 uses one SEL-RP50 site to reach the SEL-FR12 because of a mountain

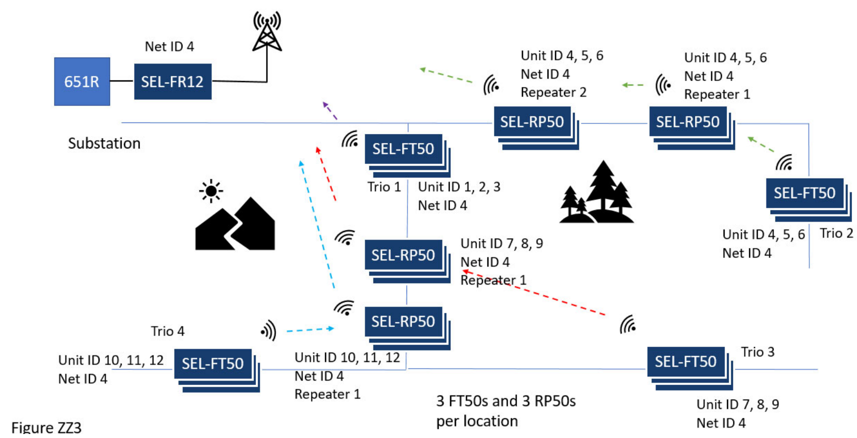


Figure 35 Energy Harvesting and SEL-RP50 Power States

The SEL-RP50 harvests energy from line current, just like the SEL-FT50.

➤ In low-load or dead-line conditions (below 5 A) there is insufficient energy available to operate the SEL-RP50. This is called the Off State.

➤ In moderate load conditions, where line currents are between 5 A and approximately 40 A, the SEL-RP50 is operating in a reduced energy mode, called the Sleep State.

➤ In regular load states, above approximately 40 A, the SEL-RP50 is fully functional, called the Awake State.

➤ During high load current or fault current conditions, energy harvesting still occurs.

➤ From the Off state and the Sleep state, a power system fault will wake up the SEL-RP50 almost instantly, and it will be listening for a fault message from the SEL-FT50 (or another SEL-RP50).

➤ If the SEL-RP50 receives a fault message (from a device with matching UNIT ID and NET ID) it will prepare to retransmit the message, and then transmit after a brief delay. The delay is a function of the Repeater ID setting, and avoids wireless signal collisions that would prevent the message from getting through the system to the SEL-FR12.

➤ When the fault current ends the SEL-RP50 will return (or stay) in an operating state that corresponds to the line current.

➤ If the SEL-RP50 is not installed on the same electrical phase as the SEL-FT50 with shared unit ID, it will not experience the same load and fault current. If the SEL-RP50 is in the Off State or Sleep State, it will not be able to wake up to hear receive any fault messages. This is why it is important to install the SEL-RP50s on the same phase as the SEL-FT50 (with matching Unit ID).

Link Message repeating:

- When a feeder is powered up to a low load condition, the SEL-RP50 wireless repeaters are in a sleep state and do not continually operate. In this state they periodically turn on the radio to listen for Link signals, and then go back to sleep to save energy. The system is designed to eventually capture an incoming Link message and then synchronize the wake up timer.
- Once synchronized, the SEL-RP50 will wake up regularly in time to catch the incoming link message, and then retransmit the link message to the next device. This synchronization can take up to 30 minutes per SEL-RP50.
- A system with the maximum of five SEL-RP50s on the same Unit ID could take several hours for the SEL-FR12 **LINK** LED to illuminate. This delay is shorter if the SEL-RP50s nearest the feeder source (substation).
- When the SEL-RP50 is in the Awake mode there is no synchronization delay because the wireless receiver is on all of the time. If the load current later drops below the level needed to remain in the Awake state, the SEL-RP50 will remember the synchronization and should be able to keep transmitting link messages without needing to resynchronize.
- If the line current drops below the sleep state level, the SEL-RP50 shuts down, and when sleep level current later comes back, it must resynchronize.
- If the system is fully synchronized but the SEL-FT50 loses current for over one minute, it will stop transmitting Link messages. Any SEL-RP50s in the sleep state will lose synchronization. When the SEL-FT50 load current reappears and it resumes transmitting Link messages, all SEL-RP50s that are in sleep mode will need to resynchronize.
- During all of these resynchronization cases, the SEL-FT50/SEL-FR12 system still responds to faults, if the devices are installed on the proper phase, as shown in *Figure 35*.

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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