BreadCrumb® ES1 Version 11 User Guide

Model Family: BreadCrumb ES1
Model: ES1-2450R
Model: ES1-5050CS
User Guide Version: 11.25 Rev A
Firmware Version: 11.25.0
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Document Revision History

Revision	Date	Changes
11.21 Rev A	07/30/2019	Initial Release of document.
11.21 Rev B	08/07/2019	Update firmware rev and EULA.
11.21 Rev C	08/14/2019	Add DIN rail kit part number.
11.22 Rev A	09/30/2019	Update version, certifications.
11.22 Rev B	04/24/2020	Add Maximum Certified Power Table for Japan.
11.22 Rev C	09/21/2020	Add Ethernet port pinout.
11.22 Rev D	11/05/2020	Correct Status LED descriptions.
11.22 Rev E	11/19/2020	Add Maximum Certified Power Table for UAE and Kenya.
11.22 Rev F	01/12/2021	Add Maximum Certified Power Table for Columbia.
11.23 Rev A	02/09/2021	Add Maximum Certified Power Table for Indonesia.
11.23 Rev B	02/23/2021	Add Maximum Certified Power Table for Brazil (Anatel).
11.23 Rev C	02/24/2021	Add Maximum Certified Power Table for Malaysia.
11.23 Rev D	04/26/2021	Add Maximum Certified Power Table for India. Update BreadCrumb Model Matrix.
11.23 Rev E	05/25/2021	Update Maximum Certified Power Table for Japan.
11.23 Rev F	07/25/2021	Add Maximum Certified Power Table for Mexico.
11.24 Rev A	12/03/2021	Add Maximum Certified Power Table for Philippines. Add ES1-5050CS model. Update Maximum Certified Power Table for Mexico.
11.25 Rev A	05/26/2022	Add FCC and IC Compliance for ES1-5050CS. Update FCC, IC and CE Maximum Certified Power specifications.

Copyright Statement

BreadCrumb® ES1 Version 11 User Guide

FCC, IC, CE and Other Certification Statements

FCC ID:

FCC ID: VJA-ES12450R, Model ES1-2450R FCC ID: VJA-ES15050CS, Model ES1-5050CS

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the device is operated in a commercial environment. This device generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with this instruction manual, may cause harmful interference to radio communications. Operation of this device in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at their own expense.

⚠ WARNING
Any changes or modifications not expressly approved by the party responsible for compliance could void your authority to operate the equipment.

For FCC Maximum Permissible Exposure (MPE), refer to International Electrotechnical Commission (IEC) Technical Report (TR) 63170:2021-1044.

Industry Canada (IC):

IC: 7382A-ES12450R, Model ES1-2450R IC: 7382A-ES15050CS, Model ES1-5050CS

This device complies with ISED licence-exempt RSS standard(s).

Operation is subject to the following two conditions:
1) This device may not cause interference
2) This device must accept any interference, including interference that may cause undesired operation of the device.

This product meets the applicable Innovation, Science and Economic Development Canada technical specifications. CAN ICES-003 (A)/NM-003(A)

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:
1) This device may not cause interference, and
2) This device must accept any interference, including interference that may cause undesired operation of the device.

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, meme si le brouillage est susceptible d'en compromettre le fonctionnement.

Radiation Exposure Statement:
This equipment complies with IC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 32cm between the radiator & your body.

Déclaration d'exposition aux radiations:
Cet équipement est conforme aux limites d'exposition aux rayonnements IC établies pour un environnement non contrôlé. Cet équipement doit être installé et utilisé avec un minimum de 32cm de distance entre la source de rayonnement et votre corps.

RCM:

This digital apparatus complies with the Australian/New Zealand AS/NZS 4268: Radiocommunications (Short Range Devices) Standard 2004 +A1:2013 +A2:2013.

Anatel:

Compliance Information (ANATEL): Este equipamento não tem direito à proteção contra interferência prejudicial e não pode causar interferência em sistemas devidamente autorizados. Para maiores informações, consulte o site da ANATEL – http://www.anatel.gov.br.

CE:

Rajant Corporation declares that the ES1-2450R and ES1-5050CS are in compliance with the essential requirements and other relevant provisions of Directive 2014/53/EC.

IMPORTER - CMI Corporation Limited
Catteshall Road,Godalming, Surrey GU7 INJ, UK

CE Declaration of Conformity may be requested from Rajant.

NOTE
Please refer to the product spec sheet at http://www.rajant.com for a list of certified model numbers.

Antennas

Antenna Installation WARNING
The installer should configure the conducted output power level according to country regulations and the applicable equivalent isotropically radiated power (EIRP) limit. Professional installation of equipment is required to ensure compliance with health and safety issues.

Required Antenna Separation

The antennas from any transceiver of the BreadCrumb ES1 may not be co-located with the antennas of any other transceiver. The co-location restriction is satisfied by maintaining 20 cm separation between the antennas of different transceivers. There is no restriction for the separation between the antennas from the same transceiver; but testing at installation is recommended to verify the system performance achieved with a specific antenna deployment.

Warning
Because the BreadCrumb ES1 case is plastic, antennas should not be directly attached and should be attached using only antenna cables. This is to avoid stressing the plastic and compromising the IP67 ingress rating. Low loss cable, such as LMR-400, is recommended for externally attached antennas.

Warning
For all BreadCrumb models, for installations that will experience vibration or shock, all antennas should be externally mounted and attached using cables. Low loss RF cable, such as LMR-400, is recommended for cable attached antennas.

Warning
If a radio port is not required for a given application, the port should be disabled in BC|Commander and a 50 Ohm terminator should be installed.

Figure: Incorrect Antenna Placement

⚠ IMPORTANT: Exposure to Radio Frequency Radiation
To satisfy FCC RF exposure requirements, a minimum safe distance of 32cm must be maintained between this device's antennas and all persons while the device is operating.

DFS Additional Antenna Separation
For 5 GHz transceivers using channels that require DFS radar detection, it is recommended to mount each antenna for a DFS channel at least 2 feet from any other 5 GHz transceiver's antenna.

Safety

⚠ Warning
The BreadCrumb ES1 is not user serviceable. Repairs must be performed at a Rajant-designated service center by trained personnel.

⚠ Warning
To protect the user against the risk of electric shock during high-voltage transient events which may occur when this equipment is installed outdoors, protective earth grounding of the Power over Ethernet (PoE) power supply is required. Case ground connections are provided on all Rajant-supplied PoE power supplies. The case ground connections must be used and must be connected to a protective earth ground. Protective earth grounding operations must be performed by trained personnel according to local electrical codes and industry best practices, as well as Rajant's own recommendations.

Modifications

⚠ CAUTION
Changes or modifications not expressly approved by Rajant Corporation could void the user's authority to operate the equipment.

Rajant products are compliant and warranted against manufacturing defects only so long as Rajant-authorized accessories are used in deployment of Rajant Breadcrumbs. It is the responsibility of the operator and the installer to ensure the system as installed operates within regional requirements.

Professional Installation Attestation

Rajant Corporation addresses the following items to ensure that the above referenced equipment is professionally installed:

- The device will only be sold by Rajant Corporation or one of its authorized dealers. Rajant Corporation and its authorized dealers will be under strict marketing control and will only market and sell the device to professionals.
- Professional installation is required for this device and will be performed only by someone knowledgeable of its use. Rajant Corporation will ensure that the device is only marketed and sold to

professionals.
- The device is not sold to the general public and is sold only for industrial or commercial use by professional installers.

⚠ CAUTION
To reduce potential radio interference to other users, the antenna type and its gain should be chosen so that the equivalent isotropically radiated power (EIRP) is not more than that permitted for successful communication.

Maximum Certified Power

ISM band radio modules may be operated at full certified power when configured with the granted antenna type. Operation of a radio at power levels that exceed the equivalent EIRP of the granted configuration is prohibited. See the following tables.

Table: Maximum Certified Power: FCC (United States)

Model ES1-2450R

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	26 (Average)	Omni-directional	5	31
5150-5250	(Average)	Omni-directional		
5180-5240	23 (Average)	Omni-directional	7	30
5725-5850	(Average)	Omni-directional		
5745-5825	25 (Average)	Omni-directional	6	31

Model ES1-5050CS

The bands being certified for ES1-5050CS are 4.9 GHz and 5 GHz (B1 through B3).

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
4940-4990	(Average)	Omni-directional		
5150-5250	(Average)	Omni-directional		
5180-5240	23 (Average)	Omni-directional	7	30
5250-5350	(Average)	Omni-directional		
5470-5725	(Average)	Omni-directional		
5725-5850	(Average)	Omni-directional		

Table: Maximum Certified Power: IC (Canada)

⚠ IMPORTANT
In Canada, a license is required to use channels in the frequency range 5150-5250 MHz (on models that offer these channels). The license may restrict transmit power. Licensing information may be found at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11294.html

Model ES1-2450R

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	26 (Average)	Omni-directional	5	31
5180-5240	23 (Average)	Omni-directional	7	30
5745-5825	25 (Average)	Omni-directional	6	31
5725-5850	(Average)	Omni-directional		

Model ES1-5050CS

The band being certified for ES1-5050CS is 5 GHz (B3).

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
5745-5825	25 (Average)	Omni-directional	6	31
5725-5850	(Average)	Omni-directional		

Table: Maximum Certified Power: CE (Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey)

⚠ IMPORTANT: Regarding indoor-only frequencies
In regions where radio frequencies are regulated by ETSI (CE), the frequency range 5170-5350 MHz is restricted to indoor use only. Check local regulations before using these channels.

⚠ IMPORTANT
In many regions where radio frequencies are regulated by ETSI (CE), a license is required to use channels in the frequency range 5735-5835 MHz (on models that offer these channels). Check local regulations before using these channels.

Model ES1-2450R

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
2412-2472	15 (Peak burst)	Omni-directional	5	20
5500-5700	24 (Average)	Omni-directional	6	30
5725-5875	26 (Average)	Omni-directional	6	32

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
5740-5860	(Average)	Omni-directional		

Model ES1-5050CS

The bands being certified for ES1-5050CS are 5 GHz (B1 through B3).

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
5180-5240	(Average)	Omni-directional	7	22.73
5260-5320	(Average)	Omni-directional	7	22.79
5500-5700	(Average)	Omni-directional	6	29.86
5725-5875	(Average)	Omni-directional	6	34.63
5740-5860	(Average)	Omni-directional		

- Electrostatic discharge (ESD) immunity testing compliant to EN 61000-4-2
- Electrical fast transient (EFT) / burst immunity testing compliant to EN 61000-4-4
- Surge immunity testing compliant to EN 61000-4-5

Table: Maximum Certified Power: RCM (Australia, New Zealand)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	29 (Average)	Omni-directional	5	34
5745-5825	29 (Average)	Omni-directional	6	35

Table: Maximum Certified Power: MIC (Japan)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Antenna Type	Antenna Gain (dBi)	EIRP (dBm)
2412-2472	16 (Average)	Omni-directional	5	21
5180-5240	21 (Average)	Omni-directional	7	28
5500-5700	15 (Average)	Omni-directional	6	21

Table: Maximum Certified Power: UAE (United Arab Emirates) (ETSI EN 301 893)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	11 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	16
5500-5720	22 (Average)	Point-to-Multipoint	Omni-directional	KMA-5550-6 or equivalent	6	28
5745-5825	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	30

For more information regarding the UAE Regulations, go to https://www.tra.gov.ae/ar/abouttra/telecommunication-sector/regulations-and-ruling/details.aspx#documents.

Table: Maximum Certified Power: (Kenya)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	8 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	13
5500-5720	22 (Average)	Point-to-Multipoint	Omni-directional	KMA-5550-6 or equivalent	6	28
5745-5825	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	30

Table: Maximum Certified Power: (Columbia)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	22 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	27
5180-5240	17 (Average)	Point-to-Multipoint	Omni-directional	KMA-5250-7 or equivalent	7	24
5745-5825	18 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	24

Table: Maximum Certified Power: (Brazil) Anatel

⚠ IMPORTANT: Regarding indoor-only frequencies

In regions where radio frequencies are regulated by Anatel, the frequency range 5150-5350 MHz is restricted to indoor use only. Check local regulations before using these channels.

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	23 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	28
5150-5250	18 (Average)	Point-to-Multipoint	Omni-directional	KMA-5250-7 or equivalent	7	25
5745-5825	21 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	27

Table: Maximum Certified Power: (Indonesia)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2472	15 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	20
5745-5825	14 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	20

Table: Maximum Certified Power: (Malaysia)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2472	22 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	27
5180-5240	22 (Average)	Point-to-Multipoint	Omni-directional	KMA-5250-7 or equivalent	7	29
5500-5620	23 (Average)	Point-to-Multipoint	Omni-directional	KMA-5550-6 or equivalent	6	29
5745-5825	23 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	29

Table: Maximum Certified Power: (India)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	29
5180-5240	22 (Average)	Point-to-Multipoint	Omni-directional	KMA-5250-7 or equivalent	7	29
5500-5720	23 (Average)	Point-to-Multipoint	Omni-directional	KMA-5550-6 or equivalent	6	29
5745-5825	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	30

Table: Maximum Certified Power: (Mexico)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	23 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	28
5150-5250	17 (Average)	Point-to-Multipoint	Omni-directional	KMA-5250-7 or equivalent	7	24
5250-5350	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-5250-7 or equivalent	7	31
5470-5600	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-5550-6 or equivalent	6	30
5650-5725	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-5550-6 or equivalent	6	30
5745-5825	21 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	27

Table: Maximum Certified Power: (Philippines)

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
2412-2462	15 (Average)	Point-to-Multipoint	Omni-directional	KMA-2400-5 or equivalent	5	20

Frequency Range (MHz)	Total Conducted Channel Power (dBm)	Mode	Antenna Type	Antenna Detail	Antenna Gain (dBi)	EIRP (dBm)
5500-5720	24 (Average)	Point-to-Multipoint	Omni-directional	KMA-5550-6 or equivalent	6	30
5745-5825	25 (Average)	Point-to-Multipoint	Omni-directional	KMA-5800-6 or equivalent	6	31

GNU General Public License Statement

Certain components of the Rajant BreadCrumb firmware are subject to the GNU General Public License Version 2, or other so-called open source licenses (“Open Source Software”). In compliance with the terms of certain Open Source Software licenses like the GNU General Public License Version 2 (“GPLv2”), Rajant makes certain modifications to Open Source Software that Rajant uses, modifies and distributes pursuant to such licenses available to customers in source code form upon request. You are free to use, modify and distribute Open Source Software so long as you comply with the terms of the relevant Open Source Software license. In particular, the GPLv2 is available in the appendix of this manual or at http://www.gnu.org/copyleft/gpl.html.

Preface

Purpose and Scope

This manual provides information and guidance to all personnel who are involved with and use Rajant Corporation's BreadCrumb ES1-5050CS.

This manual begins with an introduction to the BreadCrumb Kinetic Mesh Network. It then characterizes the features of the BreadCrumb ES1-5050CS. Finally, it describes common deployment scenarios and provides concise step-by-step instructions for each scenario.

> **Note**
> Throughout this document, unless otherwise stated, the terms ES1-5050CS and BreadCrumb are used to refer to Rajant BreadCrumb ES1-5050CS.

How to Use This Guide

This User Guide is an HTML document to be viewed using a web browser. The browser's right scroll bar, mouse scroll wheel, up/down cursor keys or Page Up/Page Down keys may be used to navigate sequentially forward or backward through the guide. In most browsers, CTRL-F can be used to search the guide and navigate to matching text. The Table of Contents at the left (or top in a small window) contains a link to the start of each chapter or appendix. After a web link or cross-reference is clicked in the guide, the browser's back arrow should return to the previous page location.

Feedback Welcome

The user of this manual is encouraged to submit comments and recommended changes to improve this manual and all Rajant products. Please send your feedback to feedback@rajant.com. Please be sure to include the version and revision number of the manual or product you are using as well as the relevant document section numbers if appropriate.

Related Documentation

For additional information, refer to these documents:

- BC|Commander® Version 11 User Guide: This document describes how to use the BC|Commander application to configure and monitor BreadCrumbs.
- BreadCrumb® Video Guide
- Range Troubleshooting Guide
- BreadCrumb RF Guide
- BreadCrumb® Security Technical Brief

These documents are available in the support section of Rajant's website at http://www.rajant.com.

Note About Shared Guide Content

Rajant BreadCrumb models have some differences in hardware and software features. Rajant hardware and software product guides include some general content that is shared between guides and may include features or settings not found in every model. The following table summarizes the main differences between several standard BreadCrumb models.

Feature	LX5	ME4/KM3	ES1	JR3	SlipStream	Peregrine/ Hawk
Wireless Transceivers	3-4	2	2	1	0	4 (Peregrine) /2 (Hawk)
Ethernet	2x 1000	1x 1000, 1x 100	1x 1000	1x 100	2x 100/1000	2x 10/100/1000 auto MDIX

Feature	LX5	ME4/KM3	ES1	JR3	SlipStream	Peregrine/ Hawk
Input Voltage	18-48 VDC	8-48 VDC (ME4)/24-48 VDC (KM3)	9-30 VDC	9-30 VDC	12 VDC	20-60 VDC
Min. Recommended PoE	24-48 VDC, 26-33 W @ 24 V (3-4 radios, un-heated)	24-48 VDC, 23 W @ 24 V	24 VDC, 19 W	24 VDC, 19 W	(AC adapter)	50 W
USB Ports	2	1	1	0	6	1
Serial Port	no (see Notes)	no (see Notes)	no	no	no	no
Realtime Clock	yes	yes	no	no	yes	yes
Case	metal	metal	plastic	plastic	metal	metal
Environment	IP67	IP67(ME4)/Indoor(KM3)	IP67	Weather Resistant	Indoor	IP67
Encryption	HW/SW	HW/SW	SW	SW	HW/SW	HW/SW
TRoIP	yes	yes	yes	no	yes	yes
Modbus	yes	yes	yes	no	yes	yes
SNMP	yes	yes	yes	no	yes	yes
Packet Capture	yes	yes	yes	no	no	yes
Gateway Mode	yes	yes	yes	no	yes	yes
Performance Tests	yes	yes	yes	no	yes	yes
Max Peers per Transceiver	250+	250+	250+	50	0	250+
RTLS (see Notes)	yes	yes	yes	no	no	yes

Notes:

- Ethernet ports also adapt to standard slower speeds.
- Unless stated otherwise, all PoE wattages are @ 24 V.
- Add 2 W per heated radio and 2.5 W per powered USB peripheral.
- JR2 included TRoIP settings but no USB port for using TRoIP.
- Performance Tests are available with firmware version 11.19 or later.
- KM3 is an indoor version of ME4.
- To provide a serial port, ME4 has serial pins documented on the Amphenol connector and supports modbus protocol on that connector.
- To provide a serial port, ME4 can use an optional cable assembly with serial pins.
- To provide a serial port, KM3 requires a special USB cable.
- To provide a serial port, LX5 has serial pins documented on the Amphenol connector and supports modbus protocol on that connector.
- Real Time Location System (RTLS)

1. Introduction to BreadCrumbs

Rajant Corporation's (http://www.rajant.com) BreadCrumbs utilize the IEEE 802.11 (Wi-Fi) wireless networking standards to form a wireless mesh network. The network is mobile, self-integrating, self-meshing, self-healing and secure. The focus is on flexibility, adaptability and simplicity.

The BreadCrumb Kinetic Mesh Network is intended for rapid deployment of a broadband wireless network into a situation or "hot zone." The network can be deployed as a stand-alone wireless network or bridged to another network (such as the Internet) utilizing available reach-back communication links (such as a DSL, cable, or satellite modem).

BreadCrumbs provide high bandwidth for applications to stream video, audio and data over large distances. The network traffic can be secured by using different security features available on the BreadCrumb. This makes the network optimal for tactical deployments as well as emergency response situations since it offers robustness, stability and ease of setup in mission critical activities.

1.1 What is a BreadCrumb?

A BreadCrumb is an IEEE 802.11 (Wi-Fi) and Ethernet compatible networking device that can connect to other BreadCrumbs or networking devices to form a BreadCrumb network. The BreadCrumb is specifically designed for the following scenarios:

- **Temporary Wireless Network:** Network that must be established quickly and with minimal effort for short-term use (e.g., a temporary network established in a tactical situation).
- **Mobile Wireless Network:** Network in which the network infrastructure itself is mobile, in addition to client devices (e.g., a convoy viewing a video stream from an unmanned aerial vehicle (UAV).
- **Wireless Network Extension:** Extension to a wireless network to quickly enable wireless communication around or through an obstacle (e.g., urban canyon, tunnels/caves, etc.)
- **Wired Network Extension:** Wireless connection between two or more wired local area networks (LANs) at different locations (e.g., to securely connect combat service support computers with logistics bases)
- **Any combination of the above:** Most BreadCrumb deployments include elements from more than one of these scenarios.

In many cases, BreadCrumbs will perform all of these tasks as shipped with no configuration necessary, providing an instant Tactical Area Network (TAN). Moreover, because BreadCrumbs use industry-standard 802.11 communication protocols, client devices (such as laptops or cell phones) require no special hardware or software and little or no configuration to access a BreadCrumb network.

> **Note**
> Although any BreadCrumb can be an access point, most access points do not provide mesh capability. Traditional access points simply allow wireless devices within range to connect to a wired network; traditional access points do not extend range through other access points.

1.2 The Mesh Network

The key feature of a BreadCrumb Mesh network is the ability for BreadCrumbs to connect, or mesh, with each other. While meshing is generally handled automatically by BreadCrumbs, complex deployment scenarios require a basic understanding of how BreadCrumbs establish and maintain a mesh.

1.2.1 Mesh – A Definition

A mesh is a collection of BreadCrumbs (or other network devices), each of which is linked to one or more other BreadCrumbs. Data can move between BreadCrumbs via these links, possibly passing through several intermediate BreadCrumbs before arriving at a final destination.

The intelligence of a BreadCrumb network is demonstrated by the rapid creation or destruction of links in the mesh as devices are moved, switched OFF or ON, blocked by obstructions, interfered with by other

devices, or otherwise affected. This adaptation takes place automatically and immediately as needed.

1.2.2 BreadCrumb Mesh Connections

In order for two BreadCrumbs to establish a mesh link to each other, both BreadCrumbs must be set to the same radio channel and have the same Network ID. The Network ID is computed from:

- Network Name (simply a configurable name for the network; default value is “Rajant Mesh Network”)
- Network Key (passphrase or key used to establish mesh connections and obfuscate unencrypted network management traffic)
- Packet cipher setting
- MAC cipher setting
- Per-hop verification setting
- Key Sequence Number (default value is 0)

To modify these BreadCrumb configuration settings, a BC|Commander user must be logged in to the BreadCrumbs with the User role **co (Crypto Officer)** and the corresponding password.

2. Description of a BreadCrumb ES1

BreadCrumb ES1 is a fixed and mobile wireless device for use in indoor, protected and outdoor locations. BreadCrumb ES1 is light-weight, supports up to 4 external antennas and is designed to be completely mobile. The BreadCrumb ES1 must be powered by an external passive Power over Ethernet (PoE) source.

2.1 Radios

The BreadCrumb ES1 contains two radios. See Appendix Radio Channels and Frequencies for a list of the channels and frequencies supported by each radio.

2.2 Enclosure

2.2.1 Enclosure Design

The ES1-5050CS enclosure is made of plastic (ASA UL94-HB) and has been designed for IP67 ingress protection against ingress of dust and water when installed with the approved mating connectors.

> **Notice**
> The ES1-5050CS nust be installed with the approved mating connectors. Ingress protection rating may be adversely affected due to exposure to direct sunlight for extended periods. Excessive shock and vibration or temperature extremes or fluctuations may void the manufacturer's warranty.

For information on the approved BreadCrumb ES1 sealed male Ethernet connector and cables, see Ethernet Connector.

For information on the approved BreadCrumb ES1 sealed protective cap and male M8 cables, see M8 Connector.

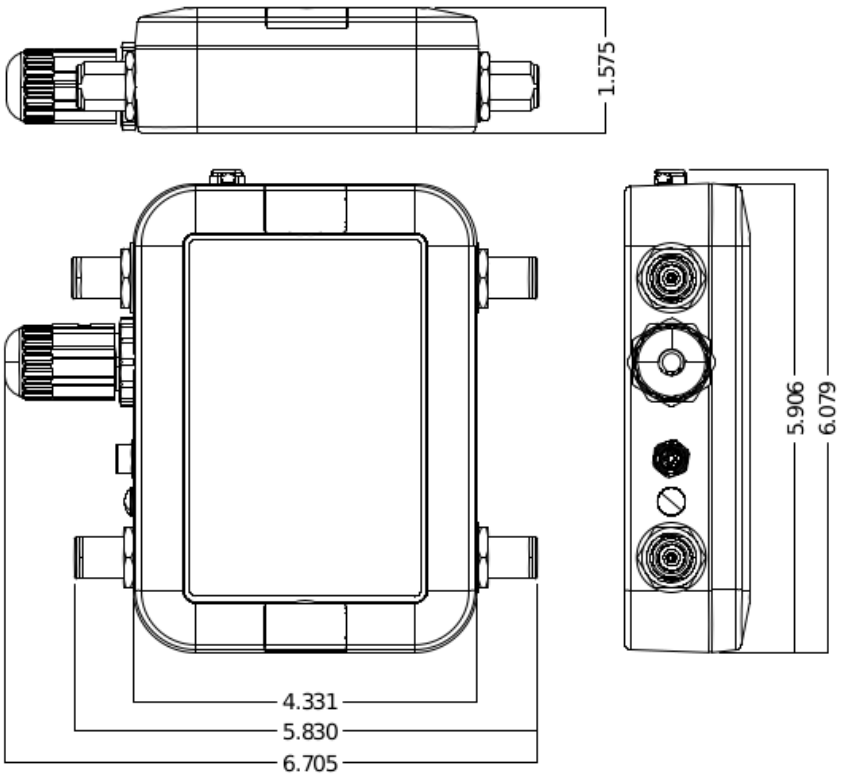
The operating temperature range for the enclosure is -40 to 60 degrees C (-40 to 140 degrees F). The storage temperature range for the enclosure is -40 to 70 degrees C (-40 to 158 degrees F).

The dimensions of the ES1-5050CS are 155 mm x 149 mm x 41 mm (6.079 inches x 5.830 inches x 1.575 inches) including all built-in features of the enclosure. These measurements do not include any antennas, cables or mating sealed Ethernet connector.

The weight of the ES1-5050CS is 440 g +/- 10 g (15.5 oz +/- 0.4 oz), depending on the transceiver configuration.

Figure: BreadCrumb ES1 Measurements in Inches (1 in = 2.54 cm)

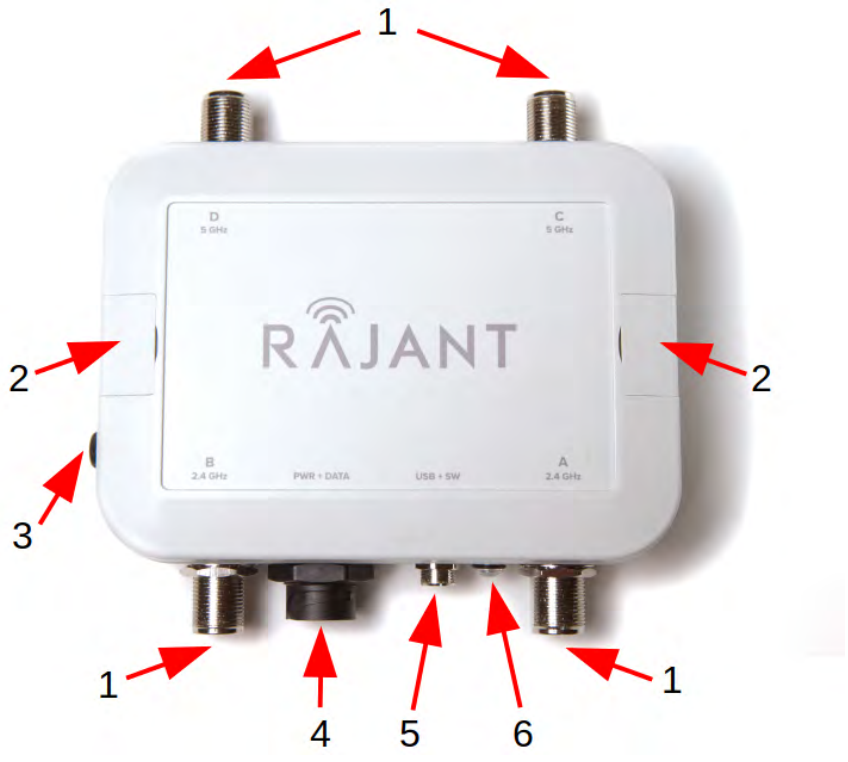
> **Note**
> The BreadCrumb ES1 is shown with a mating sealed Ethernet connector attached.



2.2.2 Enclosure Front

The following figure indicates the external features on the front of the BreadCrumb ES1 enclosure for a four-antenna model. A model that needs only three antennas will have three antenna connectors instead of four.

Figure: BreadCrumb ES1 Enclosure Front



(1) Up to four type N female antenna connectors

(2) Two flip-open accesses to mounting holes

(3) Protective vent

(4) ETH0 RJ45 female, receives power via Ethernet Passive PoE

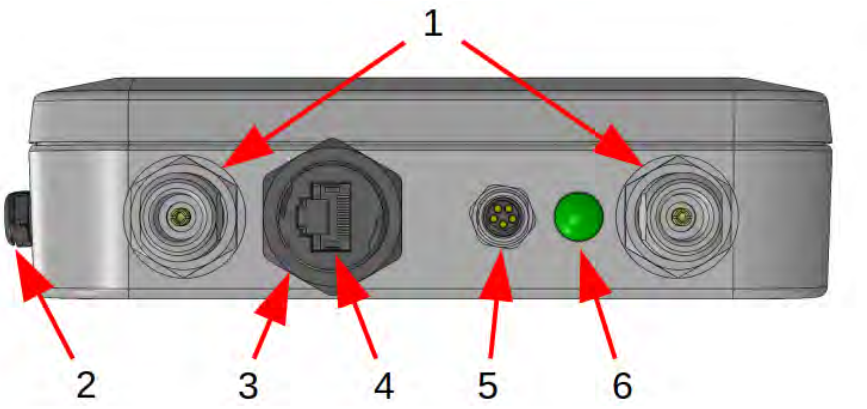
(5) 5-pin female M8 connector for Universal Serial Bus (USB) (and optionally reset) adapter cables

(6) Status light-emitting diode (LED) to indicate BreadCrumb status

2.2.3 Enclosure Bottom

The following figure indicates the external features on the bottom of the BreadCrumb ES1 enclosure.

Figure: BreadCrumb ES1 Enclosure Features (Bottom)



(1) Two (of up to four) type N female antenna connectors

(2) Protective vent

(3) Built-in half of sealed Ethernet connector

(4) ETH0 RJ45 female, receives power via Ethernet Passive PoE

(5) 5-pin female M8 connector for USB (and optionally reset) adapter cables

(6) Status LED

2.3 Antenna Connectors

The BreadCrumb ES1 provides up to four Type N female antenna connectors. Two antenna connectors are located on the top of the enclosure and two on the bottom of the enclosure.

Many BreadCrumb radios offer antenna diversity or Multiple-Input Multiple-Output (MIMO) features, in which case two antenna ports per radio are utilized. Some radios utilize only one antenna port. Each antenna connector will be labeled with a unique letter (A, B, C or D) and the frequency of its corresponding radio.

Required Antenna Separation

The antennas from any transceiver of the BreadCrumb ES1 may not be co-located with the antennas of any other transceiver. The co-location restriction is satisfied by maintaining 20 cm separation between the antennas of different tranceivers. There is no restriction for the separation between the antennas from the same transceiver, but testing at installation is recommended to verify the system performance that is achieved with a specific antenna deployment.

> **⚠ Warning**
> Because the BreadCrumb ES1 case is plastic, antennas should not be directly attached and should be attached using only antenna cables. This is to avoid stressing the plastic and compromising the IP67 ingress rating. Low loss cable, such as LMR-400, is recommended for externally attached antennas.

⚠ Warning
For all BreadCrumb models, for installations that will experience vibration or shock, all antennas should be externally mounted and attached using cables. Low loss RF cable, such as LMR-400, is recommended for cable-attached antennas.

⚠ Warning
If a radio port is not required for a given application, the port should be disabled in BC|Commander and a 50 Ohm terminator should be installed.

DFS Additional Antenna Separation
For 5 GHz transceivers using channels that require DFS radar detection, it is recommended to mount each antenna for a DFS channel at least 2 feet from any other 5 GHz transceiver's antenna.

Figure: Incorrect Antenna Placement

Most of Rajant's standard antennas are characterized by high-gain and, therefore, small vertical beamwidth. Antennas in fixed locations should be installed plumb and at the same elevation so that BreadCrumbs using these antennas will see each other without a significant loss of signal strength.

⚠ Warning
To avoid possible damage to the BreadCrumb radio(s), always connect or disconnect external antennas with the power to the BreadCrumb turned off.

The following table lists the radio band and antenna port(s) for the BreadCrumb ES1 model. This information is also available in the Details panel in BC|Commander.

Table: BreadCrumb ES1 Radios and Antenna Ports

Model Number	wlan0	wlan1
ES1-5050CS-2450R	2.4 GHz: A+B	5 GHz: C+D
ES1-5050CS-5050CS	4.9 GHz: A+B	4.9 GHz: C+D
ES1-5050CS-5050CS	5 GHz: A+B	5 GHz: C+D

2.4 Power and Ethernet

2.4.1 Ethernet Port ETH0

The BreadCrumb ES1 has one RJ45 Ethernet port (ETH0). On the BreadCrumb ES1, port ETH0 supports 10 Base-T, 100 Base-TX or 1000 Base-T configurations for Ethernet data and supports both Mode A and Mode B for Passive Power over Ethernet (Passive PoE). Therefore, ETH0 acts as a dual function Ethernet and DC power input port for the BreadCrumb ES1.

The ETH0 port supports Auto MDI/MDIX allowing the use of either straight-through or crossover data cables for connections. The data interface includes electrostatic discharge, and electrical fast transient/burst immunity compliant to the IEC 61000-4-2, and IEC 61000-4-4-EFT standards, respectively.

For more information on the BreadCrumb ES1 sealed Ethernet connector, see Ethernet Connector.

2.4.2 Ethernet Port Pinout

On the BreadCrumb ES1, the Ethernet port supports both Mode A and Mode B for Passive PoE.

The following table indicates the pinout of the BreadCrumb ES1 Ethernet port for 1000BASE-T data and power functions.

Table: BreadCrumb ES1 Ethernet Port Pinout

Pin at ETH0	Gigabit Data, Power
1	TxRx A +, DC + (mode A)
2	TxRx A -, DC + (mode A)
3	TxRx B +, DC - (mode A)
4	TxRx C +, DC + (mode B)
5	TxRx C -, DC + (mode B)
6	TxRx B -, DC - (mode A)
7	TxRx D +, DC - (mode B)
8	TxRx D -, DC - (mode B)

2.4.3 Power Requirements

The BreadCrumb ES1 ETH0 port supports Passive PoE and, therefore, acts as a dual function Ethernet and DC power input port for the BreadCrumb ES1. An external inline passive PoE injector is used to merge DC power for the BreadCrumb ES1 with data from a LAN port or a wired client.

The average idle power consumption of a BreadCrumb ES1 is 2.8 W at 24 V. The maximum peak power consumption of BreadCrumb ES1 is 15 W at 24 V. Up to 2.5 W of additional power will be needed if a peripheral is being powered by USB (500 mA at 5 V is available at the USB port).

To ensure proper operation of the BreadCrumb ES1, the inline injector must output a DC voltage between 9 VDC to 30 VDC. Rajant recommends a minimum power supply of 19 W @ 24 VDC. Using a higher output voltage facilitates longer cable runs between the inline injector and the ETH0 port on the BreadCrumb ES1. For details on Rajant's VHDC-Series power accessories, refer to the VHDC-Series spec sheet.

Table: BreadCrumb ES1 Power Requirements (Passive PoE)

Input Voltage	Avg Idle Usage @ 24 V	Max Peak Usage @ 24 V
9 - 30 VDC	2.8 W + USB usage	15 W + USB usage

Table: BreadCrumb ES1 Power Supply Options

Model	Rajant Part Number	Type	Output Voltage (V)	Max. Output Current (A)	Ethernet Link Speed (Mbps)	Environmental

Model	Rajant Part Number	Type	Output Voltage (V)	Max. Output Current (A)	Ethernet Link Speed (Mbps)	Environmental
AC 24V	25-100168-001	AC to DC	24	0.8	10/100/1000	Non-sealed
AC 24V	25-100168-002	AC to DC	24	1.5	10/100/1000	Non-sealed
VHDC-24V-50W	01-000029-01	DC to DC	24	2.08	10/100	Sealed (IP67: dust-tight, waterproof)
VHDC-24V-50W-GbE	01-000037-002	DC to DC	24	2.08	10/100/1000	Sealed (IP66: dust-tight, water-resistant)
VHDC-24V-50W-LC	01-000033-01	DC to DC	24	2.08	10/100	Non-sealed
DC 24V	25-100173-001	DC to DC	24	1.0	10/100/1000	Non-sealed

⚠ Warning
The BreadCrumb ES1 cannot be powered with a 48 V PoE power supply. Using a PoE of higher voltage than the stated ES1-5050CS voltage range may damage the ES1-5050CS and void the warranty.

NOTE: Regarding 10/100 PoE power supplies
If a 10/100 PoE power supply is used to connect a gigabit-capable (1000 Mbps) BreadCrumb Ethernet port and a gigabit-capable (1000 Mbps) network switch, autonegotiation of Ethernet speed may be very slow or may result in failed negotiation and no link. In this case, set the BreadCrumb configuration Ports: ethX: Port Speed explicitly to 100 Mbps.

Additional information about Rajant power supply accessories can be found in the Power Accessories product spec sheet at www.rajant.com.

2.4.4 PoE Power Supply Usage

The laptop in these diagrams could instead be a non-PoE switch port connecting the BreadCrumb to a LAN.

Figure: BreadCrumb ES1 Ethernet and Passive PoE AC Connections

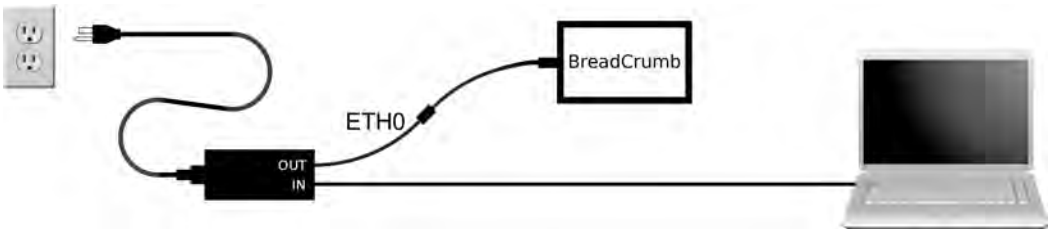
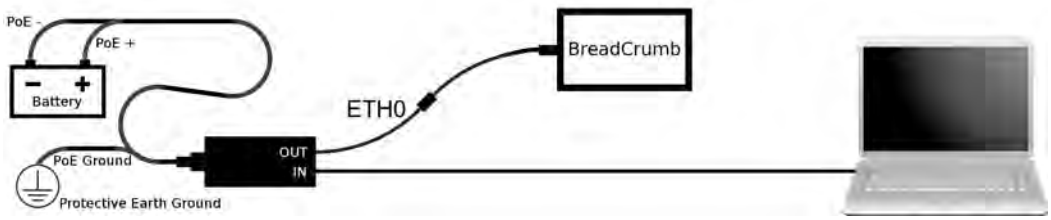


Figure: BreadCrumb ES1 Ethernet and Passive PoE DC Connections



The following steps describe the recommended best practice for connecting PoE power to the BreadCrumb ES1.

1. Disconnect power from the PoE power supply.
2. Connect PoE *Out* to BreadCrumb using a shielded Ethernet cable.
3. (Optional) Connect PoE *In* (aka *Data*) to a computer or a non-powered LAN Ethernet port.
4. Reconnect power to the PoE power supply.

⚠ Warnings: Regarding PoE Power Supply Connections
Unlike active PoE methods such as IEEE 802.3af/at, passive PoE does not include any kind of handshaking or voltage checking.
- Only connect the passive PoE power supply Output to the BreadCrumb. The output power over Ethernet can damage other devices and may damage the PoE power supply.
- Never connect the passive PoE power supply Output to an Ethernet port that supplies PoE power. This can damage equipment and may cause a fire. The Output should only be connected to the BreadCrumb.
- Never connect the passive PoE power supply Input to an Ethernet port that supplies PoE power. Applying power to the PoE Input can damage the PoE power supply. For more information see the *Technical Bulletins* Appendix document: Never Apply Power to the Data Input Port of a Rajant Mid-Span Power over Ethernet (POE) Power Supply.
- If you choose to connect a Rajant passive PoE-supporting BreadCrumb to an active PoE switch, you must first turn off the PoE capability of that switch port. For more information see the *Technical Bulletins* Appendix document: BreadCrumb Models Support Only Passive PoE.
- Unsealed PoE power supplies are for indoor use only.
Please note that Rajant warranty protection does not cover any damage caused by misuse of power supplies or by use of third-party power supplies.

⚠ Warning
To avoid sparking and possible damage to the unit, connect the powered Ethernet Output cable to the BreadCrumb before applying power to the power supply.

⚠ Warning
To protect the user and the equipment against the risk of electric shock during high voltage transient events, which may occur when this equipment or its antennas are installed outdoors, protective earth grounding of the POE power supply is required. Case ground connections are provided on all POE power supplies supplied by Rajant. The case ground connections must be used and must be connected to a protective earth ground. Protective earth grounding operations must be performed by trained personnel and according to local electrical codes and industry best practices, as well as Rajant's own recommendations.

For more information on physical installation, grounding, waterproofing connections, see Installation Guidelines and the Appendix Technical Bulletins.

2.4.5 Ethernet Connector

The Ethernet port on the BreadCrumb ES1 enclosure is the female part of a Genesis Technology sealed Ethernet connector. In a protected enviroment, such as indoors or inside a 3rd party enclosure, a standard RJ45 male shielded cable may be connected to this port. Elsewhere, the correct sealed mating connector must be used. The mating (male) part is Genesis Technology WAPV-100-AKY0T.

Figure: WAPV-1X00-AKY0T Sealed Ethernet Connector

Instructions for assembling the male sealed RJ45 connector on an unterminated shielded CAT5e or CAT6 Ethernet cable are found in Appendix: Sealed RJ45 Assembly.

Note: Premade Ethernet Cables
Ethernet cables prebuilt with this connector may be purchased from Rajant (P/N: 06-1000068-030, ES1 cable, Ethernet, Cat5e shielded, Outdoor gland, 30ft).

2.5 M8 Connector

The BreadCrumb ES1 includes a 5-pin female M8 connector that provides pins to support one USB 2.0 interface and a physical Reset button (e.g. an LED Configuration / Zeroize Keys and Restore Factory Defaults Switch).

The ES1-5050CS M8 connector is normally covered by a plastic protective cap. To remove the protective cap, turn the cap counter-clockwise. To replace the protective cap, turn the cap clockwise.

Important
Do not lose plastic protective cap. The ES1-5050CS M8 connector is protected from water only if the protective cap is closed or a Rajant ES1-5050CS M8 adapter cable is properly installed. The protective cap is Finecables Enterprise Co. Ltd. part number PCNM8x1.0-2.

A custom ES1-5050CS M8 male to USB 2.0 female adapter cable (shown in the following figure) provides a female USB A 2.0 port (Rajant p/n 06-100069-001).

Figure: ES1-5050CS M8 Male to USB 2.0 Female Adapter Cable

A custom ES1-5050CS adapter cable (shown in the following figure) from the M8 male to both a female USB A 2.0 port and a Reset button is also available from Rajant (Rajant p/n 06-100069-002).

Figure: ES1-5050CS M8 Male to USB 2.0 Female and Reset Button Adapter Cable

2.5.1 M8 Connector Diagrams

In the following three diagrams, the M8 connector on the bottom of the BreadCrumb ES1 enclosure is viewed with the front of the ES1-5050CS facing up and the bottom of the ES1-5050CS facing the user.

Figure: M8 5-pin Female (ES1-5050CS Enclosure Bottom)

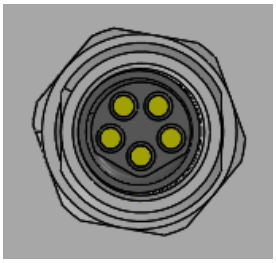
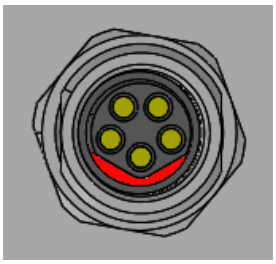
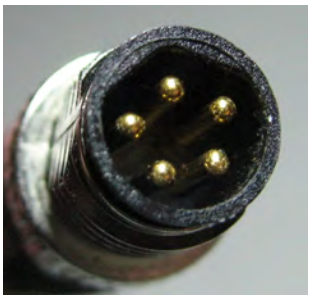


Figure: M8 5-pin Female w/ Recessed Key Highlighted (ES1-5050CS Enclosure Bottom)



The male M8 connector of the ES1-5050CS M8 5-pin male to USB 2.0 female adapter cable has the matching angular key, shown at the top of the connector in the following figure:

Figure: M8 5-pin Male (ES1-5050CS Adapter Cable)



Rajant ES1-5050CS M8 adapter cables use a connector similar to this molded straight shielded 5-pin male connector from Finecables Enterprise Co. Ltd., for example MA08MSBF05ST*XXY*B25, where *XX* is cable length and *Y* is “C” for PVC or “R” for PUR cable jacket.

2.5.2 Connecting ES1-5050CS M8 Adapter Cable

To connect an ES1-5050CS M8 adapter cable, do the followinbg:

1. Turn off power to the BreadCrumb ES1 power supply.
2. Line up the M8 keys by feel. (It is difficult to visually line up the M8 keys.) Gently press the cable’s M8 male connector against the enclosure’s M8 female connector and rotate the male connector until you feel it move slightly into the female connector.
3. While pressing the M8 male connector toward the female connector, turn the M8 male connector’s threaded metal collar clockwise to catch the first thread. Once the threads have been engaged, the connection should be more stable.
4. Repeat the following two steps until fully connected:
    a. Turn the M8 male connector’s threaded metal collar clockwise to thread it further into the enclosure’s female connector.
    b. Press the M8 male connector further into the female connector.
5. When the adapter cable is fully connected, power may be reapplied to the ES1-5050CS power supply.

Tip
The optional USB and Reset adapter cable has thicker molded plastic and a threaded collar that is harder to turn. You may need to remove an antenna or antenna cable to get a good grip on the collar and install this cable.

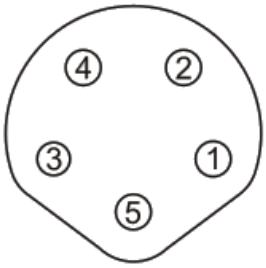
Figure: ES1-5050CS M8 to USB Adapter Cable - Connected

⚠ Important
The male M8 connector of the adapter cable is a sealed connector when properly installed. Taping is still recommended for outdoor installations. The USB 2.0 connector of the adapter cable is not sealed and, therefore, any USB connection must be taped against water ingress. The reset button of the available USB/reset adapter cable is not sealed. When the M8 port is not being used, replace the M8 protective cap by screwing it in clockwise.

2.5.3 Enclosure M8 Pinout

The following figure and table defines the pinout of the M8 5-pin female connector on the bottom of the ES1-5050CS enclosure.

Figure and Table: BreadCrumb ES1 M8 5-pin Female Pinout



Pin	Signal
1	USB 5 V +
2	USB DATA -
3	GND
4	USB DATA +
5	Reset Switch

2.5.4 USB

The BreadCrumb ES1 contains one USB 2.0 interface on the pins of its 5-pin M8 connector.

The port is compliant to the Enhanced Host Controller Interface (EHCI) and USB Transceiver 2.0 Macrocell Interface (UTMI+) Level 2 specifications. The port supports all three standard data transfer rates of low speed (1.5Mbps), full speed (12Mbps) and high speed (480Mbps). The power switch for the port includes over current protection, thermal protection, in-rush current limiting and hot-plug noise filtering.

The USB port can be used to perform a BreadCrumb firmware upgrade or USB-based zeroize process. Alternatively, these actions can be performed in BC|Commander. The USB port can also interface to an optional GPS receiver accessory available from Rajant.

2.6 Status LED

The Status LED is located on the front of the BreadCrumb ES1 enclosure.

The Status LED is used to indicate warning codes, error codes and the link state.

In BC|Commander, in the BreadCrumb configuration, the setting General: Status LED: LED Mode is used to set the mode of operation for the Status LED to **On**, **Off**, **Alerts Only** or **OFF (switchable)**.

When LED Mode is **On**, the Status LED will alternate between indicating the link state and any warnings or errors.

When LED Mode is **Off** or **Off (switchable)**, the Status LED will not indicate any warnings, errors or the link state.

When LED Mode is **Alerts Only**, when there are warnings or errors to report, the Status LED will alternate between indicating the warning or error code and indicating the link state. If there are no warnings or errors, the LED will indicate nothing.

Table: Status LED Color Codes

LED Color and Behavior	Status
Solid White (red, green and blue LEDs together; may appear pale blue or pale green)	Powered on; start of boot process
Solid Yellow	Continuation of boot process
Red-Blue-Green scrolling in succession	End of successful boot process
Solid Blue	Ready, but no connected Mesh peers (unit may have Ethernet peers)
Blinking Green	At least one connected Mesh peer; all peers are connected at less than 24 Mbps
Solid Green	At least one connected Mesh peer; one or more peers are connected at 24 Mbps or faster
Blinking Yellow (with short and long pauses between blinks)	Numeric warning code (see Appendix Error and Warning Codes)
Blinking Red (with short and long pauses between blinks)	Numeric error code (see Appendix Error and Warning Codes)
Blinking Yellow (blinking at an increasing rate)	BreadCrumb is in the process of installing firmware
All LED colors scrolling in rapid succession (with a short pause between every cycle)	BreadCrumb configuration is locked; ready for reboot
All LED colors scrolling in rapid succession (with no pause)	Identify mode is ON

In firmware and BC|Commander version 11.21 or higher, if the BreadCrumb configuration setting General: Status LED: LED Status Mode is set to **Cost to Gateway**, the connectivity-related behavior for the Status LED will be as follows:

- Solid Blue: No path to gateway, or there is no gateway configured
- Solid Green: Low InstaMesh cost to gateway
- Blinking Green: High InstaMesh cost to gateway

Prior to firmware and BC|Commander version 11.21, for the BreadCrumb configuration setting InstaMesh: Advanced: selecting the **Enable Live Trace to Gateway** check box enabled this behavior for the Status LED.

2.7 LED Configuration / Zeroize Keys and Restore Factory Defaults (Reset) Switch

⚠ Important
The BreadCrumb ES1 Zeroize aka Reset switch is available via a Rajant adapter cable for the ES1-5050CS M8 port. On a running BreadCrumb, the features of this switch are also available over the air using the BC|Commander application BreadCrumb menu and BreadCrumb configuration settings.

The LED Configuration / Zeroize Keys and Restore Factory Defaults Switch has two modes of operation. The modes are set by the length of time the switch is asserted. The modes are:

- LED Configuration
- Zeroize Keys and Restore Factory Defaults (Reset))

2.7.1 LED Configuration

LED Configuration mode is used to control the display states of the Status LED.

To activate LED Configuration mode, press the switch for two seconds and then release the switch.

While in LED Configuration mode, the configured display state of the Status LED is dictated by the LED Mode setting in the BreadCrumb configuration. Refer to the *BC|Commander Version 11 User Guide* for a more detailed description of the LED Mode setting).

While in LED Configuration mode, to toggle between the configured state and an alternate state of the Status LED, press the switch.

The following table lists the possible configured and corresponding alternate display states of the Status LED.

Table: Configured and Alternate Display States of the Status LED

Configured State	Alternate State
On	Off
Off	N/A
Alerts Only	On
Off (switchable)	On

Note that state changes can occur only between options in the same rows of the table above. For example, it is possible to toggle between the Alerts Only state and the On state, but not between the Alerts Only state and the Off state. Transitioning from the Alerts Only state to the Off state would require changing the LED Mode setting in the BreadCrumb configuration in BC|Commander.

The default setting for LED Mode for the BreadCrumb ES1 is On.

Note
There are two different configurable Off states: Off (switchable) state, which toggles to the On state, and Off (non-switchable) state, which has no alternate state. If the LED Mode is set to Off (non-switchable), pressing the LED Configuration Switch will NOT turn it on.

2.7.2 Zeroize Keys and Restore Factory Defaults (Reset)

Reset Config

The Reset Config process for a BreadCrumb, does the following:

1. Deletes all security keys from the BreadCrumb configuration.
2. Restores all BreadCrumb configuration settings to the factory default values.
3. Retains all internal logs and other support data stored on the BreadCrumb.

4. Reboots the BreadCrumb.

BreadCrumb configuration settings can be reset remotely from BC|Commander. For instructions, refer to the *BC|Commander Version 11 User Guide*.

BreadCrumb configuration settings can be reset locally at the BreadCrumb. Access to BC|Commander on a mobile device, such as a laptop, is required.

⚠ Warning
Do NOT turn off or reboot a BreadCrumb during the Reset Config process. An interruption to power during the zeroize process can result in the BreadCrumb being unable to boot properly.

To reset BreadCrumb configuration settings locally at the BreadCrumb, do the following:

1. In BC|Commander, in the BreadCrumb Configuration window, in the General category, in the Physical Buttons area, in the **Reset Button Action** list, select **Reset Config**. For instructions, refer to the *BC|Commander Version 11 User Guide*.
2. Go to the BreadCrumb device.
3. Ensure that the BreadCrumb is powered up and fully running and the color of the Status LED is green or blue.
4. On the BreadCrumb, press and hold the LED Configuration / Zeroize Keys and Restore Factory Defaults Switch. The Status LED will slowly flash white. After a few seconds, the BreadCrumb will restart.

Zeroize

The Zeroize process for a BreadCrumb, does the following:

1. Deletes all security keys from the BreadCrumb configuration.
2. Restores all BreadCrumb configuration settings to the factory default values.
3. Clears all internal logs and other support data stored on the BreadCrumb.
4. Reboots the BreadCrumb.

The Zeroize process for a BreadCrumb can be performed remotely from BC|Commander. For instructions, refer to the *BC|Commander Version 11 User Guide*.

The Zeroize process for a BreadCrumb can be performed locally at the BreadCrumb using a properly-prepared USB flash drive. Access to BC|Commander on a mobile device, such as a laptop, is required.

⚠ Warning
Do NOT turn off or reboot a BreadCrumb during the Zeroize process. An interruption to power during the zeroize process can result in the BreadCrumb being unable to boot properly.

To zeroize a BreadCrumb locally at the BreadCrumb, do the following:

1. In BC|Commander, use the USB Flash Manager utility to prepare a USB flash drive to be used to zeroize the BreadCrumb. For instructions, refer to the *BC|Commander Version 11 User Guide*.
2. In BC|Commander, in the BreadCrumb Configuration window, in the General category, in the Physical Buttons area, in the **Reset Button Action** list, select **Zeroize**. For instructions, refer to the *BC|Commander Version 11 User Guide*.
3. Go to the BreadCrumb device.
4. Ensure that the BreadCrumb is powered up and fully running and the color of the Status LED is green or blue.
5. On the BreadCrumb, press and hold the LED Configuration / Zeroize Keys and Restore Factory Defaults Switch until the Status LED blinks yellow (approximately 10 seconds), and then release the switch.
6. Wait for the Status LED to flash the yellow warning code “321” (BreadCrumb is being zeroized), then rapidly flash yellow. This code indicates that the Zeroize Keys and Restore Factory Defaults operation has been initiated and is in progress.
7. Wait for the Status LED to flash the red error code “32” (BreadCrumb has been zeroized). This error code will flash for up to 30 seconds.

8. Wait for the BreadCrumb to automatically reboot with the factory default configuration settings.

For a list of blinking LED error and warning codes, see Appendix Error and Warning Codes.

Note
A Zeroized BreadCrumb will not be able to mesh with properly-configured BreadCrumbs. Reapplication of mesh settings to the zeroized BreadCrumb may require an ethernet connection or a mesh connection with another Zeroized BreadCrumb.

3. Using BC|Commander

BC|Commander is a Rajant Corporation software product primarily used to monitor the status of BreadCrumbs and mesh links in real time in an active mesh network. BC|Commander is also used to configure BreadCrumbs, upgrade BreadCrumb firmware and perform troubleshooting tasks.

Versions of the BC|Commander are available to run on a Microsoft Windows® or Linux host that has a connection to the mesh network.

Rajant periodically releases updated BC|Commander software. Updated BC|Commander software must be obtained from Rajant and then installed. Refer to the latest *BC|Commander Version 11 User Guide* for instructions.

⚠ Important
Rajant recommendeds that the active version of BC|Commander be equal to or greater than the BreadCrumb firmware version running on any BreadCrumbs in order to perform the administation tasks for BreadCrumb firmware as described in the BC|Commander Version 11 User Guide.

Note
Some portions of the BC|Commander Version 11 User Guide assume a working knowledge of TCP/IP networking, including DHCP, NAT and DNS. While the network lay person may be able to perform some mesh network management tasks, it is recommended that network configuration be performed by experienced network administrators.

4. Deploying a BreadCrumb Mesh Network

Many factors must be considered when deploying a BreadCrumb mesh network. This chapter describes the addressing scheme of the mesh, channel assignments and some of the most common environmental factors that will have a major impact on the performance of the mesh. The Deployment Methodology subchapter provides guidelines and a methodology for deploying the mesh.

For information on physical installation, grounding waterproofing connections, see Installation Guidelines and the Appendix Technical Bulletins.

4.1 Addressing

When in gateway mode or when using its own embedded DHCP servers, the BreadCrumb mesh requires that wireless devices use IPv4 addresses in the Class A network 10.0.0.0/8 (that is, any address that begins with “10.”). If your network is not connected to another network or your network is bridging to a another network, rather than routing to the network, the wireless client devices may not have any addresses whatsoever.

Note
Each BC|Commander host must have an address in the same range as the managed BreadCrumbs. Refer to the *BC|Commander Version 11 User Guide* for details about IP address configuration for a BreadCrumb.

4.1.1 BreadCrumb Device Addresses

Each BreadCrumb radio has one IPv4 address in the Class A network 10.0.0.0/8. During the manuafacturing process, Rajant ensures that default addresses are not duplicated between any two BreadCrumb devices. Addresses assigned to BreadCrumb devices can be viewed in BC|Commander. Addresses can be configured manually or set to **DHCP**.

4.1.2 DHCP

Each BreadCrumb device includes an embedded DHCP server. You may safely enable the DHCP servers of multiple BreadCrumb devices simultaneously. Address conflicts among DHCP clients are prevented by using the unique BreadCrumb device addresses assigned at the factory as a base.

A BreadCrumb device determines its DHCP range as follows:

- Start with the first three bytes of the IPv4 address for the BreadCrumb.
- Add a low-byte range of 10 to 210.

4.2 Channel Assignments

Each BreadCrumb radio has default channels assigned based on the frequency and type of the radio.

The following table lists each radio frequency and the corresponding default channel assignments. When more than one radio of the same frequency is present, there may be default channels for the additional radios. This table includes radios that may be found in various BreadCrumb models, not one specific model.

Table: Default Channel Assignments

Radio Card Frequency and Type	Default Channel	Second Default	Third Default
900 MHz 802.11g/900 MHz 802.11n	5		
2.4 GHz 802.11n	11	1	
2.4 GHz 802.11g	11	1	

Radio Card Frequency and Type	Default Channel	Second Default	Third Default
4.8 GHz 802.11a	164	184	174
4.9 GHz 802.11a	20		
5 GHz 802.11a	153	161	
5 GHz 802.11ac	FCC:157, CE:136	FCC:48, CE:100	
5 GHz 802.11n (ME4, LX5)	FCC:157, CE:136	FCC:149, CE:100	
5 GHz 802.11n (ES1)	FCC:157, CE:136	FCC:48, CE:100	
Dual band 2.4/5 GHz 802.11n	11 (2.4 GHz)		

Note
BreadCrumb models DX2, ES1, Peregrine and Hawk do not support 802.11a or 802.11g radios.

In some cases, it may be necessary to manually set the radios to specific channels to provide critical links within a mesh. This can be especially important when using single-radio BreadCrumb devices. Refer to the *BC|Commander Version 11 User Guide* for the details about BreadCrumb channel configuration.

4.3 Physical Placement and other Considerations

Commonly occurring environmental factors have a significant impact on performance and behavior of the BreadCrumb Wireless Network. Line-of-sight (LOS) obstructions, distance, weather and device placement should all be considered when deploying a wireless network.

IEEE 802.11 wireless operation degrades gradually as distance increases between nodes or as interference becomes prominent. This manifests as a data rate reduction between nodes.

The goal in planning and deploying a BreadCrumb mesh network is to maximize both coverage and the data transfer rate between devices by taking into consideration all of the contributing factors described in this section.

4.3.1 Line-of-Sight

Unobstructed line-of-sight (LOS) between BreadCrumbs and wireless clients is critical for optimal performance of the mesh. Partial LOS obstruction results in noticeable network performance degradation. Total LOS obstruction can result in complete loss of network connectivity.

Elevating the device and external antenna will assist in providing better LOS to enable radio waves to propagate over some possible obstructions.

Each BreadCrumb device must have unobstructed LOS to the previous and subsequent BreadCrumb device.

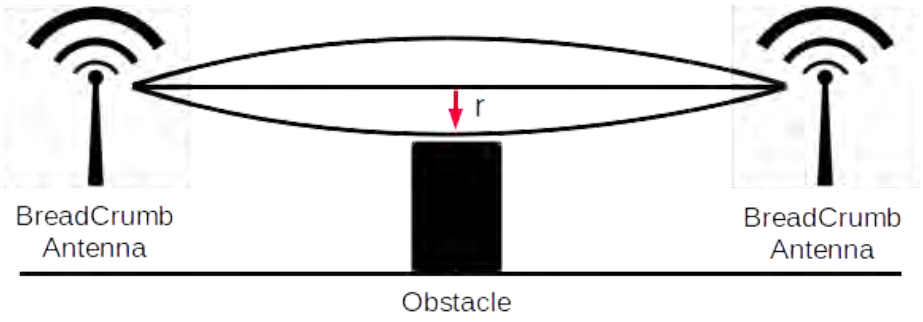
Client connectivity will degrade and drop if LOS to a BreadCrumb device cannot be maintained.

Unobstructed LOS is not necessary from every BreadCrumb device and wireless client to every other BreadCrumb device and wireless client.

Fresnel Radius

In BC|Commander version 11.9 or later, on the **Peers** tab, the radius value in the **Fresnel Radius** column can help determine where antennas must be placed for the wireless signal to sufficiently clear any obstacles between two BreadCrumbs. Obstacles include buildings, trees, vehicles and the ground.

In the following figure, “r” represents the radius of the first Fresnel Zone at a point halfway between two peer BreadCrumbs.



When the BreadCrumb configuration settings for Latitude and Longitude for two peer BreadCrumbs are correct, the **Fresnel Radius** column will contain the value “r” for the two peer BreadCrumbs. The greater the distance between BreadCrumbs, the greater the value “r” will be.

Rajant recommends that antennas be placed to achieve at least 60% (ideally 80%) first Fresnel Zone clearance in all directions.

For obstacles that are closer to one of the peer BreadCrumbs, BreadCrumb antennas with unmatched elevations or BreadCrumb placements affected by the curvature of the Earth use a Fresnel Zone calculator that includes obstacle distance and other factors.

Antenna Tuning

BC|Commander version 11.9 or later can monitor the quality of a single wireless connection between two BreadCrumbs for the purpose of antenna tuning (aka antenna peaking).

To use the Antenna Tuning feature, the BC|Commander host must be on the same network/subnet as the BreadCrumbs being monitored and must be able to directly connect to the BreadCrumbs.

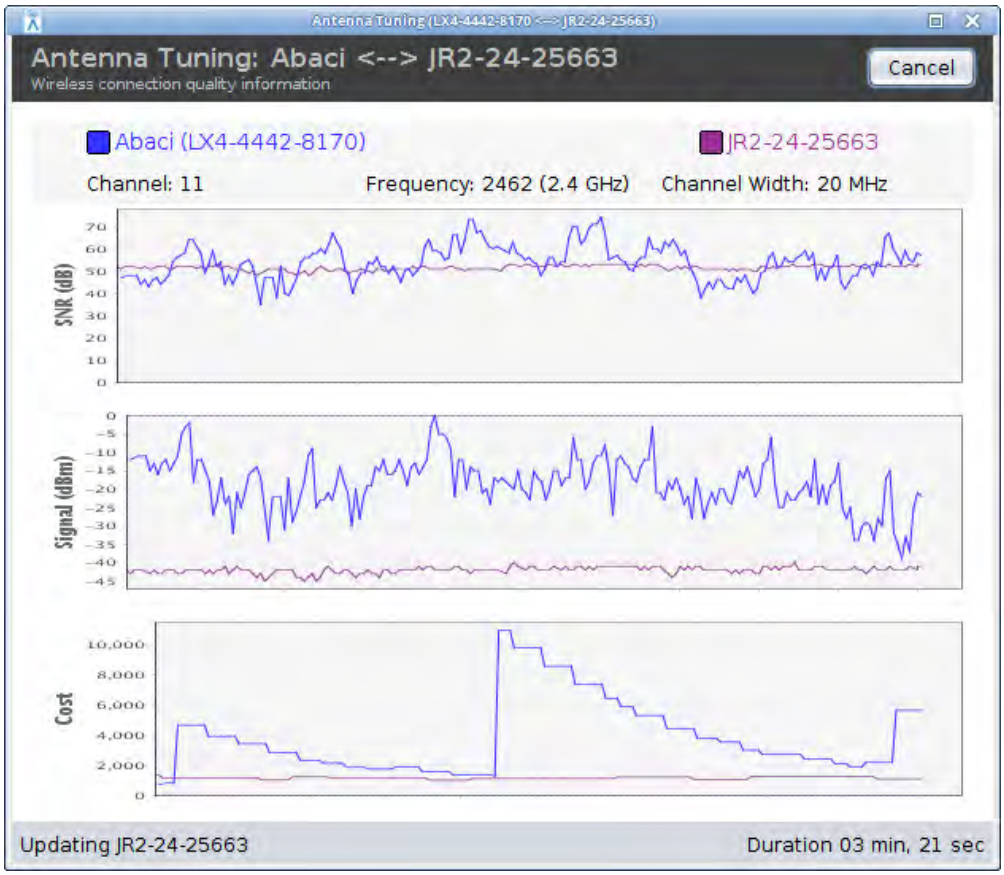
To monitor the quality of a wireless connection between a selected BreadCrumb and a peer BreadCrumb, do the following:

1. If BC|Commander is currently viewing the mesh through a BC|Connector, to switch to a Live Mesh view, on the **Mesh** menu, click **Live Mesh**.
2. In the BreadCrumb table, select a BreadCrumb. The **Peers** tab lists each peer BreadCrumb for the selected BreadCrumb and the network device for each peer connection.
3. On the **Peers** tab, right-click the row for a wireless peer connection, and then click **Antenna Tune**. The **Antenna Tune** dialog box opens and begins to graph the signal-to-noise (SNR) ratio, Signal and Cost as reported by the selected BreadCrumb and peer over the wlan link indicated for the peer BreadCrumb.

The BreadCrumbs being monitored will send wireless connection information to BC|Commander at one-second intervals (regardless of the BreadCrumb configuration setting *BCAPI: General Update Interval*). These accelerated updates will continue until the **Antenna Tuning** dialog box is closed.

Each graph is a sliding window view of the collected information and will begin to discard/age-out older data after 4 minutes of usage. Historical data is not maintained.

If either BreadCrumb were to lose the peer connection, the graphs will flatline or pause until the connection is restored. If BC|Commander were to lose connection to one of the BreadCrumbs, graphing will pause until the connection is reestablished.



Note
The Antenna Tuning feature is unlikely to work well with BreadCrumbs running firmware earlier than version 11.8, where on-demand fast updates of cost, signal and SNR were added for antenna tuning.

CAUTION:
If multiple **Antenna Tuning** dialog boxes are open simultaneously, each will add additional traffic on the mesh and use additional resources on the BC|Commander host. Reconfiguring a BreadCrumb during Antenna Tuning may lead to unexpected anomalies in BC|Commander and is strongly discouraged.

4.3.2 Distance

Many factors determine the acceptable distance between BreadCrumbs when deploying a mesh:

- If many BreadCrumbs are placed too closely together, interference may degrade system performance.
- A BreadCrumb that is placed too far away from another BreadCrumb or in an RF “shadow” may experience total loss of connection.
- RF transmit power and receive sensitivity are important in determining the distances over which the BreadCrumb device will be effective.
- When placing a BreadCrumb, use the BreadCrumb Status LED or BC|Commander to check the connection status to the nearest available BreadCrumb. If the connection is poor or non-existent, attempt to place the BreadCrumb closer to another BreadCrumb until an acceptable connection is made. If a poor connection or no connection is made at even relatively close distances, refer to the Troubleshooting chapter.
- When the connection quality indicated in BC|Commander is found to be acceptable, the distance of the BreadCrumb from the network can be increased until an optimal balance between distance, connectivity and tactical placement is achieved.

4.3.3 Weather

Precipitation and fog act as obstructions that block the propagation of radio waves in the wireless network.

Light fog or precipitation may result in noticeable degradation of wireless network performance. Heavy precipitation or fog may result in severe performance degradation and possible loss of network connectivity.

If the performance of a well-functioning network is degraded by worsening weather conditions, it may be advisable to add BreadCrumbs to the network to act as short haul repeaters to counteract the effects of the weather. An alternative is to move the BreadCrumbs closer together.

4.3.4 Interference

RF interference can degrade network performance. RF interference can come from various sources, including:

- Other BreadCrumbs that are placed too closely together.
- Other RF devices, such as microwave devices, cordless phone base stations, radio transmitters, other wireless networks, jamming devices, etc.
- Metal surfaces, such as fences and buildings, can cause radio waves to be reflected, causing multi-path interference.

⚠ Caution
Plan the BreadCrumb wireless network to minimize the effects of RF interference.

4.3.5 Placement of Mesh Components

The placement of BreadCrumbs has a major impact on maximum effective range and, therefore, network performance. Each component must be elevated above the surrounding terrain to allow for adequate wave propagation. A device that is placed directly on the ground has a significantly reduced effective range. Elevating a device above the ground dramatically increases the maximum effective range. Rajant recommends elevating each component a minimum of 6 feet above the surrounding terrain.

4.4 Deployment Guidelines and Methodology

This section addresses the actual on-site deployment of the mesh. While by no means an exhaustive treatise, this section is intended as a good source of guidelines and methodology for the successful deployment of a mesh in the field.

4.4.1 Deployment Guidelines

Follow these guidelines when deploying the mesh:

1. Placement of BreadCrumbs
    a. Directly on the ground, the maximum distance between two successive BreadCrumbs is approximately 300 feet.
    b. Directly on the ground, the maximum distance between a wireless client and the nearest BreadCrumb is approximately 300 feet.
    c. Elevate a BreadCrumb above the surrounding terrain whenever possible.
    d. Rajant recommends elevating a BreadCrumb a minimum of 6 feet for maximum range.
    e. Elevating a BreadCrumb as little as 14 inches has proven to increase the range approximately 600 feet.
2. Distance
    a. BreadCrumbs that cannot be elevated can be no more than approximately 300 feet apart.
    b. Any wireless client can be no more than approximately 300 feet from a BreadCrumb.
3. Line of sight
    a. Obstructions to LOS block/absorb/deflect radio waves in a wireless network, resulting in poor network performance or total loss of network connectivity.
    b. When placing a BreadCrumb, scan the area for LOS obstructions. Envision the BreadCrumb's radio waves as a light beam. Look for obstructions that would result in shadows in the light beam. These obstructions will most likely weaken or block the BreadCrumb's radio waves.
4. Weather

a. Light precipitation will reduce the range and performance of a BreadCrumb and wireless clients.
b. Heavy precipitation or fog will most likely result in extremely reduced range and frequent or total loss of network connectivity.

4.4.2 Deployment Methodology

The deployment process for the mesh consists of deploying each BreadCrumb. The deployment process for a BreadCrumb consists of installing the BreadCrumb hardware, powering up the BreadCrumb and waiting for the BreadCrumb to boot. BC|Commander can then discover the BreadCrumb in the network.

To successfully deploy BreadCrumbs in the mesh, adhere to the following steps:

1. Scan the terrain where the mesh will be deployed.
    a. Determine the initial distances between BreadCrumb devices. Refer to Rajant Troubleshooting Range User Guide for more information.
    b. Note any LOS obstructions.
    c. Plan the placement of each BreadCrumb to work around any LOS obstructions.
2. Identify the BC|Commander host(s) to be used for deployment.
    a. A user who deploys BreadCrumbs must carry a portable BC|Commander host, such as a laptop with a wireless Network Interface Card (NIC), to each BreadCrumb location.
    b. A user who monitors the deployment of BreadCrumbs will need a stationary BC|Commander host, such as a personal computer.
    c. The users for the BC|Commander host(s) require a means of interpersonnal communication (radio, cell phone, etc.).
3. Determine the location for the first BreadCrumb.
4. Power ON the BreadCrumb.
5. Wait approximately 90 seconds for the BreadCrumb to boot.
6. Power ON the BC|Commander host(s).
7. Start BC|Commander on the BC|Commander host(s).
8. Ensure that BC|Commander displays the BreadCrumb in the BreadCrumb Table or Topology View.
9. Determine the approximate location for the next BreadCrumb.
10. Proceed to the location for the next BreadCrumb while monitoring the BreadCrumb connectivity in BC|Commander. Do one of the following:
    a. If the BreadCrumb loses network connectivity before reaching the target location, backtrack until network connectivity is restored. The location where network connectivity is restored is most likely the farthest point in this direction where this BreadCrumb can be placed.
    b. If the target location is reached without losing connectivity, do one of the following:
        - Place the BreadCrumb in that location.
        - In an attempt to make optimal use of available BreadCrumbs, proceed until the BreadCrumb loses network connectivity and then backtrack until network connectivity is restored. The location where network connectivity is restored is most likely the farthest point in this direction where this BreadCrumb can be placed.
11. For each remaining BreadCrumb, repeat Step 9 and Step 10.

5. Firmware Upgrade and Zeroize Processes

5.1 Firmware Upgrades

5.1.1 Firmware Upgrade Requirements

Each BreadCrumb model relies on low-level software, known as firmware, for proper operation.

Rajant Corporation routinely updates the firmware for each BreadCrumb model to add new product features, support new applications and fix reported problems.

To enable each BreadCrumb to communicate with other BreadCrumbs and BC|Commander, all BreadCrumbs in the network must be operating with compatible firmware versions that are also compatible with the version of the BC|Commander software.

When a firmware update becomes available, the customer is responsible for installing the updated firmware on each affected BreadCrumb in the network.

5.1.2 Update Firmaware Remotely

A BC|Commander administrator can use BC|Commander to remotely update firmware on a wired or wireless BreadCrumb.

To apply an available firmware update for a ES1-5050CS, do the following:

1. In BC|Commander, on the **Help** menu, point to **Check for Updates**, and then click **Firmware Upgrades...**. The **Firmware Upgrades** dialog box opens and lists each new available firmware upgrade for each BreadCrumb model.
2. From the Rajant Support web site, download the updated firmware file to a local folder on the BC|Commander host. For instructions, refer to the *BC|Commander Version 11 User Guide*.
3. Use BC|Commander to remotely upload and install the firmware file from the BC|Commander host to the BreadCrumb. For instructions, refer to the *BC|Commander Version 11 User Guide*.

⚠ CAUTION
Do NOT turn off or reboot a BreadCrumb while new firmware is being installed. An interruption to power during the firmware installation process can result in the BreadCrumb being unable to boot properly.

5.1.3 Update Firmware on Location

On a BreadCrumb that has a Universal Serial Bus (USB) port, a USB storage device can be used to upgrade the firmware at the BreadCrumb location.

To use a USB storage device to upgrade firmware on a BreadCrumb, do the following:

1. Use BC|Commander to prepare a USB storage device that contains the updated firmware file. For instructions, refer to the *BC|Commander Version 11 User Guide*.
2. Do one of the following:
   - If the BreadCrumb is powered ON, connect the USB storage device to the USB port on the BreadCrumb.
   - If the BreadCrumb is powered OFF, connect the USB storage device to the USB port, and then power ON the BreadCrumb.

   Note
   With version 11, the USB flash drive can be connected to a live BreadCrumb and the firmware upgrade process will begin automatically.

   The firmware upgrade process begins.

⚠ CAUTION

Do NOT turn off or reboot a BreadCrumb while new firmware is being installed. An interruption to power during the firmware installation process can result in the BreadCrumb being unable to boot properly.

1. Observe the Status LED on the BreadCrumb for several minutes to monitor the progress of the firmware upgrade.
    a. When the USB firmware upgrade begins, the Status LED will start blinking yellow once per second to indicate progress. When the upgrade process nears completion, the blink rate will increase to several times per second.
    b. If the firmware upgrade completes successfully, the color of the Status LED will rapidly rotate between red, green, blue, cyan, magenta, yellow and white.
    c. If an error condition occurs, the Status LED will repeat a particular sequence of long and short blinks in red to indicate an error code. Do the following:
        1) Take note of the error code.
        2) For error code descriptions, see Appendix Error and Warning Codes.
        3) Leave the USB storage device connected.
        4) Turn OFF power to the BreadCrumb.
        5) Turn ON power to the BreadCrumb. A second firmware upgrade is attempted.
        6) Observe the Status LED to monitor the progress of the second firmware upgrade. If another error occurs, take note of the new error code and then apply for technical support.
2. When the USB upgrade process is complete, power OFF the BreadCrumb.
3. With the BreadCrumb powered OFF, disconnect the USB storage device.
4. Power ON the BreadCrumb. The BreadCrumb reboots with the updated firmware.

5.2 Zeroize

5.2.1 Remote Zeroize Process

BC|Commander provides a remote Zeroize process for a wired or wireless BreadCrumb.

The remote Zeroize process for a BreadCrumb, completes the following actions:

1. Deletes all security keys from the BreadCrumb configuration.
2. Restores all BreadCrumb configuration settings to the factory default values.
3. (Optional) Clears all internal logs and other support data stored on the BreadCrumb.
4. Reboots the BreadCrumb.

NOTE:
The option to clear or retain all internal logs and other support data is available with firmware version 11.17.7 or later.

To perform the remote Zeroize process for a BreadCrumb, refer to the *BC|Commander Version 11 User Guide* for instructions.

CAUTION
Do NOT turn off or reboot a BreadCrumb during the Zeroize process. An interruption to power during the zeroize process can result in the BreadCrumb being unable to boot properly.

Important:
A remotely Zeroized BreadCrumb will not be able to mesh with properly-configured BreadCrumbs. Reapplication of mesh settings to the zeroized BreadCrumb may require an Ethernet connection or a mesh connection with another Zeroized BreadCrumb.

5.2.2 USB-based Zeroize Process

On a BreadCrumb that has a Universal Serial Bus (USB) port, a USB storage device can be used to perform the Zeroize operation. The USB-based zeroize operation does not affect the firmware version running on the BreadCrumb.

The USB-based Zeroize process for a BreadCrumb completes the following actions:

1. Deletes all security keys from the BreadCrumb configuration.

2. Restores all BreadCrumb configuration settings to the factory default values.
3. Clears all internal logs and other support data stored on the BreadCrumb.
4. Reboots the BreadCrumb.

To perform a USB-based Zeroize operation for a BreadCrumb, do the following:

1. In BC|Commander, use the USB Flash Manager utility to prepare a USB storage device for a Zeroize operation. For instructions, refer to the *BC|Commander Version 11 User Guide*.
2. Connect the USB storage device to the USB port on the BreadCrumb (and, if the BreadCrumb is powered OFF, power ON the BreadCrumb at this time).

   Note
   The USB flash drive can be connected to a live BreadCrumb and the zeroize process will begin automatically.

3. The USB-based zeroize process will take less than one minute. Observe the Status LED on the BreadCrumb to monitor progress. Warning 321 “BreadCrumb has been zeroized” should be displayed. Then wait for the LED to flash error code 32 “BreadCrumb has been zeroized”.
4. Power OFF the BreadCrumb, disconnect the USB storage device, and then power ON the BreadCrumb.

6. Troubleshooting

Note
Battery tips apply to any BreadCrumb that is powered by batteries, solar power or any power source that may become irregular or weak.

DFS and Troubleshooting
When troubleshooting problems with a BreadCrumb radio on a 5 GHz DFS channel, remember that radio must listen for radar and not transmit (or mesh) for typically 1 minute after is it fully booted. Channels in the frequencies 5600-5650 MHz, if available, may have a 10 minute wait. In addition, if a radar-like noise pattern is detected on the channel, the radio will shut down for 30 minutes. For more information, including some potential causes of false radar detections, see this section: DFS and TPC.

6.1 Sporadic Network Connectivity

a. If a BreadCrumb is powered by a battery, as the battery approaches exhaustion, network connectivity will become sporadic for the BreadCrumb device and its associated wireless clients.
   - Monitor battery usage and charge or replace batteries as necessary.

b. Light precipitation or fog beginning after initial deployment of the mesh can result in sudden sporadic network connectivity for BreadCrumb devices and their associated wireless clients.
   - Increase the density of the network by adding more BreadCrumb devices or by moving existing BreadCrumbs closer together.

c. As a mobile wireless client moves around through the coverage area, line of sight (LOS) to the BreadCrumb device can become obstructed resulting in sporadic network connectivity for this wireless client.
   - Train mobile wireless client users to maintain LOS to known BreadCrumb device locations. Place BreadCrumb devices strategically to ensure coverage of areas through which users are expected to move.

d. A mobile wireless client that moves beyond the range of the mesh will experience sporadic, and eventually complete, loss of network connectivity.
   - Drop more BreadCrumb devices as necessary to increase range.

e. A wireless client cannot join the network.
   - Ensure that BreadCrumb devices are powered on.
   - Ensure that the BreadCrumb configuration has Enable Access Point checked. This is off by default.
   - Ensure that the wireless card in the client device (laptop) is enabled. This is usually indicated with a blinking light on the card.
   - Ensure that the client's wireless card is in "Infrastructure" or "Access Point" mode, and not in "Ad Hoc" mode. Scan for the default ESSID "rajant" (or the ESSID that you set for the network) using the software accompanying your wireless card.
   - Ensure that the wireless client's IP address settings are configured properly.
   - Ensure that the security settings on the client device and BreadCrumb devices match.
   - Ensure that the client device is not prevented from connecting by an Access Control List (ACL).
   - Ensure that the VLAN settings for the BreadCrumb allow clients of the ESSID being used to communicate to the Local Port of the BreadCrumb. See the VLAN section of the *BC|Commander Version 11 User Guide* for more information.

6.2 BreadCrumb Device Cannot Connect to Mesh

a. A new BreadCrumb or a BreadCrumb reset to factory defaults is running with settings which do not match those of the network to be joined.
   - Configure the BreadCrumb settings to match those of the network to be joined.

b. Discharged batteries can cause the BreadCrumb device to appear to power up, but not be able to establish connectivity to the mesh.
   - When deploying any battery-powered BreadCrumbs to the mesh, ensure that the batteries are fully charged.

c. When using external antennas, faulty cable connections or crimped cables can result in difficulty establishing and maintaining network connectivity.
    - Check antenna cables and their connections to the BreadCrumb device.

6.3 BreadCrumb Power and Start-Up Issues

a. Discharged external batteries can cause a BreadCrumb to appear to power up (“PWR” LED is lit), but fail to start-up.
    - Monitor battery usage and charge/replace batteries as necessary.
b. Electrostatic Discharge can cause a BreadCrumb to appear to power up (Status LED indicates power is on with a white light, which can sometimes appear pale blue or pale green), but fail to start-up.
    - Manually reboot the BreadCrumb device by turning off or disconnecting power to the device and turning power back on.

> **⚠ Caution**
> In order to avoid sparking and possible damage to the device, be sure to connect the power cable to the BreadCrumb before applying power to the power supply.

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7. Appendices

Appendix A: Radio Channels and Frequencies

Rajant BreadCrumbs contain from one to four radios, depending on the model. 802.11g radios are used in the 900 MHz and 2.4 GHz bands. 802.11a radios are used in the 4.8 GHz, 4.9 GHz and 5 GHz bands. 802.11n radios are used in the 2.4 GHz and 5 GHz bands. Each BreadCrumb model supports its own specified radio or combinations of radios.

The radios support the channels and frequencies listed in the following tables. Which channels are available for use depends on country and regulatory agency.

Note
Not all channels are allowed for use everywhere around the world. Check with the corresponding wireless spectrum regulatory body to determine the subset of channels authorized for use in your country.

Caution
Since the radios operate at different frequencies, you must be careful to use the correct type of antenna with each radio. As an example, a 2.4 GHz antenna will not work with a 5 GHz radio and vice versa.

A.1 Radio: 2.4 GHz 802.11n

Table: 2.4 GHz 802.11n Radio Channels and Frequencies

Channel Number	Center Frequency (MHz)	HT40 Capability
1	**2412**	HT40 +
2	2417	HT40 +
3	2422	HT40 +
4	2427	HT40 +
5	2432	HT40 +, HT40 -
6	2437	HT40 +, HT40 -
7	2442	HT40 +, HT40 -
8	2447	HT40 +, HT40 -
9	2452	HT40 +, HT40 -
10	2457	HT40 -
11	**2462**	HT40 -
12	2467	HT40 -
13	2472	HT40 -
14	2484	HT20 only

The default channel and channel mode for a BreadCrumb 2.4 GHz 802.11n radio is 11 (2462 MHz) and HT20. If a second 2.4 GHz 802.11n radio is present, its default channel and channel mode is 1 (2412 MHz) and HT20.

2.4 GHz channels support HT40 mode. In this mode, the radio binds two standard 20 MHz channels to obtain a wider bandwidth 40 MHz channel. The + or - designation describes if the second channel is above or below the base channel. Plus (+) indicates that the additional 20 MHz occurs above (at a higher frequency than) the first 20 MHz while minus (-) indicates that the additional 20 MHz occurs below (at a lower frequency than) the first 20 MHz.

Note
Note, the frequency noted is the center frequency of the base 20 MHz channel. HT40 operation (+ or -) is compatible with 802.11b and 802.11g 20 MHz, and 802.11n HT20 modes.

A.2 Radio: 5 GHz 802.11ac

Table: 5 GHz 802.11ac Radio Channels and Frequencies

Channel Number	Center Frequency (MHz)	HT40 Capability	VHT80 Capability
36	5180	HT40 +	VHT80
40	5200	HT40 -	VHT80
44	5220	HT40 +	VHT80
48	**5240**	**HT40 -**	**VHT80**
52	5260	HT40 +	
56	5280	HT40 -	
60	5300	HT40 +	
64	5320	HT40 -	
100	5500	HT40 +	
104	5520	HT40 -	
108	5540	HT40 +	
112	5560	HT40 -	
116	5580	HT40 +	
120	5600	HT40 -	
124	5620	HT40 +	
128	5640	HT40 -	
132	5660	HT40 +	
136	5680	HT40 -	
140	5700	HT20 only	
144			VHT80 only
149	5745	HT40 +	VHT80
153	5765	HT40 -	VHT80
157	**5785**	**HT40 +**	VHT80
161	5805	HT40 -	VHT80
165	5825	HT20 only	

In the United States, for a BreadCrumb 5 GHz 802.11ac radio, the default channel number is 157 (5785 MHz) with channel mode HT40+. For a second 5 GHz 802.11ac radio (if present), the default channel number is 48 (5240 MHz) with channel mode HT40-.

In Canada, for a BreadCrumb 5 GHz 802.11ac radio, the default channel number is 157 (5785 MHz) with channel mode HT20+. For a second 5 GHz 802.11ac radio (if present), the default channel number is 48

(5240 MHz) with channel mode HT40-.

In most European countries, the default channel and mode is 136 (5680 MHz) and HT40-, and if a second radio is present, its default channel and mode is 100 (5500 MHz) and HT40+. In other countries the default channels may differ based on local regulations.

Note
If the default channels are not available, the default channel will instead be the first valid channel (in order of channel number) with the largest bandwidth (up to 20 MHz) that does not conflict with other radios. If that fails, meshing will be disabled on that radio.

Some 5 GHz channels support HT40 mode. In HT40 mode, the radio binds two standard 20 MHz channels to obtain a wider bandwidth 40 MHz channel. The + or - designates whether the second channel is above or below the base channel. Plus (+) indicates that the additional 20 MHz occurs above (at a higher frequency than) the first 20 MHz; minus (-) indicates that the additional 20 MHz occurs below (at a lower frequency than) the first 20 MHz.

5 GHz channels support VHT 80 mode. In VHT 80 mode, the radio bonds four contiguous 20 MHz channels to obtain a wider bandwidth 80-MHz channel. One of these 20 Mhz channels is the “control channel” for the 80 Mhz channel.

In BC|Commander, in the BreadCrumb configuration, for wlan0 and wlan1, the Channel Number list is used to select the channel number and center frequency for the 20 MHz control channel for the 80 MHz channel.

The following six 80 Mhz channels are available:

- The first 80 Mhz channel bonds channels 36+40+44+48.
- The second 80 Mhz channel bonds channels 52+56+60+64.
- The third 80 Mhz channel bonds channels 100+104+108+112.
- The fourth 80 Mhz channel bonds channels 116+120+124+128.
- The fifth 80 Mhz channel bonds channels 132+136+140+144.
- The sixth 80 Mhz channel bonds channels 149+153+157+161.

To determine which channels support VHT 80 mode, refer to the latest channel plan at the following Web page:

https://secure.rajant.com/staticFiles/latest/channelPlans/FE1-2255B.html.

Note
The 802.11ac frequency noted is the center frequency of the base 20 MHz channel. This is different from 802.11a turbo mode where the frequency was the center of a single 40 MHz wide channel. HT40 operation (+ or -) is compatible with 802.11a 20 MHz and 802.11ac HT20 modes. HT40 operation is NOT compatible with 802.11a turbo mode.

Caution
Most 5 GHz antennas support only a subset of the 802.11ac 5 GHz frequency channels at which the Rajant radio is capable of operating. Before changing the channel of a 5 GHz radio, verify that the channel is supported by the connected antenna.

IMPORTANT: Regarding indoor-only frequencies
In regions where radio frequencies are regulated by ETSI (CE), the frequency range 5170-5350 MHz is restricted to indoor use only. Check local regulations before using these channels.

IMPORTANT
In many regions where radio frequencies are regulated by ETSI (CE), a license is required to use channels in the frequency range 5735-5835 MHz (on models that offer these channels). Check local regulations before using these channels.

IMPORTANT
In Canada, a license is required to use channels in the frequency range 5150-5250 MHz (on models that offer these channels). The license may restrict transmit power. Licensing information may be found at http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11294.html.

A.3 DFS and TPC

DFS and TPC for 5 GHz Channels

Many channels in the 5 GHz band are subject to regulations that require active avoidance of interference with weather radar and other radars (Dynamic Frequency Selection aka DFS). In many countries, regulations also require lower transmit power for nearby wireless connections (Transmit Power Control aka TPC) on the same channels. These DFS channels may be available for use in some countries on BreadCrumbs with 5 GHz radios that provide hardware support for radar detection.

The list of 5 GHz channels that are subject to DFS and TPC depends on the regulatory domain of the region of operation. In many regions any available channels from 5260-5700 MHz require DFS, or DFS and TPC. In some regions, additional channels require DFS and TPC.

DFS channels will not be available immediately upon startup and will become non-operational for a fixed period of time after radar or any radar-like pulse of noise is detected.

BreadCrumb DFS Behavior

- **After power-on or restart, all transmits on a DFS channel will be disabled for 1 minute** (typical) while the radio pre-checks for radar on that channel (the Channel Availability Check aka CAC). If the 1 minute completes without detecting radar, the radio can then start normal operation on the channel while still continuously checking for radar. Note: Channels from 5600 MHz to 5650 MHz, if available, may have a 10 minute CAC period.
- **If radar detection is triggered on a DFS channel, that radio will stop transmitting for 30 minutes** (the Non-Occupancy period aka NOP). Warning code 382 “Radar detection paused radio: wlanN (wlanN …)” will be displayed in BC|Commander if the affected unit was able to report its warning status over another radio or over ethernet.
- **When the 30 minute NOP period of not transmitting completes, before reusing the DFS channel, the radio must not transmit for 1 additional minute** (may be 10 minutes for 5600-5650 MHz) while pre-checking for radar (a CAC period). If no radar is detected during the CAC period, normal radio operation is resumed with continuous checking for radar.
- **When resuming normal operation after a radar detection,** the radar detection warning 382 will be removed from the radio and a warning 383 “Radio resumed from radar pause: wlanN (wlanN, …)” will be added. This 383 “unpaused” warning will remain up for 12 hours so that personnel will know what radios were affected by DFS stoppages. Warning 383 will be removed when all listed radios have been aged out.

About Radar Detection

Radar is detected as pulses (spikes) of radio frequency (RF) noise. If pulses of noise make it past several range checks, and the pattern of pulses is sufficiently similar to a radar pattern, a radar detection event will occur. False detections may be caused by anything that creates RF interference including electrical equipment, improperly positioned antennas, nearby wireless radio devices and RF reflections caused by antennas too close to the ground, walls or other RF-reflecting surfaces.

If possible, use of DFS channels should be avoided for critical network paths, especially if the BreadCrumb has no other wired or wireless network connections to the mesh.

DFS Additional Antenna Separation
For 5 GHz transceivers using channels that require DFS radar detection, it is recommended to mount each antenna for a DFS channel at least 2 feet from any other 5 GHz transceiver’s antenna.

Note: Two new DFS-related fields can be examined in BCAPI Explorer. For wireless DFS channels, these fields will indicate the count of RF interference pulses encountered as well as a count of how many were deemed sufficiently similar to radar by the radar pattern detector.

- state.wireless[n].stats.pulseEvents – Raw count of interference pulses detected by the radio
- state.wireless[n].stats.radarDetections – Count of pulses that triggered radar detector

TDWR

Terminal Doppler Weather Radar (TDWR) operates in the frequencies 5600-5650 MHz. TDWR helps protect airplanes from hazardous weather such as wind shear and gusts. Wireless network installations within 35 km of or in line-of-sight of a TDWR must not use TDWR frequencies and should avoid using channels within 30 MHz of the TDWR frequencies. A list of U.S. TFDR radar coordinates may be found at WISPA.org:
WISPA.org - see TDWR Resources

⚠ Warning
Operating this equipment in violation of Local, Regional or National Standards, including interfering with radar, is likely to result in substantial sanctions to the User, including fines, imprisonment, confiscation of equipment, and other penalties as determined by your local regulatory authorities.

Appendix B: Error and Warning Codes

Possible BreadCrumb error and warning codes are listed below.

A BreadCrumb can have multiple errors or warnings listed in the Alerts tab of BC|Commander but only one code will be flashed on the BreadCrumb's status LED. A few codes such as 811 and 335 are non-flashing alerts. For a BreadCrumb with other active alerts, the lowest number error code will flash on the BreadCrumb's status LED, and if there are no errors then the lowest number warning will flash.

Numeric error codes are flashed as groups of red (error) or yellow (warning) LED blinks. For example, a meshed BreadCrumb displays a green LED. If the BreadCrumb starts to display warning 37, the following would be seen: green (link state), yellow blinks 3 times, short pause, yellow blinks 7 times, long pause of green (link state), yellow blinks 3 times, short pause, yellow blinks 7 times, etc.

Model-specific differences:

- JR models have multiple green LEDs. JR's flash error codes on the ERR LED and warnings on the WARN LED.
- DX2 models have a bicolor green/red LED. Both errors and warnings are flashed in red.
- SlipStream does not have a software-controllable LED and cannot display warning/error codes. Use BC|Commander to view error status.

Code	Firmware Upgrade Codes (1*)
11	Flash image file does not exist.
12	Current flash image version is greater than versions of files found on USB drive.
13	No flash image files found.
14	Unable to mount USB drive.
16	Continuous Transmit Mode
115	Copying failed.
116	Flash unbundle failed.
117	Version information in flash file name and breadcrumb-buildinfo.conf do not match.
1171	Platform information in flash file name and breadcrumb-buildinfo.conf do not match.
118	Untar failed.
119	FIS directory update of kernel failed.
125	Failed to set boot path to next image.
127	Failed to copy file system image.
135	Failed to copy init image.
136	Failed to copy bootloader image.
137	This flash image may not be installed onto this BreadCrumb.
142	The version you are installing does not support the configured Packet Cipher
143	The version you are installing does not support the configured MAC Address Cipher
144	The version you are installing does not support the configured Per-hop Authentication algorithm
145	The version you are installing does not support the configured security policy
146	Failed to verify consistent country settings

Code	Firmware Upgrade Codes (1*)
147	The configured countries are not consistent
151	Pre-manufacturing install process failed
152	Firmware install failed
153	Post-manufacturing install process failed
154	The autorun is missing required symbols
155	GSC firmware update failed
Code	**Diagnostic Codes (2*)**
21	Recovery log detected. To clear this message, please take a diagnostic snapshot and upload to https://secure.rajant.com.
22	Internal error detected. Please take a diagnostic snapshot and upload to https//secure.rajant.com. This message will be cleared on the next reboot.
23	Internal developer settings detected - may cause undefined behavior. Use zeroize to clear.
233	This device is not configured for commercial use and will cause undefined behavior. Contact support to rectify.
234	This device is running BETA software. Contact support for the latest supported version.
24	Stress mode is running - may cause undefined behavior. Reboot to clear.
242	Internal hardware error detected via stress testing. Take a diagnostic snapshot and upload to https//secure.rajant.com for analysis.
25	Internal developer overrides detected.
Code	**Self-Test Codes (3*)**
31	Hardware configuration not set. Factory initialization required.
311	Hardware error detected.
32	BreadCrumb has been zeroized.
321	BreadCrumb is being zeroized.
322	Breadcrumb is in Deployment Mode.
33	Radio(s) not detected.
331	Radio in MANUAL compliance mode is violating country regulation.
332	Spectrum Access not granted
333	Low Battery
334	Gas gauge not initialized. To initialize, please power off unit and fully charge.
335	Non-compliant radio configuration in use
37	Failed to configure ethernet port
38	Resetting radio due to error.
381	Noise floor threshold exceeded
382	Radar detection paused radio
383	Radio resumed from radar pause
385	Radio(s) failed to initialize

Code	Firmware Upgrade Codes (1*)
386	Radio(s) warming up.
387	High internal temperature detected.
388	Low input voltage detected.
389	High input voltage detected.
Code	**FIPS Codes (4*)**
41	FIPS Power-on self-tests failed.
411	FIPS DRBG power-on self test failed.
412	FIPS DRBG continuous test failed.
413	FIPS DRBG health check failed.
414	Kernel integrity check failed.
415	Filesystem integrity check failed.
417	FIPS Invalid configuration.
421	Default password in use
Code	**Fatal and Serious Codes (5*)**
51	Internal error, system will restart.
52	hostapd fatal error.
521	HT40 bandwidth reduced to HT20 due to nearby access point on HT40 secondary channel
522	IEEE 802.11 TKIP countermeasures initiated
53	Taking over as APT master
531	High cost APT link
541	Software error
56	APT peer bridge settings do not match
57	logwatcher start timeout
Code	**Battery Gas Gauge Codes (6*)**
61	Battery gas gauge i2c device could not be found.
62	Incorrect gas gauge revision 1 EEPROM settings.
63	Incorrect gas gauge revision 2 EEPROM settings.
64	Incorrect gas gauge revision 3 EEPROM settings.
65	Unknown gas gauge revision.
66	Incorrect ME3 gas gauge revision 0 EEPROM settings.
67	Internal battery charger disabled.
Code	**Other Codes (7, *8*, 9*)**
71	Host flapping detected.
73	Invalid channel configured.
741	Signing key installation failure.

Code	Firmware Upgrade Codes (1*)
76	Potential loop detected, turned off port
77	Model is not supported in this version of firmware. Contact support.
81	reserved
811	Default Network Key is in use.
82	reserved
83	reserved
84	reserved
85	reserved
86	reserved
87	reserved
88	reserved
89	reserved
91	Invalid SSL Handshake Priority String:

Appendix C: Ports and Protocols

Table: Ports and Protocols

Service	From	To	Protocol
BreadCrumb Discovery	Ephemeral port on BC|Commander host	224.0.0.224, port 35057 (UDP IPv4 multicast); FF02::1, port 35057 (UDP IPv6 multicast); BreadCrumb IPv4 or IPv6 addresses, port 35057 (UDP IPv4 or IPv6 unicast)	IPv4 UDP, IPv6 UDP
BreadCrumb Discovery	BreadCrumb IPv4 or IPv6 address, port 35057	Ephemeral port on BC|Commander host (UDP IPv4 or IPv6 unicast); FF02::1, port 35057 (UDP IPv6 multicast) at BreadCrumb startup	IPv4 UDP, IPv6 UDP
BCAPI (BC|Commander)	Ephemeral port on BC|Commander host	BreadCrumb IPv4 or IPv6 addresses, port 2300 (default)	IPv4 TCP, IPv6 TCP
BC|Connector Discovery	Ephemeral port on BC|Commander host	BC|Connector server port 35057	IPv4 UDP, IPv6 UDP
BC|Connector Discovery	Ephemeral port on BC|Enterprise server	BC|Connector server port 35057	IPv4 UDP, IPv6 UDP
BC|Connector	Ephemeral port on BC|Connector server	BreadCrumb IPv4 or IPv6 addresses, port 2300	IPv4 TCP, IPv6 TCP
BC|Connector with LDAP enabled	Ephemeral port on BC|Connector server	LDAP server port 3268 or 389 (whichever is used)	IPv4 UDP, TCP; IPv6 UDP, TCP
BC|Enterprise setup only	Ephemeral port on BC|Enterprise server	BC|Connector TCP port 23000	IPv4 TCP, IPv6 TCP
BC|Enterprise graphing service	Ephemeral port on BC|Enterprise server	BC|Enterprise server port 3000	IPv4 TCP, IPv6 TCP
BC|Enterprise metrics service	Ephemeral port on BC|Enterprise server	BC|Enterprise server port 8889	IPv4 TCP, IPv6 TCP
BC|Enterprise time-series database service	Ephemeral port on BC|Enterprise server	BC|Enterprise server port 9090	IPv4 TCP, IPv6 TCP
BC|Enterprise user interface	Internet browser on BC|Enterprise client workstation	BC|Enterprise server port 8888	IPv4 HTTP, IPv6 HTTP
BC|Enterprise metrics request and publishing	Ephemeral port on BC|Enterprise server	BC|Connector server port 23002	IPv4 TCP, IPv6 TCP

Service	From	To	Protocol
Automatic Protocol Tunneling (APT)	BreadCrumb ethernet interface IPv6 link-local address, ephemeral port	BreadCrumb ethernet interface IPv6 link-local address port 2210 for the service listener, ephemeral port for data flow	IPv6 UDP
RPT (SCTP default)	BreadCrumb IPv4 or IPv6 address, ephemeral port	BreadCrumb IPv4 or IPv6 address, SCTP port 2210 for the service listener, ephemeral port for data flow	IPv4 or IPv6 SCTP
RPT (UDP option)	BreadCrumb IPv4 or IPv6 address, ephemeral port	BreadCrumb IPv4 or IPv6 address, UDP port 2211 for the service listener, ephemeral port for data flow	IPv4 or IPv6 UDP
TRoIP Audio RTP Traffic	BreadCrumb IPv4 address, ephemeral port	IPv4 multicast address 225.0.0.1-225.0.2.255 port 24680	IPv4 UDP
Remote Packet Capture	Remote Packet Capture client (BC|Commander)	BreadCrumb configured TCP port (default:5825)	IPv4 TCP
Performance Test (iperf3)	BreadCrumb IPv4 or IPv6 address, ephemeral port	BreadCrumb IPv4 or IPv6 address, port 5201	IPv4 UDP, TCP; IPv6 UDP, TCP
Real Time Location System (RTLS)	BreadCrumb ephemeral port	RTLS server UDP port 12092	IPv4 UDP
RTLS	RTLS server ephemeral port	BreadCrumb UDP port (default:1144)	IPv4 UDP

Appendix D: Installation Guidelines

Guidelines follow for installing a typical Rajant BreadCrumb. The order of installation may differ depending on the location where the BreadCrumb will be installed and configured.

Also read all warnings and guidance in the rest of this guide.

D.1 Professional Installation Is Required

Model: BreadCrumb ES1

Professional installation is required for this device and will be performed only by someone knowledgeable of its use. Rajant Corporation will ensure that the device is only marketed and sold to professionals.

The device is not sold to the general public and is sold only for industrial or commercial use by professional installers.

> ⚠ **Antenna Installation WARNING**
> The installer should configure the conducted output power level according to country regulations and the applicable EIRP limit. Professional installation of equipment is required to ensure compliance with health and safety issues.

> ⚠ **IMPORTANT: Exposure to Radio Frequency Radiation**
> To satisfy RF exposure requirements a minimum safe distance must be maintained between this device's antennas and all persons while the device is operating. The minimum distance for this model is stated in the the FCC chapter of this guide.

D.2 Safety

> ⚠ **Warning**
> The BreadCrumb ES1 is not user serviceable. Repairs must be performed at a Rajant designated service center by trained personnel.

Also see the warnings in the Connecting Power section below.

D.3 Modifications

> ⚠ **CAUTION**
> Changes or modifications not expressly approved by Rajant Corporation could void the user's authority to operate the equipment.

Rajant Products are compliant and warranted against manufacturing defects only so long as Rajant-authorized accessories are used in deployment of Rajant Breadcrumbs. It is the responsibility of the operator and the installer to ensure the system as installed operates within regional requirements.

D.4 Attaching Antenna Cables and Antennas

Most of Rajant's standard antennas are characterized by high-gain and, therefore, small vertical beamwidth. Antennas in fixed locations should be installed plumb and at the same elevation so that BreadCrumbs using these antennas will see each other without a significant loss of signal strength.

> ⚠ **Warning**
> To avoid possible damage to the BreadCrumb radio(s), always turn off power to the BreadCrumb before connecting or disconnecting external antennas.

Required Antenna Separation

The antennas from any transceiver of the BreadCrumb ES1 may not be co-located with the antennas any other transceiver. The co-location restriction is satisfied by maintaining 20 cm separation between the

antennas. There is no restriction for the separation between the antennas from the same transceiver; but testing at installation is recommended to verify the system performance that is achieved with a specific antenna deployment configuration.

⚠ Warning
For installations that will experience vibration or shock, all antennas should be externally mounted and attached to the ES1-5050CS using cables. Low loss RF cable such as LMR-400 is recommended for cable attached antennas. If a radio port is not required for a given application, the port should be disabled in software using BC|Commander, and a 50 Ohm terminator should be installed.

DFS Additional Antenna Separation
For 5 GHz transceivers using channels that require DFS radar detection, it is recommended to mount each antenna for a DFS channel at least 2 feet from any other 5 GHz transceiver's antenna.

Summary

- Each antenna must be installed at least 20 cm from the antennas of any other transceivers.
- For locations with vibration or shock, no antennas should be directly attached to the BreadCrumb.
- For antennas connected to the BreadCrumb via cables, low loss cabling such as LMR-400 is recommended.
- Any unused antenna ports should be disabled in BC|Commander and have a 50 Ohm terminator installed.
- Antennas in fixed locations should be installed plumb and at the same elevation.
- The BreadCrumb and its antennas must be located a distance from any persons when operating. The minimum distance for this model is stated in the the FCC chapter of this guide.

Also Note:

- Power to the BreadCrumb should be OFF when attaching or removing antennas or terminators.
- To reduce shock and vibration, BreadCrumbs on mobile equipment should be mounted in or on the cab.
- See Physical Placement and other Considerations regarding Line of Sight and Fresnel Radius.
- Mounting hardware for cabled antennas may be purchased from Rajant.
- 5 GHz channels requiring DFS radar detection may get false triggers if antennas are placed near reflecting surfaces/objects or other electrical or radio equipment.

D.5 Grounding and Surge Protection

⚠ Warning
To protect the user against the risk of electric shock during high voltage transient events which may occur when this equipment is installed outdoors, protective earth grounding of the POE power supply is required. Case ground connections are provided on all Rajant supplied POE power supplies. The case ground connections must be used and must be connected to a protective earth ground. Protective earth grounding operations must be performed by trained personnel, and according to local electrical codes and industry best practices, as well as Rajant's own recommendations.

To assure continuity of ground from the BreadCrumb to the PoE to the ground, and to help protect the BreadCrumb and any attached equipemt from electrical damage, please see:

- Rajant Best Practices: Grounding and Surge Protection

D.6 Waterproofing

For outdoor installations, Rajant recommends waterproofing all connections as follows:

- See Waterproofing Rajant BreadCrumb RF Connections

D.7 Connecting Power

- For power requirements and PoE usage diagrams, see the Power and Ethernet section.
- The BreadCrumb's on/off switch (if any) should be off when connecting or disconnecting power.
- BreadCrumbs only support Passive PoE. Do not use a Cisco switch PoE to power a BreadCrumb (set switch port's power to "never").

D.8 Configuration

Configure the BreadCrumb to be compatible with any existing or planned BreadCrumb mesh network. This will include configuring the desired channel and bandwidth and configuring security settings. Complete and test the configuration before mounting the BreadCrumb anywhere unreachable.

- See the BreadCrumb model guide's chapter Deploying a BreadCrumb Mesh Network.
- See the *BC|Commander User Guide* chapters "Administrative Tasks" and "BreadCrumb Configuration".

D.9 Placement

See the BreadCrumb model guide's chapter "Deploying a BreadCrumb Mesh Network" starting at the section Physical Placement and other Considerations.

Appendix E: Sealed RJ45 Assembly

> **Important**
> Installing the WAPV male sealed RJ45 connector requires proper tools and expertise in building shielded CAT5e / CAT6 network cables.

> **Warning**
> While the sealed RJ45 is being built there should be NO POWER attached to the cable.

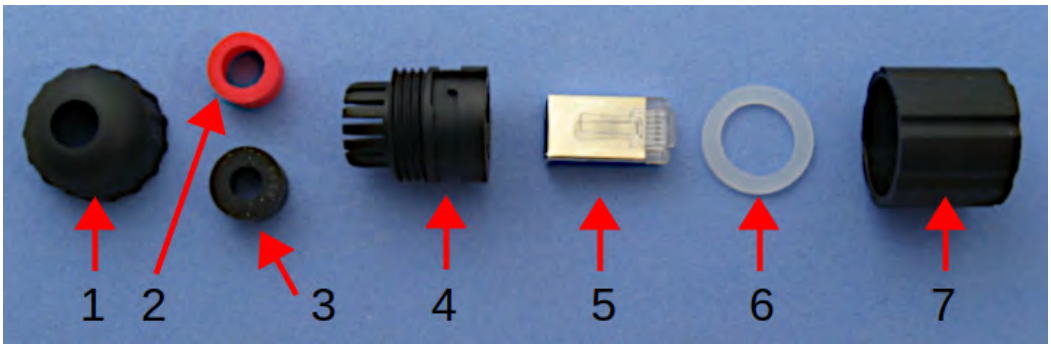
The male sealed RJ45 connector is a Genesis Technology WAPV-100-AKY0T which includes soft plugs to fit two different ranges of cable diameter. This section will refer to the connector as just “WAPV”.

E.1 Parts of the Male Sealed RJ45 Ethernet Connector

The following image shows the parts of the WAPV male connector in the same order they are assembled on an unterminated Ethernet cable. Rajant recommends using shielded CAT5e or CAT6 cable. Any lower quality of cable may not support full Ethernet speed.

> **Note on CAT Cable Sizes**
> Note that the overall cable diameter and the individual wire diameters of CAT6A cables and some CAT6 and CAT5e cables may be too thick to be used with the shielded RJ45 connector that comes with the WAPV sealed connector.

Figure: WAPV Male Sealed Ethernet Connector Parts



(1) Cap

(2) Red soft plug for cable 7.0 - 8.1 mm diameter cable

(3) Black soft plug for cable 5.0 - 6.0 mm diameter cable

(4) Inner shell

(5) Metal-shielded male RJ45 plug (plastic latching tab visible on top)

(6) Soft circular washer

(7) Outer shell

> **Important**
> Keep track of the small parts when assembling the connector. It is easy to lose a small soft plug or the soft circular washer. The soft circular washer can even slip out of the fully assembled connector. If cables are being pre-assembled, it might be a good idea to tape a plastic bag around the finished connector until it is time to mate it to the female WAPV part on the ES1-5050CS enclosure.

E.2 Choose the Correct Soft Plug

Only one soft plug is used when building the connector. Measure the diameter of your Ethernet cable and choose the one that is correct for that diameter. This is important for getting a sealed connection.

- Red plug is for cable 7.0 - 8.1 mm diameter.
- Black plug is for cable 5.0 - 6.0 mm diameter

Figure: Red or Black WAPV Soft Plug Choice

E.3 Pre-thread Before Termination

Three WAPV parts (cap, soft plug, inner shell) must be pre-threaded onto the not-yet-terminated end of the Ethernet cable. In this example, the red soft plug is used because this Ethernet cable's diameter is 7 mm. Note that one end of the soft plug is wider. The wider end of the soft plug faces the cap. The narrower end faces the inner shell.

Figure: WAPV Pre-thread Before Termination

(1) Cap

(2) Appropriate soft plug for cable diameter

(3) Inner shell

(4) Unterminated end of Ethernet cable

(5) Metal-shielded male RJ45 plug (plastic latching tab visible on top)

(6) Outer shell with soft circular washer placed inside (see note below)

Tip
If you look/feel inside the outer shell you will see that one end has larger rectangular keys (blocky bumps) on the inside. The larger keys are the ones that will mate with the female WAPV connector on the ES1-5050CS enclosure. The smaller keys inside the other end of the outer shell are the ones that will mate with the inner shell. The end wih smaller keys (which is shown closest in the photo above) will also receive the soft circular washer which will rest on a narrow shelf that circles the inside of the outer shell.

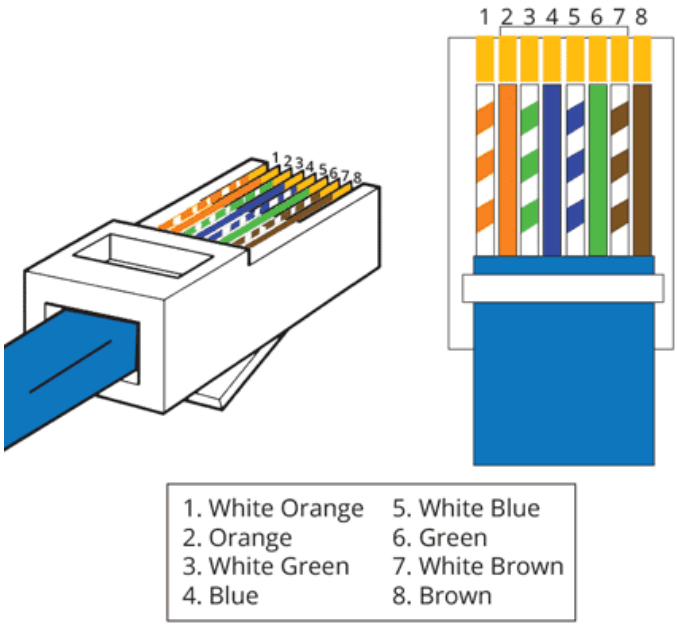
E.4 Terminate Cable with the Metal-Shielded RJ45 Plug

Important
This step should be performed by someone with the proper tools and expertise in building CAT5e / CAT6 network cables.

Expose the eight insulated wires and the drain or braid of the unterminated end of the Ethernet cable and then install the metal-shielded male RJ45 plug. This requires proper tools and expertise in building shielded network cables. The eight wires have to be in a particular order (the same order as the other end, typically T568B wiring standard) and all well-crimped into the RJ45 plug.

For reference, this is the T568B wiring order for RJ45. If the other end of your Ethernet cable uses T568B wire ordering then this is the order for crimping the wires into the metal-shielded male RJ45 connector. Make sure the drain wire or braided shield of the cable also makes good contact with the metal shield of the RJ45 connector.

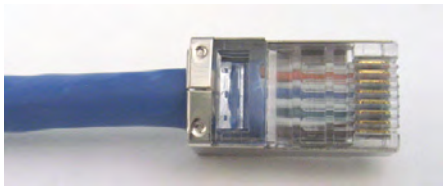
Figure: RJ45 Male with T568B Wiring



E.5 Test the Ethernet Cable

The terminated cable should then be tested with an Ethernet cable tester to check the continuity of all eight wires and the ground/shield. If problems occur installing the RJ45 plug, a typical CAT5e or CAT6 metal-shielded RJ45 plug of the same size and shape should be a suitable substitute.

Figure: Cable Terminated with Metal-shielded RJ45 Plug



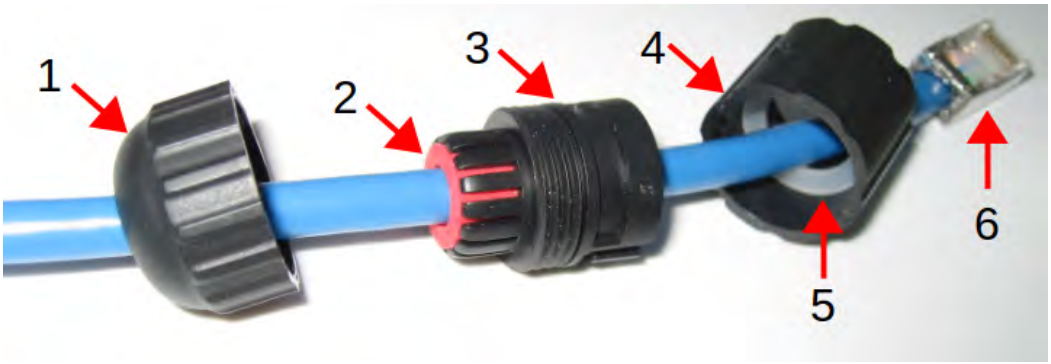
E.6 Preparation After Termination

- First thread the soft circular washer over the RJ45 plug.
- Then look/feel inside the outer shell to determine the correct orientation for threading it over the RJ45 connector. The closest end in the following image shows the end of the outer shell that should be threaded over the RJ45 plug. Note that this end has the smaller key blocks and the narrow shelf where the soft circular washer will rest.

Figure: WAPV: End of Outer Shell that Mates with Inner Shell

Figure: WAPV Pre-thread After Termination

Figure: WAPV Preparation After Termination



(1) Cap

(2) Soft plug pressed most of the way into inner shell (wide end ridge of soft plug remains outside)

(3) Inner shell

(4) Outer shell (thread the soft washer over the RJ45 first, then the outer shell, then place washer in outer shell)

(5) Soft circular washer positioned on the “shelf” inside inner shell

(6) Metal-shielded male RJ45 plug crimped on cable (the termination)

E.7 Mate Inner and Outer Shells

Next, the inner and outer shells are mated with a bayonet-like action. It’s very important that the soft circular washer stay in place in on the narrow “shelf” the outer shell while doing this.

Tip
Although the next photo was shot with the cable laying on a flat surface, holding the shells more vertically with the outer shell lower may help keep the white soft circular washer in position on the narrow shelf inside the outer shell.

Inside the outer shell (where it faces the inner shell) are the small square keys (block-like bumps). Line up those keys with the recessed channels on two sides of the inner shell. Then hold the inner shell (1) and press the outer shell (2) onto the inner shell. Use some pressure to get around the tight corner of the channel, then rotate the outer shell in the direction shown by the yellow arrow below. Once mated, the outer shell should be loosely trapped over the inner shell. Now look inside the end of the outer shell (where 2 is pointing) and make sure the white soft circular washer is laying flat. If not, fix.

Figure: Lining Up and Mating Inner and Outer Shells

(note: Cap is not shown above but is on the cable to the left of the inner shell)

(1) Inner shell with soft plug in place (wide end ridge of soft plug remains outside)

(2) Outer shell

(3) Metal-shielded RJ45 plug

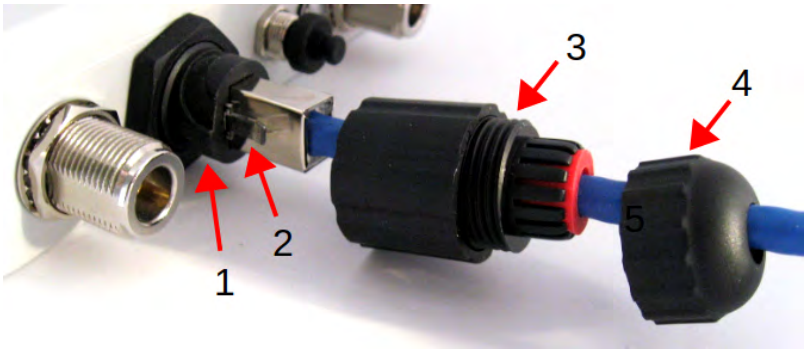
The following photo shows how the inner and outer shells appear after they are mated with each other.

Figure: Mated Inner and Outer Shells

E.8 Connect RJ45 to Female WAPV RJ45

Connect the RJ45 plug to the RJ45 port on the ES1-5050CS.

Figure: RJ45 Connection



(1) Female WAPV RJ45 port on ES1-5050CS enclosure (will be on the bottom when ES1-5050CS is mounted)

(2) Male metal-shielded RJ45 plug (arrow pointing at the plastic latching tab)

(3) Combined male WAPV inner and outer shell w/ soft plug and soft circular washer

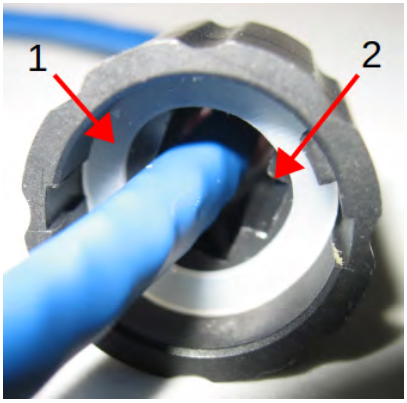
(4) Cap

Note the location of the RJ45 plug's plastic latching tab, pointed at by arrow (2) in the photo above.

E.9 Mate and Then Cap the WAPV

Look inside the end of the combined male WAPV shell that faces the RJ45 plug. You should be able to see the soft circular washer laying flat, and directly beneath that see the RJ45-shaped (keystone-shaped). The keystone-shaped hole is like a rectangle with an extra small rectangular notch on one side. This notch (at arrow 2 below) will need to be lined up to fit over the plastic latching tab of the RJ45 plug (at arrow 2 above) when mating the male connector to the female connector on the enclosure of the BreadCrumb ES1.

Figure: View inside the Combined Shells



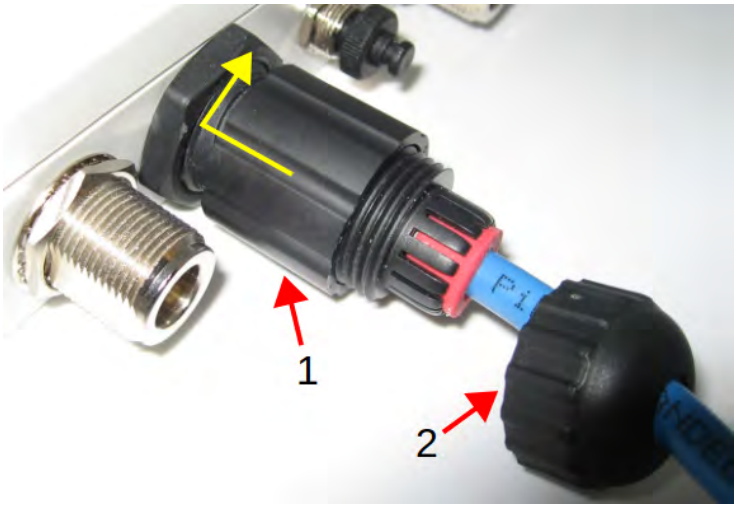
(1) Soft circular washer laying flat on its shelf in the outer shell

(2) RJ45/Keystone-shaped hole, arrow (2) pointing at the notch

To mate the WAPV male (cable) and WAPV female (enclosure) parts:

- Align the keystone hole's notch with the plastic latching tab of the RJ45 plug and slide the WAPV combined shell over the RJ45 plug.
- Next, rotate the outer shell gently left and right while pressing forward until the shell's rectangular keys locate the matching channels in the outside of the female WAPV, and push the combined shell further forward onto the female WAPV.
- Now bayonet the outer shell forward and clockwise (shown below by the yellow arrow below) to connect the male WAPV to the female WAPV.
- To complete the mating, firmly screw the cap clockwise onto the combined male WAPV shells.

Figure: WAPV: Mating Male and Female WAPV



(1) Combined male WAPV inner and outer shell w/ soft plug (and soft circular washer is inside)

(2) Cap

Figure: Fully Mated WAPV Connection

Note

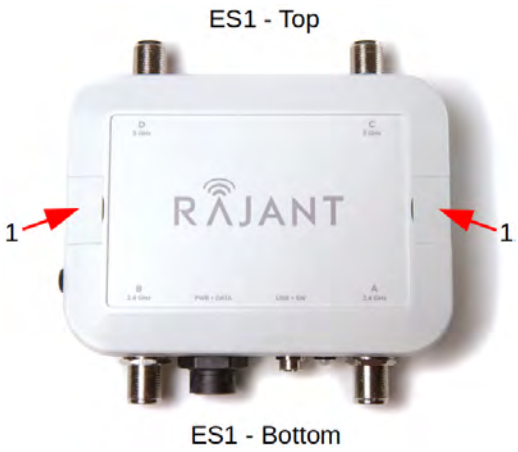
Even though these parts should form a sealed connection, Rajant recommends taping all outdoor connections. For general information on taping connections, see the documents *Waterproofing Rajant BreadCrumb RF Connections* and *Waterproofing Rajant BreadCrumb RF Connections* in the *Technical Bulletins* appendix of this guide.

Appendix F: Mounting Instructions

The BreadCrumb ES1 has two mounting holes which are found on the center left and right of the front and back of the ES1-5050CS. The mounting holes are 131 mm (5.15 inches) apart (center to center) and are intended for M4 machine screws with washers to distribute the pressure on the plastic.

The two mounting holes are accessed from the front of the BreadCrumb ES1 via small flip-up access compartments on the left and right front border of the ES1-5050CS.

Figure: BreadCrumb ES1 Front Flip-Up Mounting Hole Accesses

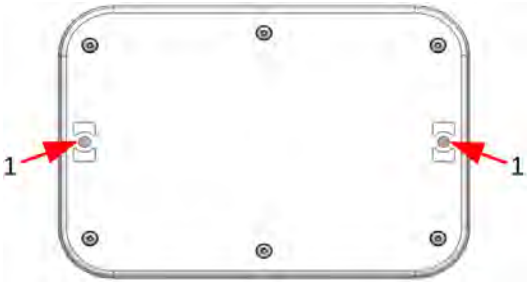


1. Front flip-up mounting hole accesses

Tip Regarding Orientation
The following simplified diagrams do not show the external features of the BreadCrumb ES1 such as the antenna ports, Ethernet port, Status LED. In all vertically-oriented diagrams, the side with the Ethernet port, M8 port, Status LED is facing down. The flip-up covers on the front of the mounting hole accesses are also not shown in the following diagrams.

The two mounting holes are located on the back of the BreadCrumb ES1 as shown below.

Figure: BreadCrumb ES1 Back Mounting Holes



1. Mounting holes from back of ES1-5050CS

A pole mounting kit and a 35mm DIN rail mounting kit are available for the BreadCrumb ES1.

F.1 Pole Mount Kit

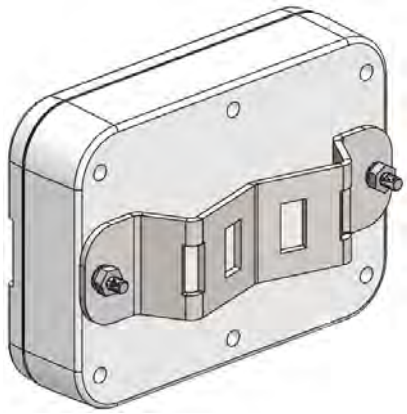
The pole mounting bracket for BreadCrumb ES1 attaches to the back of the ES1-5050CS as described below. The ES1-5050CS pole mount kit is Rajant P/N 90-100104-001.

The following diagram shows a BreadCrumb ES1 with pole mounting bracket attached. Note that the bracket has a choice of two pairs of slots where a hose clamp can be threaded. A hose clamp for a narrow diameter pole should be threaded only through the inner pair of slots (thread the hose clamp down into

one slot and up through the matching slot of the pair). A hose clamp for a wider diameter pole should be threaded only through the outer pair of slots. Hose clamps ½ to ¾ inch wide may be used.

It may be easier to thread the hose clamp before attaching the pole mounting bracket to the BreadCrumb ES1. Continue for the correct use of washers and nut when attaching the pole mounting bracket.

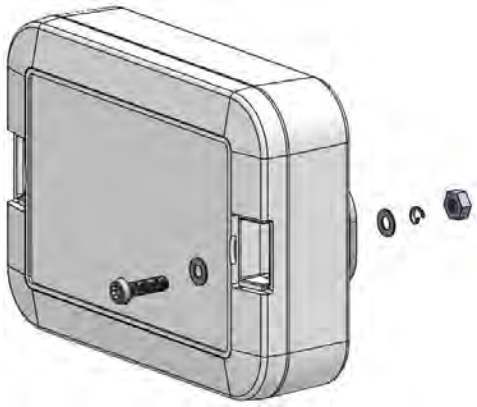
Figure: BreadCrumb ES1 Pole Mounting Bracket Attached



The mounting holes for attaching the pole mount bracket are accessible from the front of the BreadCrumb ES1 enclosure via small flip-up accesses on the left and right borders of the front of the ES1-5050CS enclosure.

The following diagram shows the order of washers, lock washer and nut used when attaching one end of the ES1-5050CS pole mounting bracket to the enclosure of the BreadCrumb ES1. Both ends of the pole mounting bracket should be attached to the BreadCrumb ES1. Some may wish to first thread the hose clamp through the slots of the pole mounting bracket (using the inner pair of slots for a smaller diameter pole/hose clamp, the outer pair of slots for a larger diameter pole/hose clamp).

Figure: Attaching the Pole Mounting Bracket to the BreadCrumb ES1



The attachment order of parts from front to back are:
M4 machine screw, washer, BreadCrumb ES1 (front to back), pole mounting bracket, washer, lock washer, nut

If the hose clamp was not threaded on before attaching the pole mounting bracket to the ES1-5050CS, thread it through the pole mounting bracket now. The hose clamp may then be tightly secured around a pole.

Figure: BreadCrumb ES1 Attached to a Pole

F.2 DIN Rail Mount Kit

The DIN rail mounting bracket and 35 mm top hat DIN rail clip for BreadCrumb ES1 attach to the back of the ES1-5050CS as described below. The ES1-5050CS DIN rail mount kit is Rajant P/N 90-100104-002.

The following diagrams show a BreadCrumb ES1 with DIN rail mounting bracket attached. In these diagrams, the DIN rail mounting bracket is attached so the DIN rail clip will be over the left side of the ES1-5050CS (the side with the protective vent). It is also possible to attach the mounting bracket with the DIN rail clip portion over the right side of the ES1-5050CS. The end of the bracket where the DIN rail clip attaches has a choice of two screwholes in the middle so the DIN rail clip can be attached in the proper orientation whether the bracket is mounted over the left or right side of the ES1-5050CS.

Reminder Regarding Orientation
The following simplified diagrams do not show the external features of the BreadCrumb ES1 such as the antenna ports, Ethernet port, Status LED. In all vertically-oriented diagrams, the side with the Ethernet port, M8 port, Status LED is facing down. The flip-up covers on the front of the mounting hole accesses are also not shown in the following diagrams.

Figure: BreadCrumb ES1 DIN Rail Mounting Bracket Attached (Back Corner View)

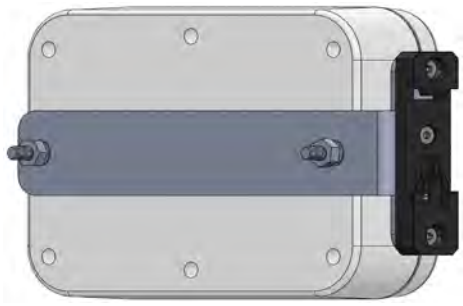
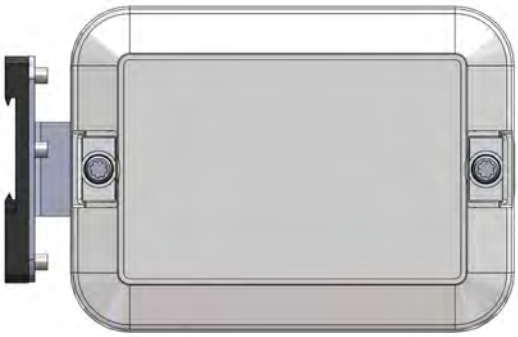


Figure: BreadCrumb ES1 DIN Rail Mounting Bracket Attached (Front View)

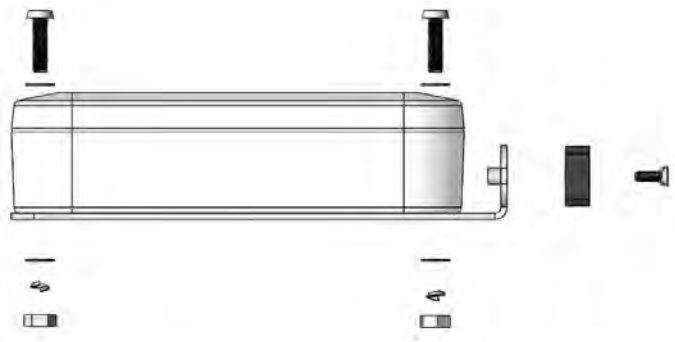


Note
The proper orientation for the DIN rail clip is with the fixed (non spring-loaded) end up, and the spring-loaded end of the DIN rail clip at the bottom. This insures that the fixed end of the clip will bear the weight. The Ethernet port, M8 port and status LED are on the bottom side of the BreadCrumb ES1.

The mounting holes for attaching the DIN rail mounting bracket are accessible from the front of the BreadCrumb ES1 enclosure via small flip-up accesses on the left and right borders of the front of the ES1-5050CS enclosure.

The following diagram shows the order of washers, lock washer and nut used when attaching one end of the ES1-5050CS DIN rail mounting bracket to the enclosure of the BreadCrumb ES1. The DIN rail mounting bracket should be attached to both mounting holes of the BreadCrumb ES1.

Figure: Attaching the DIN Rail Mounting Bracket to the BreadCrumb ES1 (Top View)



The attachment order of parts from front to back are:
M4 machine screw, washer, BreadCrumb ES1 (front to back), DIN rail mounting bracket, washer, lock washer, nut

The DIN rail clip is attached to the end of the DIN rail mounting bracket using three machine screws.

Figure: Attaching the DIN Rail Mounting Bracket to the BreadCrumb ES1 (Front View)

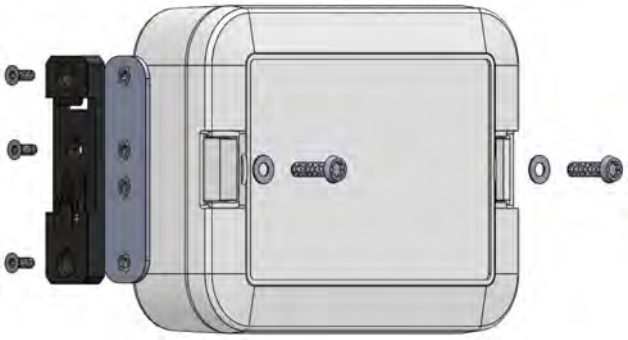
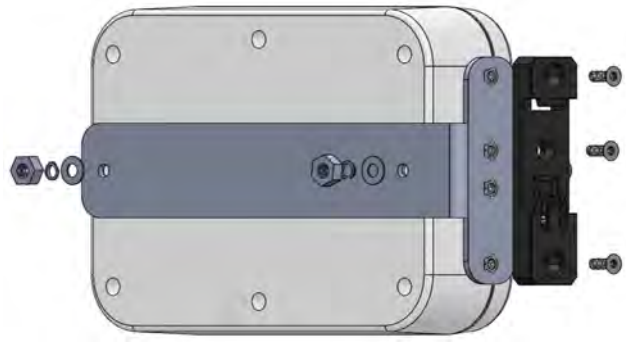


Figure: Attaching the DIN Rail Mounting Bracket to the BreadCrumb ES1 (Back View)



The BreadCrumb ES1 may now be attached to a 35 mm top hat DIN rail.

Appendix G: Technical Bulletins

G.1 Rajant Best Practices: Grounding and Surge Protection

July 11, 2018

G.1.1 Introduction

The Rajant BreadCrumb product line is designed to withstand the toughest conditions imposed by military and industrial scenarios. Although some basic protection from electrical surges is built into the design, this protection is not adequate to compensate for the damaging effects of high-energy electro-static discharge or lightning strike events. To ensure reliable operation and long service life, additional measures need to be taken to protect BreadCrumb equipment from electrical surges.

⚠ Important
Rajant equipment will most likely not survive a lightning strike even if the grounding and surge protection best practices detailed in this document are followed.

⚠ Important
It is not necessary for a lightning strike to hit equipment directly in order to cause damage. The electromagnetic forces caused by lightning are so powerful that even a strike that lands near the equipment may cause damage. The best practices detailed in this document are aimed at protecting the equipment from nearby strikes, rather than direct hits.

G.1.2 Environment

BreadCrumbs are often installed in environments susceptible to lightning, electro-static discharge (ESD), and other high-energy electrical surge events. A dry windy environment is more likely to create a large buildup of static energy that leads to electro-static discharges.

G.1.3 Recommendations

Rajant recommends the following best practices for installing BreadCrumb equipment (except the C1D2 – see the C1D2 User Guide for C1D2 installation):

- Use only shielded Ethernet cables with metal-shielded connectors. The metal-encased connectors provide the continuity of the ground from the BreadCrumb case to the PoE and AC ground or protective earth ground.
- Use an Ethernet surge protector for each utilized BreadCrumb Ethernet port.
- Use antenna surge protectors on all pole-mounted antennas.
- In order to avoid sparking and possible damage to the device, be sure to connect the surge protector and the powered Ethernet cable to the BreadCrumb before applying power to the PoE power supply.
- Always power off a BreadCrumb device prior to connecting or disconnecting external antennas.
- Ground all equipment:
  - Ground the BreadCrumb enclosure.
  - Ground the BreadCrumb power supply.
  - Ground the Ethernet surge protector(s).
  - If antennas are not connected directly on BreadCrumb antenna ports and offer exposed metal bases, then ground the bases of the antennas. If antennas are connected directly on BreadCrumb antenna ports, then they will be grounded through the BreadCrumb enclosure.

We continue to elaborate on these recommendations in the following sections.

G.1.4 Ethernet Surge Protection

An Ethernet cable provides a path for a power surge to enter a BreadCrumb. The longer the cable, the more susceptible it is to picking up surges. In case of a lightning strike, the cable will act as an antenna and absorb the electro-magnetic wave caused by the strike even from a long distance. Surges through the Ethernet port can be suppressed by an Ethernet surge protector.

Selecting Ethernet Surge Protectors

There are several aspects to consider when selecting an Ethernet surge protector:

- It is important to know how large a surge the protector can handle and how many strikes it can withstand before needing to be replaced.
- Be sure that the surge protector supports passive PoE. Installing the wrong surge protector on the PoE line can prevent the BreadCrumb from getting enough power to turn on.
- The surge protector will cause a voltage drop in the PoE power carried over the Ethernet cable. The voltage drop should be small enough so that enough power reaches the BreadCrumb.
- The surge protector will cause some degradation to the Ethernet data signal. Be sure that the degradation to the signal does not severely impact Ethernet throughput, especially on longer Ethernet cable runs.

Rajant recommends the L-Com ALS-CAT6HPW Ethernet surge protector (www.l-com.com, P/N: ALS-CAT6HPW) (see Figure 1).

Figure 1: L-Com ALS-CAT6HPW Ethernet Surge Protector

The features of this device are:

- Designed to meet the GR-1089 Intra-Building surge protection requirements.
- Weatherproof ABS enclosure with gasketed cover and PG16 cable glands for outdoor operation.
- External ground clamp to provide a tie point for earth ground.
- Compatible with 10/100/1000 Base-T equipment.
- Compatible with CAT5, CAT5e and CAT6 cables.
- Robust, two-stage TVS diode and differential gas tube suppression.
- Tested and fully compatible with Rajant BreadCrumb ME3, ME4, and LX4 devices.

Installing the Ethernet Surge Protector

The Ethernet surge protector should be installed as close to the BreadCrumb as practical, and ideally within 50 cm (20 in) of the device. The surge protector should be grounded as described in its operating manual, and according to local electrical codes and industry best practices. When a BreadCrumb is powered through its Ethernet port (i.e., PoE), the surge protector should *always* be installed between the BreadCrumb and its power source.

> **⚠ Warning**
> In order to avoid sparking and possible damage to the device, be sure to connect the surge protector and the powered Ethernet cable to the BreadCrumb before applying power to the PoE power supply.

G.1.5 Antenna Surge Protection

Antenna surge protectors should be used for all pole-mounted BreadCrumb antennas. Consider the following aspects when choosing an antenna surge protector:

Rajant recommends the PolyPhaser GT-NFM-AL antenna surge protector (www.streakwave.com, P/N: GT-NFM-AL) (see Figure 2).

Figure 2: PolyPhaser GT-NFM-AL antenna surge protector.

> **⚠ Warning**
> In order to avoid sparking and possible damage to the device, be sure to connect the antenna surge protector to the BreadCrumb before applying power to the BreadCrumb power supply.

G.1.6 The Goal: The Ground

The goal is to have a continuity of ground from the BreadCrumb to the destination AC ground or protective earth ground.

If the BreadCrumb uses an AC PoE, the ground pin of the AC plug should be plugged into a properly grounded AC socket.

If the BreadCrumb uses a DC PoE, the grounding connections of the DC PoE should be properly connected to an earth ground. Use 10 AWG or lower (larger) gauge wire for grounding cables and be careful to avoid any sharp bends. Examples of earth ground are:

G.2 Waterproofing Rajant BreadCrumb RF Connections

TECH SERVICE BULLETIN

ISSUE

For BreadCrumb products deployed in outdoor installations, it is recommended to waterproof all RF connections to the BreadCrumb. Waterproofing is recommended for both direct attach antenna applications and cabled antenna applications.

REQUIRED MATERIALS

Self-fusing, all weather, ethylene propylene rubber (EPR) tape. McMaster-Carr 7682A65 or equivalent.

Scotch® Premium Vinyl Electrical Tape 88-Super-3/4x44FT, 3/4 in x 44 ft (19 mm x 13.4 m)

SEALING BREADCRUMB RF CONNECTIONS

1. Clean the RF connectors on the BreadCrumb and the antenna. Clean the RF coupler (if used). For cabled antennas, clean the connector on the antenna cable that connects to the BreadCrumb. Allow all connections to dry. Attach antennas or antenna cables to the BreadCrumb.
2. For direct attach antenna applications, identify weep holes that may be present in the body of the antenna. Do not cover the weep holes with sealing tape as they are required to allow condensation to drain from the antenna.
3. The sealing process applies a single layer of EPR tape and two layers of all-weather electrical tape. For a direct attach antenna, the tape is applied from the RF connector on the antenna to the case of the Breadcrumb. For an antenna that is connected to a cable, the tape is applied starting 1" behind the cable connector and continues to the case of the BreadCrumb.

4. For either the direct attach antenna configuration, or the cabled antenna configuration, the installation sequence of each tape wrap is critical to the performance of the environmental seal.

   a. **Application of EPR tape layer:**
   Remove the backing liner from the EPR tape prior to installation. To maximize protection from water ingress, the layer of EPR tape must be applied opposite to the direction of water flow.

   For an RF connection to the top side of the BreadCrumb case, the wrap would start at the case of the BreadCrumb and wrap up to just above the antenna connector. For an RF connection to the bottom side of the BreadCrumb case, the wrap would start just below the antenna connector and wrap up to the BreadCrumb case.

   Slightly stretch the EPR tape while wrapping to insure a good seal. The target overlap of the EPR tape layer is ½ the width of the EPR tape. When the EPR tape is applied per this procedure, the seams of the EPR wrap layer will have full overlap in the direction of water flow. Figure 1 and Figure 2 show a properly installed layer of EPR tape for a directly mounted antenna installed on the top side of the BreadCrumb (antenna ray dome facing up). Note the full overlap of the EPR tape seams in the direction of water flow.

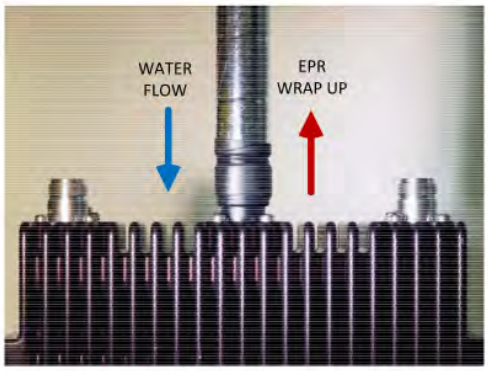


FIGURE 1 VIEW OF EPR TAPE APPLIED TO DIRECT ATTACH ANTENNA INSTALLED ON TOP SIDE OF BREADCRUMB

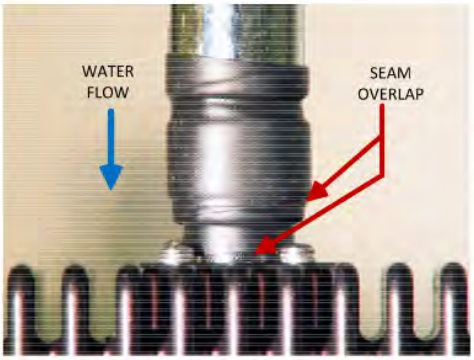


FIGURE 2 CLOSE-UP VIEW OF SEAM OVERLAP OF EPR TAPE

	SIZE		TSB #	
	A		03-100136-001	A
	SCALE		Page 3 of 5	REV

b. **Application of All-Weather Electrical Tape Layers**
Two layers of all-weather electrical tape are applied over the single layer of EPR tape. To maximize protection from water ingress, it is critical that the second layer of electrical tape is wrapped in the opposite direction of water flow (wrap up).

For an RF connection at the top side of the BreadCrumb case, the first wrap layer of all-weather electrical tape would start at the antenna connector just above EPR tape and wrap down to the case of the BreadCrumb. The second layer of all-weather electrical tape would start at the case of the BreadCrumb and wrap up to overlap the first layer of electrical tape.

For an RF connection to the bottom side of the BreadCrumb case, the first wrap layer of all-weather electrical tape would start at the BreadCrumb case and wrap down to antenna connector just past the layer of EPR tape. The second layer of all-weather electrical tape would wrap up toward the case of the BreadCrumb and fully overlap the first layer of electrical tape.

Slightly stretch the all-weather electrical tape while wrapping to insure a good seal. The target overlap of the layer of all-weather electrical tape is ½ the width of the tape.

FIGURE 3 and FIGURE 4 show the two layers of all-weather electrical tape for a directly mounted antenna installed on the top side of the BreadCrumb (antenna ray dome facing up). Note: FIGURE 4 shows the full overlap of the tape seams in the direction of water flow.

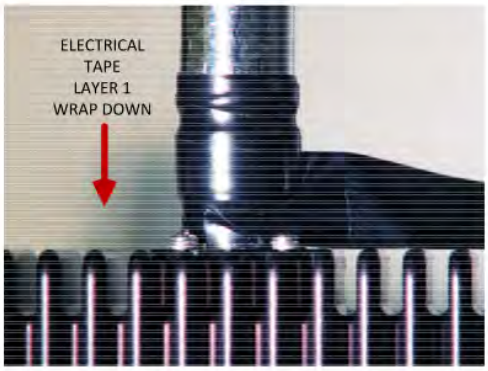


FIGURE 3 FIRST LAYER OF ALL-WEATHER ELECTRICAL TAPE APPLIED TO DIRECT ATTACH ANTENNA INSTALLED ON TOP SIDE OF BREADCRUMB

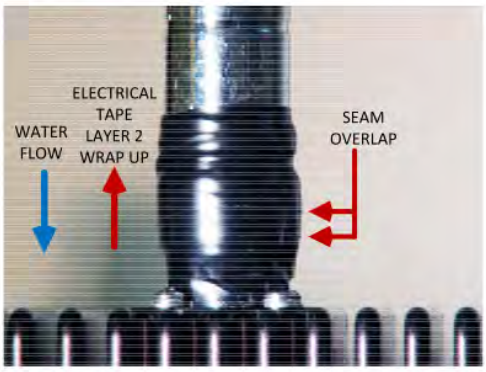


FIGURE 4 SECOND LAYER OF ALL-WEATHER ELECTRICAL TAPE APPLIED TO DIRECT ATTACH ANTENNA INSTALLED ON TOP SIDE OF BREADCRUMB

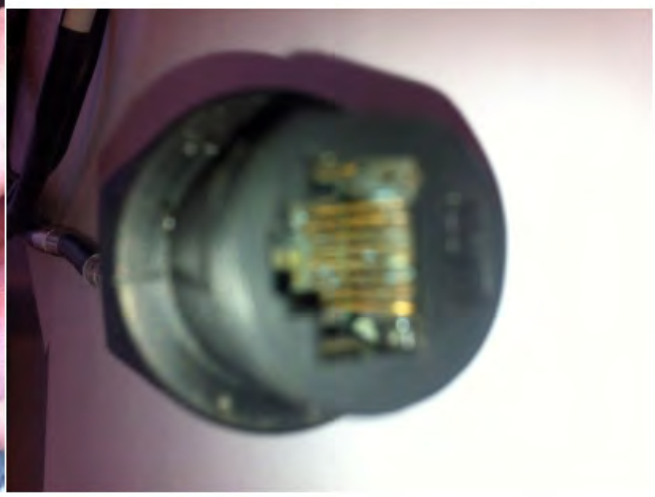
	SIZE		TSB #	
	A		03-100136-001	A
	SCALE		Page 5 of 5	REV

G.3 Waterproofing BreadCrumb Cable Connections

Rajant Technical Service Bulletin: Instructions to properly seal Squid cables

Issue:

For BreadCrumb products deployed in outdoor installations, it is recommended to waterproof all Squid cable connections to the BreadCrumb to prevent any liquid from seeping into the connectors.



Items needed:

Self fusing weather proofing tape

http://www.amazon.com/Emergency-Repair-Tape-Self-Fusing-Silicone/dp/B00KBSWRDO/

Star Brite Liquid Electric tape (do not use Gardner Bender brand Liquid tape.)

http://www.amazon.com/Star-brite-84134-Liquid-Electrical/dp/B000Y82XVC/

Di-Electric Grease

Use the Di-Electric Grease shown above to fill any gaps in the threads of the connectors.

http://www.amazon.com/CRC-Technician-Di-Electric-Precision-Applicator/dp/B000CCIDAA/

Solution:

Properly apply Di-Electric Grease, Fusing Silicone weatherproofing tape and Starbrite liquid electric tape to “weather proof” the connectors.

Below are instructions on how to seal both the Amphenol and LTW connectors to prevent any fluid seepage.

> ***NOTE:*** *A BreadCrumb LX4 is used for the photos.*

Apply a small strip to the female threads of Eth connectors, USB port and the outside of the female Amphenol connector. The brand of Di-Electric grease is unimportant. However a gel type is preferred.

Make the connections ensuring that the connectors are secure but not over tightened which may cause cross threading on the LTW connectors. Ensure that the Amphenol connector is properly locked into place.

Wrap the Amphenol connector with Fusing Silicone weatherproofing tape starting at the bottom and wrapping upward so that overlaps are at the bottom. Stop at the top of the connector as shown below.

Add a thin layer of Liquid electrical tape to the top of the connector overlapping the self fusing silicone tape to seal the top of the connector as seen above.

Next connect the LTW connector on the Eth0 port and replace the caps on the Eth1 and USB ports. If the Eth 1 or the USB port is going to be used connect the LTW side of the cable to the squid. Apply a thin layer of Star Brite Liquid tape. Just enough to seal the gap between the cap and threads to the thread side of the cap or connector making sure to pay attention to the flat spot on the female thread side. The liquid tape should be allowed to dry for approximately 5 minutes before moving the connectors.

The Liquid Electric tape should remain pliable so it can be removed to service the radio.

Do not use Gardner Bender brand Liquid tape. This brand tends to become very hard over long periods of time which may impair removal.

Additional Notes:

When installing the BreadCrumb, the Squid cable should be secured but hang down. Bending the Squid cable up may compromise the integrity of the adhesive in the heatshrink allowing liquid to build up and possibly flow into the cable.

This does not protect against pressure washing.

G.4 BreadCrumb Models Support Only Passive PoE

> ⚠ **IMPORTANT**
> This applies to many Rajant BreadCrumb models, not just those listed. Consult your BreadCrumb model user guide.

RAJANT Product TIB Notice No.: 2015002

Date: 10/30/2015

Technical Information Bulletin

Product(s) Affected: Rajant BreadCrumb® ME4, LX5, and JR2 models; passive PoE devices

Description: The first ME4 Ethernet port (eth0), both LX5 Ethernet ports (eth0, eth1), and the only Ethernet port on the JR2 support passive power over Ethernet (passive PoE). Unlike other PoE methods such as IEEE 802.3af/at, passive PoE does not include any kind of handshaking or voltage checking.

Some Cisco switches support both IEEE 802.3af/at PoE or their own proprietary version. Their default mode is mamed “auto.” In “auto” mode, the switch will try to automatically detect the type of PoE the plugged-in device supports. The Cisco switch auto method does not work with passive PoE equipment including plugging into the data input ports of Rajant PoE devices that are used with the ME4, LX5, and JR2. The link will not come up or will “flicker” up and down.

To connect a Cisco PoE switch to a Rajant PoE capable device, you must turn off the PoE capability for this port. You must set the “"power inline”“ setting of the port to ”“never.” For information about configuring this port, refer to the following:

http://www.cisco.com/c/en/us/td/docs/switches/lan/catalyst4500/122/25ew/configuration/guide/conf/PoE.html includes information for configuring the port.

Remarks:

Do not attempt to combine Cisco automatic PoE detection with the input port of Rajant passive PoE devices used with the ME4, LX5, and JR2 models. Set the “power inline” setting of the port to “never”. Contact a technical support representative for further information.

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G.5 Never Apply Power to the Data Input Port of a Rajant Mid-Span Power over Ethernet (POE) Power Supply

⚠ IMPORTANT
This applies to all Rajant BreadCrumb models using passive PoE power supplies.

RAJANT Product TSB Notice No.: 03-100162-001

TECH SERVICE BULLETIN

Never Apply Power to the Data Input Port of a Rajant Mid-Span Power over Ethernet (POE) Power Supply

Summary:

With exception to the Rajant VHDC-24V50W-GbE, never connect the data input port of any Rajant supplied mid-span POE power supply to a POE powered data port. Rajant 10/100 POEs will not work properly, and Rajant 10/100/1000 POEs will be permanently damaged causing the Ethernet data link to fail.

Background:

Many Rajant BreadCrumb models including KM3, ME4, ME3, LX5, LX4 and the JR family do not support 802.3 af/at automatic power negotiation. These BreadCrumb models must be powered from Rajant-approved passive mid-span POE power supplies. Rajant mid-span POE power supplies do not support 802.3 af/at automatic power negotiation. With exception to the Rajant VHDC-24V50W-GbE, the data input port of all other Rajant POE power supplies must never be connected to a POE powered data port.

The Ethernet data lines of the Rajant 10/100/1000 AC/DC mid-span POE power supply are protected by low voltage TVS diodes. These protection diodes are intended to prevent damage to equipment from short duration voltage transients, such as electrostatic discharge. The TVS diodes will fail to a permanent short circuit condition if continuous DC voltage is applied. When the TVS diodes are damaged, the POE data path will no longer work. The Ethernet data link will fail, or will never form.

Field Test:

Use the following procedure to test a Rajant mid-span POE for data path damage.

1. Remove the AC power cord from the Rajant POE.
2. Using two data cables, connect both the data INPUT and data plus POE OUTPUT port of the Rajant POE to an unmanaged switch.
3. Confirm that a data link is formed by inspecting the link lights on the Ethernet switch ports.
4. If the POE does not form a data link on both ports of the Ethernet data switch, replace the POE with a new one.

Mitigation:

The recommended best practice is to only connect the Rajant POE IN port to a non-POE Ethernet switch. Always connect the OUT port of a Rajant POE power supply to a BreadCrumb.

If only a POE switch is available, a data isolation transformer, such as L-COM BT-CAT6-P1 may be used with Rajant POE power supplies. Connect the data port of the L-COM BT-CAT6-P1 to the POE switch port, and connect the DATA+POWER port of the L-COM BT-CAT6-P1 to the Rajant POE power supply data input port.

G.6 Installation Constraints for Rajant AC Powered Accessory POE Power Supplies

RAJANT Product TSB Notice No.: 03-100163-001

TECH SERVICE BULLETIN

The approved use of Rajant supplied AC powered mid-span POE power supplies (as shown in the photo) is limited to indoor, environmentally sheltered, non-damp locations that are isolated from shock or vibration. The AC powered POE power supplies are not sealed for dust or water ingress, and are not intended to operate in an environment with condensing humidity. The construction of these POE models is not ruggedized for exposure to mechanical shock or vibration.

Failure to observe the recommended installation restrictions may result in network outages and poor network performance as POE device failure is likely, and will void the Rajant warranty of the accessory POE. Damage to a Rajant BreadCrumb resulting from misuse of the AC powered POE may not be covered by the BreadCrumb warranty.

Rajant Corporation does offer DC powered midspan POE models – namely the VHDC series – that are suitable for use in non-environmentally sheltered locations, such as vehicles and outdoor trailers. Verify the ingress performance of the specific Rajant VHDC model on the product datasheet when selecting a mid-span POE for a specific application.

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Version 2, June 1991

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