BreadCrumb® ME4

v11 User Guide

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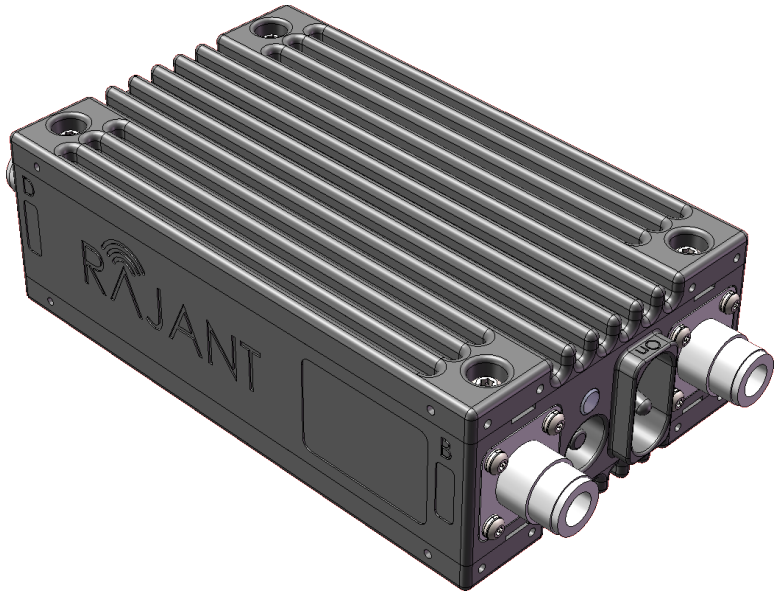

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Copyright Statement

BreadCrumb® ME4 v11 User Guide

FCC and IC Statements

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.

This Class A digital apparatus complies with Canadian ICES-003 and RSS-210 rules.

Cet appareil numérique de la classe A est conforme à la norme NMB-003 et CNR-210 du Canada.

Required Antenna Separation

The FCC/IC wireless approval for this product is conditional on maintaining at least 20cm separation between the antennas. At least one of the antennas must be connected to the BreadCumb with 50 ohm coaxial cable. Low loss LMR400 cable is recommended for this application.

WARNING: To satisfy FCC RF exposure requirements a minimum safe distance of 20 cm must be maintained between this device and all persons while the device is operating.

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.

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

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Preface

Purpose and Scope

This manual provides information and guidance to all personnel who are involved with and use Rajant Corporation's BreadCrumb ME4.

This manual begins with an introduction to the BreadCrumb Kinetic Mesh Network. It then characterizes the features of the BreadCrumb ME4. 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 *ME4* and *BreadCrumb* are used to refer to *Rajant BreadCrumb ME4*.

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 support@rajant.com. Please be sure to include the version number of the manual or product you are using as well as the relevant page numbers if appropriate.

Related Documentation

For additional information, refer to these documents:

- *BC|Commander® v11 User Guide*: This document contains information on the BC|Commander management application, which is used to configure BreadCrumbs before or during a deployment.
- *BreadCrumb® Video Guide*
- *Rajant Troubleshooting Range User Guide*
- *RF Component Installation and Verification in BreadCrumb® Networks*

1 Introduction to BreadCrumbs

Rajant Corporation's (http://www.rajant.com) BreadCrumbs utilize the 802.11 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 as well as 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 which has the ability to connect to other BreadCrumbs or networking devices to form a BreadCrumb network. The BreadCrumb is specifically designed for the following scenarios:

Temporary Wireless Networks
: Networks that must be established quickly and with minimal effort for short-term use (e.g., a network established to provide First Responder support at the site of a disaster).

Mobile Wireless Networks
: Networks in which the network infrastructure itself is mobile, in addition to client devices (e.g., a convoy viewing a video stream from a UAV).

Wireless Network Extension
: Networks in which a wireless network must be quickly extended around or through obstacles that block wireless communications (e.g., urban canyon networks, tunnels/caves, etc.)

Wired Network Extension
: Networks in which two or more wired LANs at different locations must be connected wirelessly (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 the above scenarios.

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

Note	Although all BreadCrumbs can be access points, most access points do not provide mesh capability. Traditional access points simply allow wireless devices within range to connect to a wired network; they do not extend range through other access points.

1.2 Mobility through Meshing

The key component of a BreadCrumb network is the ability for BreadCrumbs to connect, or Mesh with each other. While this 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 its final destination.

The intelligence of a BreadCrumb network is in how it adapts rapidly to the creation or destruction of the 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, they must be set to the same radio channel, and have the same Network ID. The Network ID is computed from the BreadCrumb's Network Name, Network Key, and a collection of Crypto settings. The Network Name is simply a name for a Mesh network. By default, BreadCrumbs use the Network Name "Rajant Mesh Network". The Network Key is a passphrase or key used to secure the network. The Crypto settings include a packet cipher, MAC cipher, per-hop authentication, and a key sequence number. All of these settings on the BreadCrumbs can be configured using BC|Commander v11. The Crypto settings can only be configured if the application is logged into the BreadCrumbs using Crypto Officer credentials.

Note	Version 10 firmware uses the BreadCrumb's primary ESSID instead of the Network Name to form Mesh links.

2 Description of a BreadCrumb ME4

BreadCrumb ME4 is a portable, wireless device deployable in almost any environment. It is light in weight, supports up to 4 external antennas and is designed to be completely mobile as worn by an individual. The BreadCrumb ME4 must be powered by an external source.

2.1 Radios

The BreadCrumb ME4 contains two radios in the 900 MHz, 2.4 GHz, 4.9 GHz or 5 GHz bands. Custom radio configurations, including a mix of licensed, military or unlicensed frequencies are available upon request. There are several different models of ME4, each with a different combination of radios. See Appendix A for a list of the channels and frequencies supported by each of the radios.

2.2 Enclosure

The ME4 enclosure has been designed to operate in extreme conditions, with protection against ingress of dust as well as protection against immersion in water. The enclosure dimensions are 189 mm x 95 mm x 51 mm (7.46” x 3.75” x 2.00”). The external features of the enclosure are shown in Figure 1 and Figure 2.

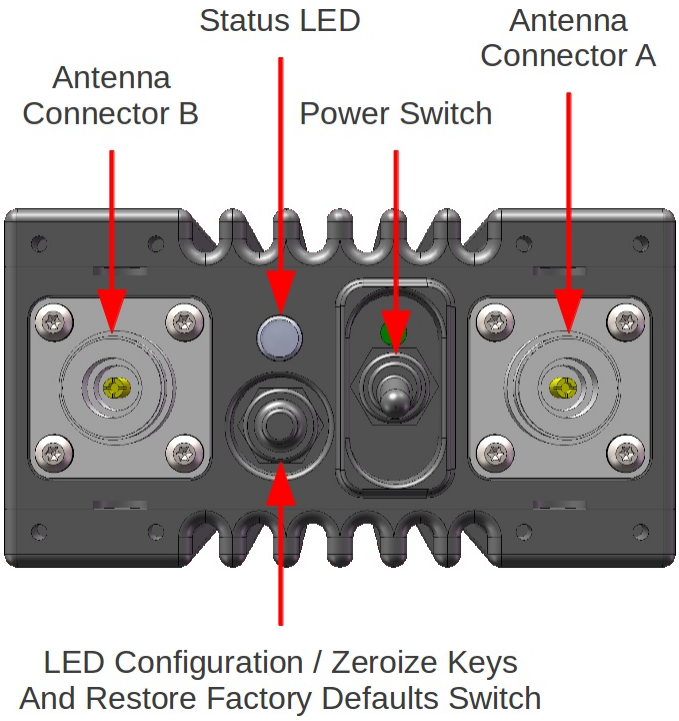

Figure 1: BreadCrumb ME4 Enclosure Features (Front)

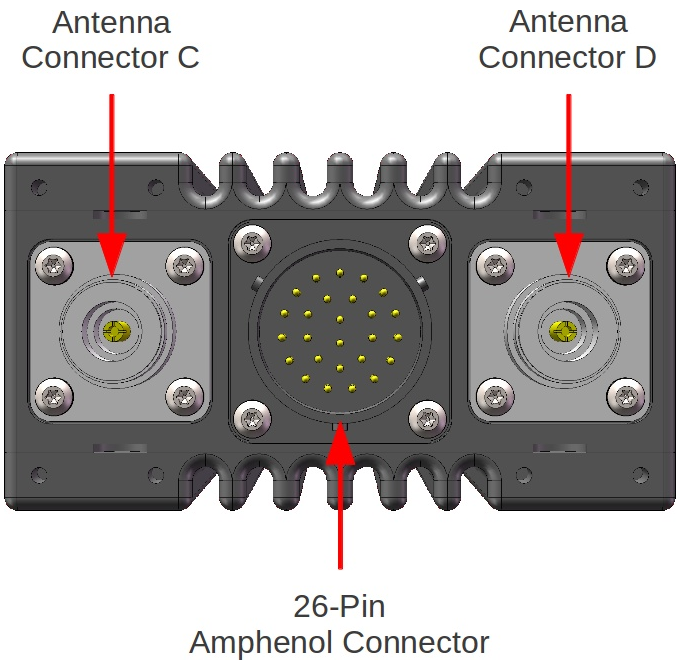

Figure 2: BreadCrumb ME4 Enclosure Features (Back)

2.3 Antenna Connectors

The BreadCrumb ME4 provides up to four Type N female antenna connectors. Two connectors are located on the top side of the enclosure (see Figure 1), the other two connectors are located on the bottom side of the enclosure (see Figure 2). In general, only one antenna port per radio is utilized. Some BreadCrumb models offer antenna diversity or Multiple-Input and Multiple-Output (MIMO) features, in which case two antenna ports per radio are utilized. There are many different ME4 Models available, each with a different configuration of radios and antennas. Each antenna connector will be labeled with the frequency of its corresponding radio.

Important Most ME4 models do not support directly attaching antennas under FCC regulations.

When using the pole mount option for deploying the ME4, care should be taken to make sure the antennas, and therefore the pole is mounted plumb. This is because most of Rajant's standard antennas are characterized by high-gain and therefore small vertical beamwidth. The small vertical beamwidth necessitates the antennas to be plumb, so that units 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 ME4 turned off.

2.4 26-Pin Amphenol Connector

The majority of the signals and features of BreadCrumb ME4 can be accessed through the 26-pin Amphenol connector on the enclosure (see Figure 2). The most important of these interfaces are external power, Ethernet, and USB, which are described in more detail in the following sections. The 26-pin Amphenol connector interfaces to the ME4 cable assembly that provides access to input power, Ethernet and USB ports of the device.

2.4.1 Power

The input power interface to the BreadCrumb ME4 resides on the 26-pin Amphenol connector (see Figure 2). The device accepts external power in the range of 8 to 48 VDC. The average idle power consumption of BreadCrumb ME4 is 5.5 W at 24 V. The maximum peak power consumption of BreadCrumb ME4 is 19 W at 24 V.

2.4.2 Ethernet

The first Ethernet port (eth0) on the BreadCrumb ME4 supports 10 Base-T, 100 Base-TX or 1000 Base-T configuration. The second Ethernet port (eth1) supports 10 Base-T, or 100 Base-TX configuration. Both Ethernet ports can be accessed through the 26-pin Amphenol connector on the enclosure (see Figure 2). Both ports support 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.

The ME4 cable assembly plugs into the 26-pin Amphenol connector and provides two standard RJ-45 Ethernet connectors for easy access to the the ME4 Ethernet ports.

2.4.3 USB

The ME4 contains one USB port, which can be access through the 26-pin Amphenol connector on the enclosure (see Figure 2). 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 BreadCrumb firmware upgrades and USB-based zeroize. It can also interface to an optional GPS receiver accessory available from Rajant.

2.5 ME4 Cable Assembly

The ME4 comes with a standard cable assembly that connects to the BreadCrumb's 26-pin Amphenol connector. The cable assembly includes two Ethernet ports and one USB port.

2.6 Status LED

The Status LED (see Figure 1) is capable of displaying warning and error codes, and link states. The LED Mode can be configured in BC|Commander to be ON (switchable), ALERTS ONLY (switchable),

OFF (non-switchable), or OFF (switchable). When the LED Mode is ON, the BreadCrumb LED alternates between displaying the link state and any warnings or errors. When the LED Mode is OFF, the BreadCrumb LED does not display any warnings, errors, or the link state. When the LED Mode is set for ALERTS ONLY, the BreadCrumb LED alternates between displaying the link state and any warnings or errors only if there are warnings or errors to report. If there are no warnings or errors, the LED displays nothing.

The Status LED combines the three base colors of red, green and blue to display a broader spectrum of colors which indicate the current status of a BreadCrumb. The meanings of the color code indicators are given in Table 1.

Table 1: Status LED Color Codes

Color	Status
White (red, green and blue LEDs together; may appear pale blue or pale green)	Powered, early boot process
Red-Blue-Green scrolling in succession	Success, end of boot process
Solid Blue	Ready, but no peers
Blinking Green	At least one peer
Solid Green	At least one 24 Mbps or higher peer
Blinking Yellow (at a constant rate)	Progress
Blinking Yellow[1] (with short and long pauses between blinks)	Warning
Blinking Red[1] (with short and long pauses between blinks)	Error
All Status LED colors scrolling in succession	Success/Completion

2.7 LED Configuration / Zeroize Keys and Restore Factory Defaults Switch

The LED Configuration / Zeroize Keys and Restore Factory Defaults Switch (see Figure 1) has two modes of operation. The modes are set by the length of time the switch is asserted. The modes are:

- LED Configuration

1 For a list of error and warning codes refer to Appendix B at the end of this document.

- Zeroize Keys and Restore Factory Defaults

2.7.1 LED Configuration

This mode is used to control the display states of the Status LED. The LED Configuration function is accessed by pressing the switch and releasing it after a two second hold. The configured display state of the Status LED is dictated by the LED Mode setting that is configured from BC|Commander (please refer to the BC|Commander v11 User Guide for a more detailed description of the LED Mode setting). The user can toggle between the configured state and an alternate state of the Status LED by pressing the switch and activating the LED Configuration function.

Table 2 lists the possible configured and corresponding alternate display states of the Status LED.

Table 2: Configured and Alternate Display States of the Status LED

Configured State	Alternate State
On	Off
Alerts Only	On
Off (non-switchable)	N/A
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 the state back and forth between Alerts Only and On, but not between Alerts Only and Off. Transitioning from Alerts Only to Off would require changing the LED mode setting in BC|Commander.

The default LED Mode for the ME4 is On.

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

2.7.2 Zeroize Keys and Restore Factory Defaults

This mode is is used to erase the security protocol keys of a BreadCrumb ME4 and to restore its software configuration to the factory default state. To operate this switch follow these procedures:

- Ensure that the BreadCrumb is powered on, has fully booted-up and its Status LED color is green or blue (see Table 1).
- Press and hold the switch for approximately 10 seconds until the Status LED changes to blinking yellow (see Table 1). This indicates that the Zeroize Keys and Restore Factory Defaults operation has been initiated and is in progress.

- Release the switch. The Status LED should change to display the blinking red error code 32. See Appendix B for a description of the blinking red color sequence. The BreadCrumb will then reboot using the factory default configuration.

⚠ **Warning**	Do NOT turn off or reboot a BreadCrumb that is being zeroized. An interruption to power during the zeroization process can result in the BreadCrumb being unable to boot properly.

Tip	The process of zeroizing keys and restoring factory defaults can also be performed remotely with the BC|Commander management software or with a properly prepared USB drive. For more information, refer to the BC|Commander v11 User Guide.

3 Using BC|Commander

BC|Commander is Rajant's BreadCrumb administration software package used for monitoring the status of BreadCrumbs and mesh links. BC|Commander is also used for configuring BreadCrumbs, upgrading BreadCrumb firmware, and graphically displaying the network topology.

BC|Commander can be run on any computer that has access to the BreadCrumb network. Versions of the software package are available for Microsoft Windows® or Linux.

BC|Commander includes an option called v10 Compatibility Mode. This allows a user to run a mixture of BreadCrumbs with firmware version 10 and firmware version 11 within the same mesh network. This is very useful when BreadCrumbs in a very large network are being upgraded from version 10 to version 11 firmware.

Rajant periodically releases updated BC|Commander software. The updated software must be obtained from Rajant. Refer to Rajant's most recent *BC|Commander v11 User Guide* for instructions on how to install the latest version of BC|Commander on your computer and how to use BC|Commander with Rajant's BreadCrumbs.

Important It is recommended that the BC|Commander version used be equal to or greater than the firmware version running on any administered BreadCrumbs in order to administer all BreadCrumb firmware features covered in Rajant's *BC|Commander v11 User Guide*.

Note Some portions of the *BC|Commander v11 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

There are many factors which need to be taken into account when deploying a BreadCrumb mesh network. Section 4.1 describes the addressing scheme of the mesh. Section 4.2 discusses channel assignments. Section 4.3 details some of the most commonly occurring environmental factors that will have a major impact on the performance of the mesh. Finally, section 4.4 details guidelines and methodology needed to follow when deploying the mesh.

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 you are not connected to another network, or if you are bridging to one rather than routing to it, your wireless client devices may have any address whatsoever.

Note	Any computers running the BC|Commander management application must have an address in the same range as the BreadCrumbs they manage. Refer to the *BC|Commander v11 User Guide* document for the details of the BreadCrumb IP address configuration.

4.1.1 BreadCrumb Device Addresses

Each BreadCrumb radio has one IPv4 address in the Class A network 10.0.0.0/8. Rajant ensures during manufacturing that the default addresses are not duplicated between any two BreadCrumb devices. Addresses assigned to BreadCrumb devices can be viewed using BC|Commander. They 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, and it is in fact the most common case that all BreadCrumb devices in a mesh run DHCP servers. 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 first radio's IPv4 address.
- Add a low-byte range of 10 to 210.

4.2 Channel Assignments

BreadCrumb radios have default channels assigned, based on the frequency of the radio. See Table 3 for a list of available radios and their default channel assignments.

Table 3: Default Channel Assignments

Radio Card Frequency	Default Channel
900 MHz	5
2.4 GHz	11
4.9 GHz	20
5 GHz	153

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 v11 User Guide* for the details of 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. These can be maximized by taking into consideration all of the contributing factors described in this section.

4.3.1 Line-of-Sight

Unobstructed line-of-sight (LOS) 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. This can allow the radio waves to propagate over some possible obstructions.

Unobstructed LOS is not necessary from every BreadCrumb device and wireless client to every other BreadCrumb device and wireless client. However, each device must have unobstructed LOS to the previous and subsequent device.

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

4.3.2 Distance

Many factors determine acceptable distances between BreadCrumb devices when deploying a mesh:

- If many devices are placed too closely together, it is possible that interference will degrade the performance of the system.

- Devices placed too far away or in RF “shadows” may experience total loss of connection.
- RF transmit power and receive sensitivity are important in determining the distances over which the device will be effective.
- When placing a BreadCrumb device, check the connection status to the nearest available device using either the BreadCrumb device’s status LED (described in section 2.6 Status LED), or the BC|Commander management application. If the connection is poor or non-existent, attempt to relocate the BreadCrumb device closer to another device until an acceptable connection is obtained. If a poor connection or no connection is made at even relatively close distances, you should refer to Chapter 6 Troubleshooting.
- When the connection quality is found to be acceptable from BC|Commander, the distance of the BreadCrumb device 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 also act as obstructions blocking the propagation of the wireless network’s radio waves.

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 BreadCrumb devices into the network to act as short haul repeaters to counteract the effects of the weather. An alternative is to move the devices closer together.

4.3.4 Interference

RF interference can degrade network performance and can come from many different sources, including:

- Other BreadCrumb devices 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 building can cause radio waves to be reflected, causing multipath interference.

Caution Plan the BreadCrumb Wireless Network to minimize the effects of RF interference.

4.3.5 Placement of Mesh Components

The placement of BreadCrumb devices has a major impact on maximum effective range, and therefore network performance. The components must be elevated above the surrounding terrain to allow for adequate wave propagation. A device placed directly on the ground has a significantly reduced effective

range. Elevating a device above the ground dramatically increased the maximum effective range. Rajant recommends elevating the components a minimum of 6 ft. above the surrounding surface.

4.4 Deployment Guidelines and Methodology

This section addresses the actual on-site deployment of the mesh. While by no means an exhaustive treatise, it 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) Elevate the BreadCrumbs whenever possible.
      i. Directly on the ground, the maximum distance between any two BreadCrumbs is approximately 300 ft. Also, the maximum distance between a wireless client and the nearest BreadCrumb is approximately 300 ft.
      ii. Rajant recommends elevating each BreadCrumb a minimum of 6 ft. above the surrounding terrain for maximum range. Elevating the BreadCrumbs, as little as 14 inches, has proven to increase the range out to approximately 600 ft.
2. Distance
   (a) If you cannot elevate the BreadCrumbs, they can only be approximately 300 ft. apart. Also, any wireless clients can be no farther than approximately 300 ft. from a BreadCrumb.
3. Line of sight
   (a) Obstructions to line-of-sight block/absorb/deflect the wireless network's radio waves, resulting in poor network performance or total loss of network connectivity.
   (b) When placing the BreadCrumbs, 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, they will most likely weaken or block the BreadCrumb's radio waves.
4. Weather
   (a) Light precipitation will reduce the range and performance of the 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 steps detailed in this section should assist you in successfully deploying the mesh.

1. Scan the terrain on which 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, and plan BreadCrumb placement to work around them.

2. Identify the PC on which BC|Commander will be run.
   (a) This PC should have a wireless NIC, as you will need to carry it with you as you deploy the mesh.
      i. Alternatively, the BC|Commander PC can be stationary with one person monitoring BC|Commander while another deploys the BreadCrumbs. This method requires some form of communication (radio, cell phone, etc.) between the two persons.
3. Determine the location for the first BreadCrumb.
4. Power ON the device.
5. Wait approximately 90 seconds for the device to boot.
6. Power ON the BC|Commander PC.
7. Start BC|Commander.
8. The BC|Commander console should display the first BreadCrumb.
9. Determine the approximate location for the next BreadCrumb.
10. Proceed to the location for this BreadCrumb, observing the network in BC|Commander as you progress.
    (a) If the BreadCrumb loses network connectivity before you reach its destination, backtrack until network connectivity is restored. The point at which network connectivity for this BreadCrumb is restored is most likely the farthest point in this direction at which you will be able to place this BreadCrumb.
    (b) If you reach the destination without losing connectivity you can place it there.
        i. At this point, you may choose to proceed farther in an attempt to make optimal use of the available BreadCrumbs.
        ii. If so, proceed until network connectivity is lost and then backtrack until network connectivity is restored for this BreadCrumb. The point at which network connectivity is restored for this BreadCrumb is most likely the farthest point in this direction at which you will be able to place this BreadCrumb.
11. Repeat steps 9 and 10 for any remaining BreadCrumbs.

5 Firmware Upgrade

Each BreadCrumb relies on low-level software known as *firmware* for proper execution. For a BreadCrumb to communicate with other BreadCrumb devices or a BC|Commander client, the firmware version of the device must be compatible with the firmware versions of all other devices within the network, and with the version of BC|Commander running on the client computer.

Note	For procedures to install and upgrade the BC|Commander management application, refer to the latest *BC|Commander v11 User Guide*.

The firmware is routinely updated by Rajant Corporation to add new product features, support new applications, and to fix reported problems. To upgrade the firmware on a BreadCrumb, you must obtain the appropriate firmware file for your BreadCrumb model from Rajant. Save the file on a computer on which the BC|Commander management application has been installed.

5.1 Over The Air Firmware Upgrade

One method of upgrading the firmware is a process called “Over-the-Air (OTA) firmware upgrade”. This is a remote process, controlled and initiated by a system administrator using BC|Commander. Follow the instructions in the *BC|Commander v11 User Guide* (Administrative Tasks – Over-the-Air (OTA) firmware upgrade) to perform the firmware upgrade process.

5.2 USB Firmware Upgrade

Another method is the USB firmware upgrade. This process takes place at the BreadCrumb's location and requires a properly prepared USB storage device. To perform the firmware upgrade process, follow these procedures:

1. Prepare a USB storage device with the appropriate firmware file using BC|Commander. Follow the instructions in the *BC|Commander v11 User Guide* (Administrative Tasks – USB Firmware Upgrade).
2. Connect the USB storage device to the BreadCrumb's USB port and turn on the BreadCrumb.

Note	With v11, the USB drive can be connected to a live BreadCrumb and the upgrade process will begin automatically.

3. The firmware upgrade process will take several minutes. Observe the BreadCrumb's Status LED to monitor progress.
   (a) When the USB firmware upgrade begins, the Status LED will start blinking yellow, which indicates progress. When the process nears completion, the blink rate will increase from once per second to several times per second.
   (b) If the firmware upgrade completes successfully, the Status LED will rapidly rotate between red, green, blue, cyan, magenta, yellow and white colors.

(c) If an error condition is encountered, the Status LED will start repeating a particular sequence of long and short blinks in red, indicating the error code. Take note of the error code (see Appendix B for an explanation of error codes). Leaving the USB storage device connected, turn power to the BreadCrumb OFF and then ON again. Observe the Status LED to monitor progress. If, during this second firmware upgrade attempt, another error occurs, take note of the new error code and then apply for technical support.

4. When complete, turn power to the BreadCrumb OFF, disconnect the USB storage device, then turn power to the BreadCrumb back ON.

5.3 USB-Based Zerioze

As of firmware version 10.27, there is a USB-based Zeroize feature. This feature does not upgrade or in any other way affect the firmware version running on the BreadCrumb. This process takes place at the BreadCrumb's location and requires a properly prepared USB storage device. To perform the firmware upgrade process, follow these procedures:

1. Prepare a USB storage device using BC|Commander by selceting the “Zeroize (Do Not Upgrade)” option in the USB Flash Manager. Please see the *BC|Commander v11 User Guide* (Administrative Tasks – USB-Based Zeroize) for more detailed instructions on how to properly prepare the USB storage device.
2. Connect the USB storage device to the BreadCrumb's USB port and turn on the BreadCrumb.

Note	With v11, the USB 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 a minute. Observe the BreadCrumb's Status LED to monitor progress. Wait for the LED to flash error code 32 “BreadCrumb has been zeroized.”
4. Turn power to the BreadCrumb OFF, disconnect the USB storage device, then turn power to the BreadCrumb back ON.

6 Troubleshooting

6.1 Sporadic Network Connectivity

Table 4: Sporadic Network Connectivity Issues

Problem	Resolution
As a BreadCrumb device's battery approaches exhaustion, network connectivity will become sporadic for the BreadCrumb device and its associated wireless clients.	Monitory battery usage and charge/replace batteries as necessary.
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.
As a wireless client moves around through the coverage area, LOS to the BreadCrumb device can become obstructed resulting in sporadic network connectivity for this wireless client.	Train 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.
A 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.
A wireless client cannot join the network.	● Ensure that BreadCrumb devices are powered on. ● 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 wireless card is in "Infrastructure" or "Access Point" mode, and not in "Ad Hoc" mode. Scan for the default ESSID "breadcrumb54-v10" (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

Problem	Resolution
	client device and BreadCrumb devices match. ● Ensure that the client device is not prevented from connecting by an 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 manual for more information.

6.2 BreadCrumb Device Cannot Connect to Mesh

Table 5: BreadCrumb to BCWN Connectivity Issues

Problem	Resolution
Discharged batteries can cause the BreadCrumb device to appear to power up, but not be able to establish connectivity to the mesh.	When deploying the mesh, ensure that the batteries are fully charged.
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

Table 6: BreadCrumb Power and Start-Up Issues

Problem	Resolution
Discharged external batteries can cause a BreadCrumb to appear to power up(“PWR” LED is lit), but fail to start-up.	Monitory battery usage and charge/replace batteries as necessary.

Problem	Resolution
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 device by turning off or disconnecting power to the device and turning power back on. For BreadCrumbs powered by PoE, in order to avoid sparking and possible damage to the device, be sure to connect the powered Ethernet cable to the BreadCrumb **before** applying power to the power supply.
Rapid power cycling can cause a BreadCrumb JR to appear to power up (“PWR” LED is lit) but fail to start-up.	Turn off power to the device, wait at least 10 seconds and turn power back on. The BreadCrumb should start-up normally.
Connecting a cable assembly which has an active power source (like a battery pack) to a BreadCrumb JR can cause the power to fluctuate at startup if it is connected with an unsteady hand. This can cause the BreadCrumb to appear to power up (“PWR” LED is lit), but fail to start-up.	● Disconnect the cable assembly, wait 10 seconds, and try to make the connection again more smoothly. ● Try connecting the cable assembly to the BreadCrumb **before** connecting or applying power to the power supply.

Appendix A: Radio Channels and Frequencies

Rajant's BreadCrumbs can contain up to four radios. 802.11g radios are used in the 900 MHz and 2.4 GHz bands, and 802.11a radios are used in the 4.8 GHz, 4.9 GHz and 5 GHz bands. The radios support the channels and frequencies listed in the following tables for use in the United States and Canada.

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.

Table 7: 900 MHz Radio Channels and Frequencies

Channel Number	Center Frequency (MHz)	Channel Bandwidth
4	907	Half (10 Mhz)
5	**912**	**Full (20 Mhz)**
6	917	Full (20 Mhz)
7	922	Half (10 Mhz)

The default channel for a 900 MHz BreadCrumb radio is 5 (912 MHz). Half (10 MHz) and Quarter (5 MHz) bandwidth support is available on all 900MHz channels.

Note Channels 4 and 7, as well as Half (10 MHz) and Quarter (5 MHz) bandwidth may not be supported on some BreadCrumbs with 900MHz radios.

Table 8: 2.4 GHz Radio Channels and Frequencies

Channel Number	Center Frequency (MHz)
1	2412
2	2417
3	2422
4	2427
5	2432
6	2437
7	2442
8	2447
9	2452
10	2457
11	**2462**

The default channel for a 2.4 GHz BreadCrumb radio is 11 (2462 MHz).

Table 9: 4.8 GHz Radio Channels and Frequencies

Channel Number	Center Frequency (MHz)	Channel Number	Center Frequency (MHz)
162	4810	175	4875
163	4815	176	4880
164	**4820**	177	4885
165	4825	178	4890
166	4830	179	4895
167	4835	180	4900
168	4840	181	4905
169	4845	182	4910
170	4850	183	4915
171	4855	**184**	**4920**
172	4860	185	4925
173	4865	186	4930
174	**4870**		

The default channel for a 4.8 GHz BreadCrumb radio is 164 (4820 MHz). If a second 4.8 GHz radio is present, it's default channel is 184 (4920 MHz). If a third 4.8 GHz radio is present, it's default chanel is 174 (4870 MHz)

Table 10: 4.9 GHz Radio Channels and Frequencies

Channel Number	Center Frequency (MHz)	Channel Bandwidth
5	4942.5	Quarter (5 Mhz)
10	4945.0	Half (10 Mhz)
15	4947.5	Quarter (5 Mhz)
20	**4950.0**	**Full (20 Mhz)**
25	4952.5	Quarter (5 Mhz)
30	4955.0	Full (20 Mhz)
35	4957.5	Quarter (5 Mhz)
40	4960.0	Full (20 Mhz)
45	4962.5	Quarter (5 Mhz)
50	4965.0	Full (20 Mhz)
55	4967.5	Quarter (5 Mhz)
60	4970.0	Full (20 Mhz)
65	4972.5	Quarter (5 Mhz)
70	4975.0	Full (20 Mhz)
75	4977.5	Quarter (5 Mhz)
80	4980.0	Full (20 Mhz)
85	4982.5	Quarter (5 Mhz)
90	4985.0	Half (10 Mhz)
95	4987.5	Quarter (5 Mhz)

The default channel for a 4.9 GHz BreadCrumb radio is 20 (4960.0 MHz).

Table 11: 5 GHz Radio Channels and Frequencies

Band	Channel	Center Frequency (MHz)	Turbo Capability
U-NII Upper Band (5725 - 5825 MHz) / ISM Band (5725 - 5875 MHz)	149	5745	No
	152	5760	Static Turbo
	153	**5765**	**No**
	157	5785	No
	160	5800	Static Turbo
	161	5805	No
	165	5825	No

The default channel for a 5 GHz BreadCrumb radio is 153 (5765 MHz). Some 5 GHz channels support *Static Turbo* mode. In this mode, the radio binds two standard 20 MHz channels to obtain a wider bandwidth 40 MHz channel. The end result is improved throughput and/or communication range for the radio. Users should refer to the applicable compliance regulations in the intended region of deployment for use of these frequencies.

Caution

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

Appendix B: Error and Warning Codes

All possible BreadCrumb error and warning codes are listed below:

JR/LX/LX3/ME3/UX2400 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.

15 Unlocking of /dev/mtd0 failed.

16 fconfig for SetFailsafeBoot failed.

17 Unlocking of /dev/mtd0 failed.

18 fconfig for SetMainBoot failed.

19 Copying of zImage failed.

111 Copying of ramdisk failed.

112 FIS directory update of ramdisk failed.

113 Copying of etc failed.

114 FIS directory update of /etc failed.

115 Copying failed.

116 flashunbundle 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.

121 Failed to unmount /etc.

122 In Failsafe mode, but no USB drive detected.

123 BreadCrumb will be in failsafe mode and unable to communicate with other BreadCrumbs after next reboot.

124 Failed to suspend bcconfigd.

125 Failed to set boot path to next image.

126 Failed to erase end of next file system image.

127 Failed to copy file system image.

128 Failed to checksum file system image.

129 Failed to create directory for next file system image.

131 Failed to mount next file system image.

132 Failed to create directory for settings.

133 Failed to copy current settings to next file system image.

134 Failed to unmount next file system image.

135 Failed to mount /etc.

141 Error retrieving flash file.

Self-Test Codes (3*)

31 Hardware configuration not set. Factory initialization required.

311 InstaMesh license update required.

32 BreadCrumb has been zeroized.

321 BreadCrumb is being zeroized.

33 Radio not detected. Turn the unit off, and then back on. If the problem persist, contact technical support.

333 Low Battery.

334 Gas gauge not initialized. Please fully charge unit turned off to initialize.

34 Cannot read /dev/nand6 information, or cannot resize or format /dev/nand6.

36 Hardware monitor missing.

37 Failed to add ethernet port to bridge.

38 Resetting radio due to error.

FIPS Codes (4*)

41 FIPS self-tests failed.

411 OpenSSL FIPS vector test programs not found.

412 OpenSSL FIPS vector test hash mismatch.

413 802.11i AES-CCMP test vectors failed.

414 Unable to use FIPS CCMP encryption.

415 Kernel integrity check failed.

416 Filesystem integrity check failed.

42 Mixed SecNet/Non-SecNet configuration.

43 Rekeying error.

44 Rekeying error.

45 Rekeying error.

46 Rekeying error.

47 Rekeying error.

48 Rekeying error.

49 Rekeying error.

431 Rekeying error.

432 Rekeying error.

433 Rekeying error.

434 Rekeying error.

435 Rekeying error.

436 Rekeying error.

441 Status override CPLD feature not available (wrong CPLD version).

Fatal Codes (5*)

51 instamesh fatal error.

52 hostapd fatal error.

53 cvm fatal error.

54 fatal error.

55 Low memory - automatic reboot scheduled.

UX Battery Fault Codes (51*)

See BC|Commander System Alerts for more detailed information.

511 Pack 1: does not exist|charge fault|charge gauge fault|discharge fault.

512 Pack 2: does not exist|charge fault|charge gauge fault|discharge fault.

513 Pack 3: does not exist|charge fault|charge gauge fault|discharge fault.

514 Pack 4: does not exist|charge fault|charge gauge fault|discharge fault.

515 Pack 5: does not exist|charge fault|charge gauge fault|discharge fault.

516 Pack 6: does not exist|charge fault|charge gauge fault|discharge fault.

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.

Other Codes (7*, 8*)

71 Host flapping detected.

72 Critical I2C failure.

81 <Username>@<IP address> issued reboot on <date> <time>

Appendix C: Using Pole Mount Bracket

- Use the two (2) supplied U-bolts and four (4) nuts to secure the Pole Mount Bracket to a pole up to 3” in diameter (See Figure 1 below).
- Use the eight (8) supplied screws to attach the BreadCrumb ME4 to the Pole Mount Bracket (See Figure 2 below).

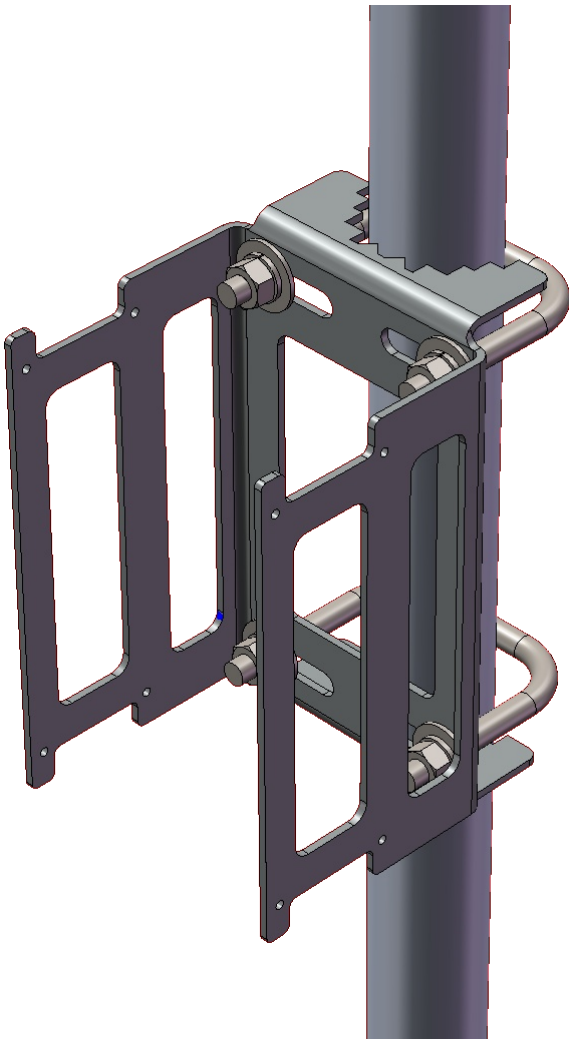

Figure 3: ME4 Pole Mounted Bracket

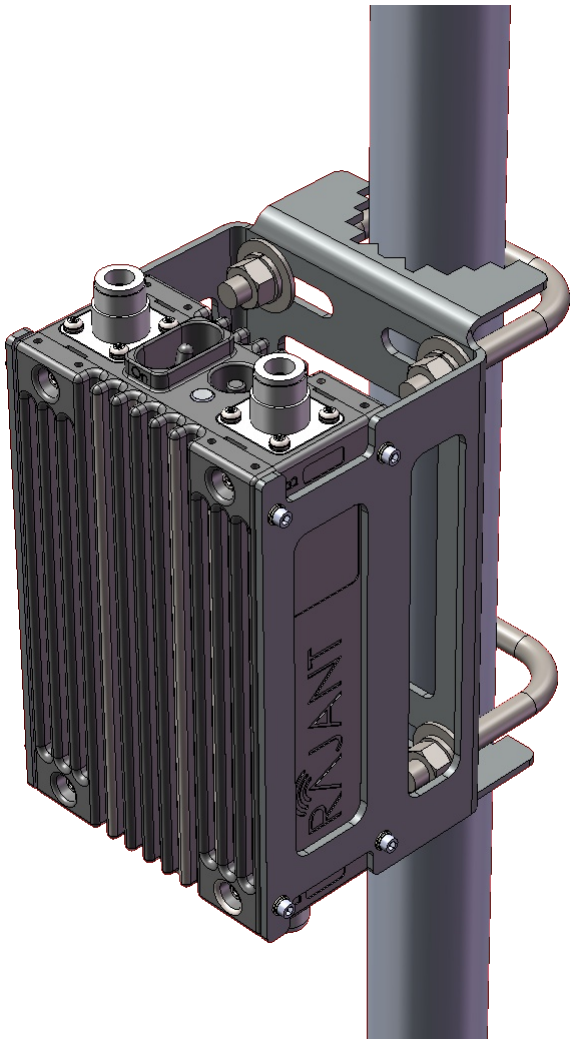

Figure 4: ME4 Mounted to Pole

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Version 2, June 1991

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