Afar communications

Cluster-Hub Point to Multi-Point Wireless Ethernet Bridge

Operator's Manual

Models: AR-9010E

AR-9027E

AR-24010E

AR-24027E

AR-24110E

June 2019

AFAR Communications Inc.
81 David Love Place
Santa Barbara, CA 93117

Tel: +1 805 681 1993
Fax: +1 805 681 1994

go the distance

Cluster-Hub Point to Multi-Point Wireless Ethernet Bridge

Operator's Manual

Models: AR-9010E

AR-9027E

AR-24010E

AR-24027E

AR-24110E

June 2019

$25.00

Customer Service

AFAR provides customer service during normal U.S. Pacific Coast business hours and may be reached by voice, fax, or email as follows:

Tel: +1 805 681 1993
Fax: +1 805 681 1994
email: support@afar.net

If you must return the equipment, please contact us for a Return Material Authorization (RMA) number. Equipment should be shipped to:

AFAR Communications Inc.
81 David Love Place,
Santa Barbara, CA 93117
U.S.A.

STATEMENT OF WARRANTY

Afar Communications Inc. products, except as otherwise stated in an applicable price list, are warranted against defects in workmanship and material for a period of one (1) year from date of delivery as evidenced by Afar Communications Inc.'s packing slip or other transportation receipt.

Afar Communications Inc.'s sole responsibility under this warranty shall be to either repair or replace, at its option, any component which fails during the applicable warranty period because of a defect in workmanship and material, provided **purchaser** has promptly reported same to Afar Communications Inc. in writing. All replaced products or parts shall become Afar Communications Inc.'s property.

Afar Communications Inc. shall honor this warranty at its facility in Goleta, California. It is **purchaser**'s responsibility to return, at its expense, the defective Product to Afar Communications Inc. **Purchaser** must notify Afar Communications Inc. and obtain shipping instructions prior to returning any product. Afar Communications Inc. will pay the transportation charges for the return of the Product to **purchaser** but not including any custom clearance fees and other related charges which shall be paid by **purchaser**. If Afar Communications Inc. determines that the Product is not defective within the terms of the warranty, **purchaser** shall pay Afar Communications Inc. all costs of handling, transportation and repairs at the prevailing repair rates.

All the above warranties are contingent upon proper use of the Product. These warranties will not apply (i) if adjustment, repair, or parts replacement is required because of accident, unusual physical, electrical or electromagnetic stress, negligence, misuse, failure of electric power environmental controls, transportation, or abuses other than ordinary use (ii) if the Product has been modified or has been repaired or altered outside Afar Communications Inc.'s factory, unless Afar Communications Inc. specifically authorizes such repairs or alterations; (iii) where Afar Communications Inc. serial numbers, or quality assurance decals have been removed or altered.

Afar Communications Inc. reserves the right to make product improvements without incurring any obligation or liability to make the same changes in Products previously manufactured or purchased.

No person, including any dealer, agent or representative of Afar Communications Inc. is authorized to assume for Afar Communications Inc. any other liability on its behalf except as set forth herein. Afar Communications Inc. hereby disclaims all implied warranties of products including without limitation, all implied warranties of merchantability or fitness for a particular purpose. The warranties expressly stated herein are the sole obligation or liability on the part of Afar Communications Inc. arising out of or in connection with the sale or performance of the products.

In no event will Afar Communications Inc. be liable to **purchaser** for (i) procurement costs; (ii) special, indirect or consequential damages; (iii) any damages resulting from loss of use, data or profits arising out of the use of Afar Communications Inc. products. In no event shall Afar Communications Inc. be liable for any breach of warranty in an amount exceeding the net selling price of any defective Product.

FCC Notice

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

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Changes or modifications not expressly approved in writing by AFAR Communications Inc. may void the user's authority to operate this equipment. AFAR Communications Inc. can not accept any financial or other responsibilities that may be the result of your use of this information, including direct, indirect, special, or consequential damages. Refer to warranty documents for product warranty coverage and specifics.

Industry of Canada Notice

These devices have been designed to operate with two antennas each, listed on page 3-6, and having a maximum gain of 15 dBi at 900 MHz, or 24 dBi at 2.4 GHz. Antennas having a gain greater than the values above are strictly prohibited for use with these devices. The required antenna impedance is 50 ohms.

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.

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

TABLE OF CONTENTS

1   PRODUCT DESCRIPTION

1.1 Radio Overview

The family of *pulsAR* Wireless Ethernet Bridges consist of license free radios that can be used to bridge Ethernet LANs (Local Area Networks) across distances ranging from a few hundred feet to 50 miles (80 km) and beyond. You can deploy them in a variety of topologies from a simple point-to-point link to a general mesh "tree" topology where any subscriber node can also be used as an access point to nodes further downstream. For mobile applications you can configure subscriber nodes to autonomously roam between multiple access points, keeping the mobile nodes connected to the network at all times.

All radios use Direct Sequence Spread Spectrum and operate in the "Industrial Scientific and Medical" (ISM) bands, either at 900 MHz or 2.4 GHz. Table 1 shows the main characteristics of the 5 models. Refer to appendix B for the complete specifications.

Table 1.1   *pulsAR* radio models

Model number:	AR-9010E	AR-9027E	AR-24010E	AR-24027E	AR-24110E
Frequency Band (MHz)	902 to 928	902 to 928	2400 to 2483	2400 to 2483	2400 to 2483
Occupied Bandwidth (MHz)	1.7	4.6	1.7	4.6	17
Maximum data rate (Mbps)	1.1	2.75	1.1	2.75	11.0

This Operator's Manual covers a specific topology consisting of a point-to-multipoint network with multiple hubs that provide hub-redundancy, rf-link redundancy and increased geographic coverage. This operation requires the radios to be running a different firmware load from the generic Wireless Bridge Ethernet firmware that supports the Mesh/Tree network.

The *pulsAR* radios are designed from the ground up to provide reliable wireless networks under adverse conditions, often encountered in the unlicensed bands. This includes the following features:

1. All the electronics are housed in an environmentally sealed enclosure rated for outdoor installation. You can mount the unit in close proximity to the antenna, which increases system performance by avoiding RF cable losses or expensive rigid coax cables. The radio is powered over the Ethernet cable.

2. Several models have an RF bandwidth that is much narrower than other unlicensed devices. This has several advantages, namely (i) the radio sensitivity is greatly improved allowing longer ranges, (ii) there is a much larger number of non-overlapping channels to choose from, and (iii) it is much easier to find an unused gap in a crowded spectrum.

3. For long range links in a crowded spectrum the most desirable receive frequencies at each end of the link are often different. In all p*ulsAR* radios the transmit and receive frequencies can be selected independently of each other.

4. The radio incorporates spectrum analysis and timing analysis tools, which allows you to quickly perform a survey of the RF environment without the need for spectrum analyzers.

5. Unique antenna alignment aid provides audio feedback proportional to the RSSI, freeing the installer's hands to adjust and tighten the antenna without having to hold or look at other instrumentation.

The radios implements a transparent bridge algorithm, where each unit automatically learns the addresses of all stations in the network and forwards over RF only the traffic that needs to be delivered to the remote units. In the mesh tree network where packets may need to go through multiple hops, the radios always route the packets to reach their destination with the minimum number of hops.

Each *pulsAR* radio can be configured over a local serial interface or over the Ethernet using an "Ethernet console" program provided by Afar. Once a unit is configured with an IP address you can also configure and monitor the unit using Telnet or SNMP. The radio firmware, in non-volatile memory, can also be updated remotely.

1.2 Radio Components

Table 1.1 below shows the part numbers of various accessories related with the *pulsAR* radio. You may have received some of these accessories bundled with your radios.

Table 1.2 – *pulsAR* acccessories

Description	Part No.
Bracket hardware for securing the *pulsAR* unit to an outdoor mast	KIT-0601
Bracket hardware for securing the *pulsAR* unit to a flat surface	KIT-0605
AC Power Inserter Module with 110-240 VAC power supply	
with a 6 ft USA 3-prong power cord:	PWI-0109-06A
with a 6ft European connector (Schuko) power cord	PWI-0109-06B
DC Power Inserter Module with pigtail for external DC connection	PWI-0210
CD with this Operator's Manual, Econsole program, and other application notes.	
Outdoor rated cat5 cable for connection between *pulsAR* radio and power inserter module (xxx is the length is feet)	CBL-0503-xxx
Auxiliary port cable for RS-232 connection (3 ft)	CBL-0403-003
Auxiliary port cable with Audio jack for antenna alignment	CBL-0404
Lightning arrestor for the antenna ports	SUR-0205
Surge suppressor for the Ethernet and Power CAT5 cable	SUP-0207

1.3 Radio Connectors

Figure 1.1 shows a *pulsAR* radio mounted on a mast. The radio is housed in a metal enclosure with two N-female connectors at the top for connection to RF antennas, and two special purpose connectors, at the bottom, for DC power, Ethernet data and control.

Figure 1.1: Pole Mounted Radio

The function of each connector is described in the table below.

Table 1.3 – *pulsAR* Connectors

Connector	Type	Function
A	N-Female	RF connector to antenna A
B	N-Female	RF connector to antenna B (used in the tree topology)
C	Lumberg 3 pin male	Auxiliary port (3 pin) used as an antenna alignment aid and for RS-232 console port.
D	Lumberg 8 pin male	10/100 Base-T data interface and DC power input (8 pin). Must be connected to the "Power Inserter Unit" with a CAT 5 cable.

An eight-conductor CAT 5 cable must be connected between the *pulsAR* radio and either a Power Inserter Unit or an Ethernet port capable of providing Power over Ethernet (PoE) per IEEE 802.3af. The wiring for this cable is shown in Figure 1.3.

Table 1.4 shows the pin assignment of the three pin auxiliary port connector. The unit is shipped with a cover in this connector. The connector can be used during installation as a console port and also as an audio antenna alignment aid. There are two optional cables to convert from this non-standard 3-pin connector to either a DE-9 connector (for RS-232 console) or to a standard audio jack (for connection to a headphone). See Appendix D for cable diagrams.

Table 1.4 – Auxiliary Port Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Receive Data	RD	Radio Output
2	Transmit Data	TD	Radio Input
3	Ground	GND	

1.4 Radio Power

The pulsAR radio complies with the IEEE 802.3af Power over Ethernet (PoE) standard when power is applied over the data line pairs (pins 1-2 and 3-6). You typically can connect the radio directly to a PoE port of an Ethernet switch or router and it will provide power to the radio.

Figure 1.2 – AC (left) and DC (right) Power Inserter Units

Alternatively the radio may also be powered over the spare cat5 line pairs (pins 4-5 and 7-8). On these lines the radio accepts a DC voltage over a very wide range (10 VDC to 58 VDC), allowing it to

easily be powered by a 12 V battery. This method is not in compliance with the IEEE 802.3af mode B which restricts the voltage range to 48 VDC..

Afar provides two Power Inserter devices (figure 1.2) that use this second method. One is for operation from an AC source (110-240 VAC), and the other for operation from a DC source (10 to 58 VDC).

The AC Power Inserter Unit includes a power supply for connection to an AC outlet (110-240 VAC). The DC Power Inserter Unit comes with a 10 ft pigtail for connection to your DC supply voltage. Both inserters have two RJ45 connectors and a bi-color LED. The two RJ-45 connectors are labeled "To LAN" and "To Radio".

Table 1.5 – Power Inserter Units

Connector/LED	Type	Function
To LAN	RJ-45	10/100 Base-T to be connected to the Local Area Network. You can connect this directly to the LAN port of a computer or to an Ethernet hub. The radio auto-detects and provides the cross-over function when required. See table 1.5 for pin assignments.
To Radio	RJ-45	Carries the DC power and Ethernet signals to the radio. See table 1.6 for pin assignments.
LED (AC Power Inserter)	Amber/ Green	**Amber**: Indicates that the power inserter unit has power from the wall supply but no power is being drawn by the radio. **Green**: Indicates that the radio is drawing power.
LED (DC Power Inserter)	Green	Indicates that there is DC power in the pigtail input

WARNING

The Power Inserter connectors labeled "To radio" includes DC voltage in two of the pins. It must **not** be connected to a LAN as this voltage may damage some LAN cards.

Table 1.6 – "To LAN" Ethernet Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Ethernet Tx	Tx (+)	Radio to Ethernet[1]
2	Ethernet Tx	Tx (-)	Radio to Ethernet[1]
3	Ethernet Rx	Rx (+)	Ethernet to Radio[1]
4	(not connected)		
5	(not connected)		
6	Ethernet Rx	Rx (-)	Ethernet to radio[1]
7	(not connected)		
8	(not connected)		

[1] With auto-negotiation enabled the radio also provides an automatic cross-over function.

Table 1.7 – "To Radio" Ethernet Connector Pin Assignments

Pin	Signal Name	Abbr.	Direction
1	Ethernet Tx	Tx (+)	Radio to Ethernet
2	Ethernet Tx	Tx (-)	Radio to Ethernet
3	Ethernet Rx	Rx (+)	Ethernet to Radio
4	VDC	DCV (+)	Power Inserter to Radio
5	VDC	DCV(+)	Power Inserter to Radio
6	Ethernet Rx	Rx (-)	Ethernet to Radio
7	ground	GND(-)	Power Inserter to Radio
8	ground	GND(-)	Power Inserter to Radio

1.5 Outdoor Interconnect Cable

The interconnect cable between the Power Inserter Unit and the radio carries the following signals

1. DC voltage to supply power to the *pulsAR* radio.
2. 10/100 Base-T Ethernet data.

Both these signals are carried in a single CAT 5 cable. The system is designed to allow cable lengths in excess of the 100 meters (300 feet) of the IEEE Ethernet specification. Figure 1.3 shows the interconnect diagram for this cable and connector types. Table 1.8 lists a few part numbers and sources of appropriate CAT 5 cable for this application. Afar Communications Inc. carries several pre-made cables of different lengths. See Appendix D for connector diagrams, part numbers, and assembly instructions.

RJ 45 MALE		Radio "D" Port (Lumberg Connector)
1	RADIO_ETH_TX+	1
2	RADIO_ETH_TX-	7
3	RADIO_ETH_RX+	2
4	VDC	3
5	VDC	5
6	RADIO_ETH_RX-	4
7	GND	8
8	GND	6
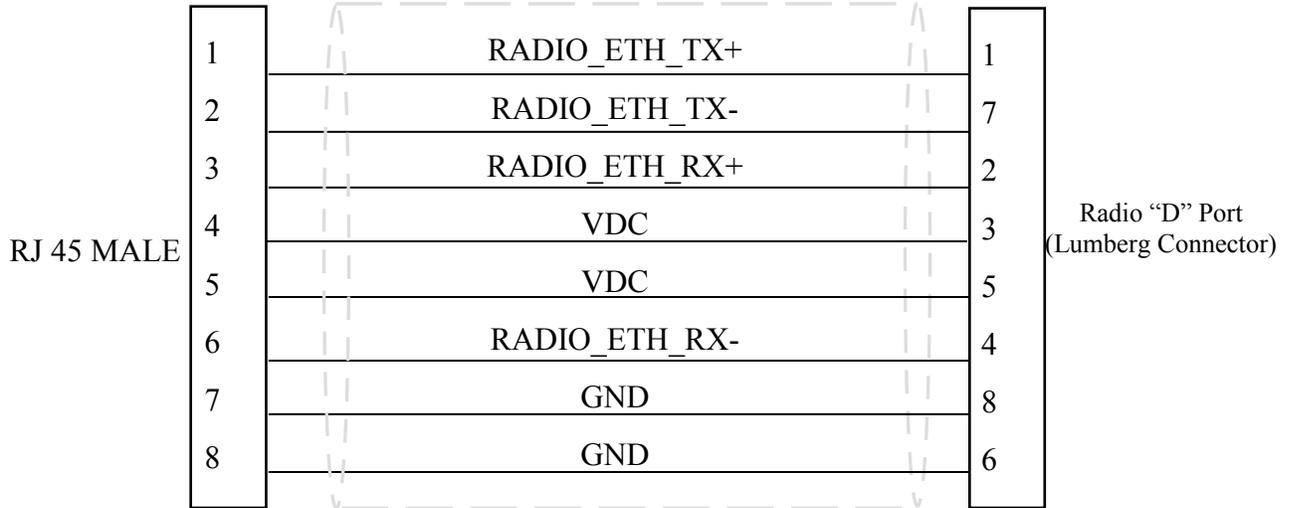
Figure 1.3 - CAT 5 Outdoor Interconnect cable diagram

Table 1.8 – Indoor/Outdoor Unit CAT 5 cable

Part number	Manufacturer	Description
7919A	Belden	Shielded outdoor rated cable
18-241-31(gray) 18-241-11 (beige)	Superior Essex	Unshielded outdoor rated cable
5EXH04P24-BK-R-CMS-PV	CommScope	Unshielded outdoor rated cable
2137113 (ivory) 2137114 (gray)	General Cable	Unshielded outdoor rated cable
BC1002	Belden	Unshielded outdoor rated cable

2   THEORY OF OPERATION

2.1 Introduction

In a standard **point-to-multipoint** topology one radio, designated as the **hub,** establishes communications with multiple **remote** radios. The firmware in the hub performs automatic association of new remotes, and allocates bandwidth to each remote, on demand, depending on its traffic load. The radio network automatically **bridges** all the LANs attached to the radios, such that all devices on the various sites look like they are in the same LAN.

In a fixed deployment the hub radio is typically equipped with an omni antenna while the remotes have directional antennas pointing at the hub. In an environment where the remotes are mobile all radios would typically have omni antennas.

When nodes are mobile, the reliability of the wireless communication link can degrade significantly. This is due to several factors:

1.   The links have lower fade margin due to the use of omni antennas.

2.   Omni antennas expose the radio receiver to more interfering sources.

3.   The mobile remotes may become physically hidden from the hub.

4.   Mobility causes variable multi-path effects that affect radio reception.

The **cluster-hub** enhancement to the point to multipoint topology is designed to overcome some of these factors. This section describes the Cluster Hub Point-to-multipoint topology and its operation.

To deploy a network using this cluster-hub topology the radios need to be running a special firmware version, which is different than the standard radio firmware. The radio non-volatile memory can hold various programs at any given time but only one program can be running at a time (use the >**directory** command to view all the files loaded into the radio memory). The different software programs are identified in the table below. The filename itself identifies the version of the software. The file CLH01_22 for example, is version 1.22 of the Cluster-Hub Point to Multipoint firmware.

Topology	File Name
Cluster-Hub PmP	CLH0x_xx
Point to Multi-Point and Mesh/Tree	PMP0x_xx

This Manual covers only the Cluster-Hub Point-to-Multipoint operation. A separate Manual covers the standard Point-to-Multipoint and Mesh/Tree topology operation.

2.2 Cluster Hub Point-to-Multipoint topology

Figure 2.1 shows a diagram of a Cluster Hub Point-to-Multipoint wireless network. The cluster hub consists of radios Hub-1 through Hub-N, which are at fixed locations and connected by a wired 100 MHz LAN. The multiple hub radios can be spaced far apart to increase the total RF coverage. Within the region covered by these hubs there may be multiple remote nodes which would typically be mounted on mobile vehicles.

On the hub side the user equipment (base-station) connects to the same LAN that interconnects all the hubs. On the mobile nodes the user equipment attaches to the Ethernet port of the remote radios.
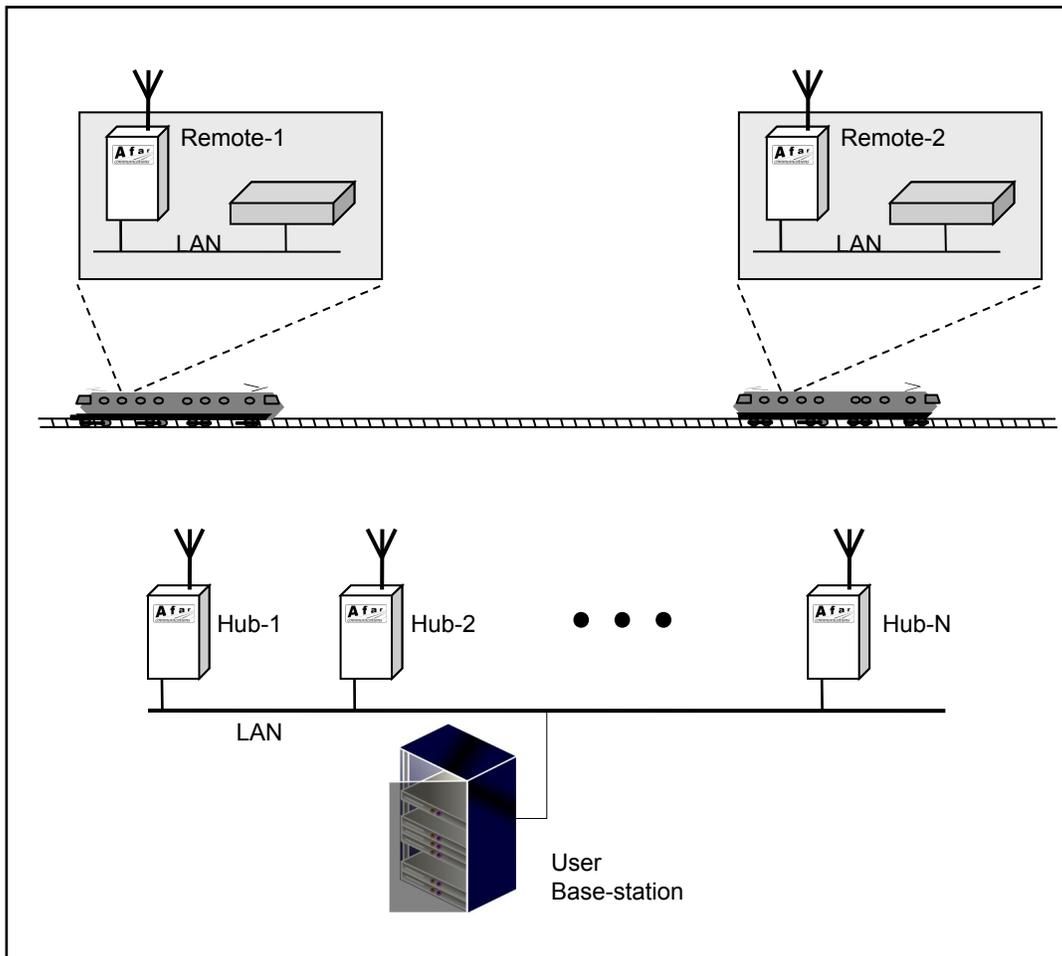
Figure 2.1 – Cluster-Hub Point to Multipoint Network

The radio subsystem is designed to provide a reliable and robust Point-to-Multipoint communication network between the user base-station and the equipment connected to the remote radios. Once a vehicle is within the RF range of one or more hubs in the cluster the radio subsystem automatically bridges the vehicle Ethernet LAN to the base-station LAN. The multiple hub radios are used to enlarge the RF coverage and also as redundant units in the RF communications. The multiple RF transmissions and receptions work transparently to the user equipment which does not need to be "aware" of the multiple hub radio implementation.

All radios are configured to operate on the same frequency channels. There is an outbound channel (for communications between hubs and remotes), and an inbound channel (remotes to hubs). These two channels can be different, although they are typically set to be the same value.

Below is a list of the major characteristics of the Cluster-Hub PmP network:

- Multiple redundant hub radios, which together form a single "hub" to implement a robust point-to-multipoint system.

- No single-point-failure among the hub radios. The mastership function is autonomously allocated and gets re-allocated in case of failures.

- Automatic acquisition and deletion of remote radios as vehicles move in and out of the coverage area.

- Selectable number of redundant outbound transmissions.

- Dynamic selection of most favorable hub radios to transmit outbound messages.

- Transparent bridging between base-station LAN and the LAN on the vehicles, with automatic filtering of all redundant RF messages so that the redundancy is invisible to the user equipment attached to the radios.

- Bandwidth allocated on demand to all radios in the system, including dynamic allocation for inbound and outbound traffic.

2.3 Multi-cluster networks

The size of one cluster-hub network as described in the previous section can not grow indefinitely. The main reason is that within one cluster all radios transmit at different times to avoid RF collisions. Even though the allocation of transmit slots is dynamic and on demand (explained in the next section), as the number of remotes in one cluster grows they all share a single radio maximum throughput capacity. Depending on the application, at some point this capacity is not enough, and you start experiencing network congestion.

In these situations you can divide the coverage area into different regions and deploy a separate cluster in each region. Within each cluster only one radio transmits at a given time, however, radios in different clusters will now be transmitting at the same time. Since adjacent clusters usually have overlapping coverage areas, you operate each cluster on different non-overlapping channels.

Using different frequencies on adjacent clusters avoids interference and RF collisions for the most part. However, in the overlapping areas there is often a need to deploy two or more hubs at the same location, each hub belonging to a different cluster,. These hubs, even when operating on different channels, can easily interfere with each other. This interference is created when a hub radio in one cluster is trying to receive a signal from a remote radio, while the nearby hub, belonging to a different cluster, is performing an RF transmission. If the RF coupling between the two hubs is significant the hub performing the transmission can easily saturate the receiver front end of the co-located hub and cause it to drop the reception.

Version 3.00 and later of the firmware includes a feature that eliminates this interference altogether. The concept is to synchronize the **cycles** of the separate clusters such that their outbound and inbound phases overlap and line-up. In this way the situation where a hub radio is transmitting (outbound phase) while a co-located hub radio is receiving (inbound phase) will never occur. This

synchronization scheme takes place over the Ethernet and requires all clusters to be interconnected as shown in Figure 2.2. The next section describes this synchronization mechanism in detail.
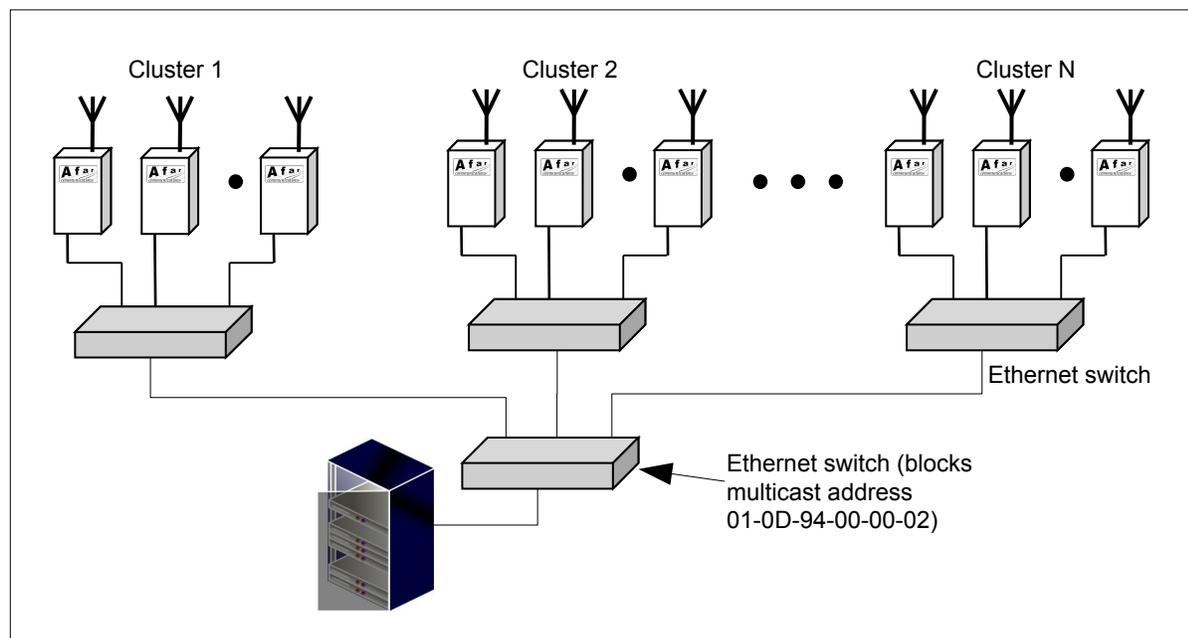
Figure 2.2 – Multi-cluster network

Note that in a multi-cluster environment the radios do not perform an automatic "hand-off" of the remotes between the different clusters. The user equipment needs to be involved, to, at least change the receive channel of the remote radios when it moves from one cluster to the next. Once the radio channel is changed the remote radio disconnects from the existing cluster and connects to the next one. On the wayside, if you have different computers connected to each cluster controlling each region separately, those computers need to coordinate the "hand-off".

2.4 Functional Operation

2.4.1   Time Division Multiplex operation

All radios within one cluster operate in a Time Division Multiplex (TDM) mode, with each radio transmitting on dynamically allocated time slots thereby avoiding all collisions. The overall **cycle time** is fixed (you can select 20, 40,60 or 80 ms cycle times), and consists of an **outbound phase** where hub radios transmit, followed by an **inbound phase** where remote radios transmit.

During each cycle radios are allocated zero, one or several contiguous **slots** for transmission. Each slot is approximately 1 ms. The slot allocation is dynamic and based on demand so that radios that have no data to transmit never take more than one slot (if any). Even though the total cycle time is constant, the split between outbound and inbound phases can be dynamic or set to a fixed value between 20 and 80% (in a multi-cluster deployment you should use a fixed split value).

2.4.2   Cluster Master radio

Within each cluster all hub radios autonomously select among themselves one radio to assume a master role. This radio performs the following special functions:

- **Inbound Packet Aggregator**: All hub radios send any inbound packets received over RF to the cluster-master. The master discards repeated packets and reassembles fragmented packets. Once an inbound packet is reassembled the master forwards it to the user base-station.

- **Outbound packet distribution**: The cluster-master processes the outbound packets from the base-station and distributes them to a subset of the hub radios for transmission over RF.

- **Scheduler**: The cluster-master allocates slots to the various radios in the cluster and multicasts a **schedule** packet for the upcoming cycle informing all radios of the planned schedule.

2.4.3   Cluster Master selection

The autonomous allocation of the cluster-master function is achieved as follows: once per second all hub radios multicast, over the Ethernet, a status packet, which is received by all other hub radios. This packet includes the radio unique serial number and whether it is the current master.

Each hub radio continuously listens and records the serial numbers of all other hub radios on the same cluster. From this list it determines if it has the highest serial number in the cluster. When there is no master already selected the radio with the highest serial number assumes the master role.

When a new hub radio joins a cluster where there is already a master the new radio does not take the master role even if it has the highest serial number. This way you can add or remove most radios from the system with minimal effect on system operation. If the master radio goes off-line then the master function is assumed by another hub radio. When such an event occurs there will be a slight delay and possibly some packet losses as the new master radio reacquires all the remotes. However the system will recover within about two seconds.

The serial number of the cluster-master radio becomes the RF address for the entire cluster. All hub radios program their RF port address to this value. This way all hub radios receive the RF packets transmitted by remote radios which are addressed to this common cluster address.

In addition to the autonomous selection described above you can also configure one radio in the cluster as the preferred master. If that radio is present it will always assume the master role. If there is no radio configured as the cluster-master then the algorithm described above selects one hub to take that role. This feature is useful for maintenance and troubleshooting. The cluster-master tracks a number of network statistics, so it is useful to know which radio is the master at all times.

In the case of a multiple cluster deployment the negotiation described above takes place separately within each cluster. During this negotiation all hubs multicast their status packet to a "local multicast address" (01-0D-94-00-00-02). You should configure the ethernet switch fabric to block this multicast address from reaching the other clusters (see figure 2.2).

2.4.4 Cycle Synchronization

The cycle synchronization is achieved by having a single hub radio assume a "clock-master" role. If your network consists of a single cluster the radio that was selected as the cluster-master also assumes the clock-master role. When you have multiple clusters the various cluster-masters negotiate between them which one should become the clock-master. This selection works as follows:

Once a hub radio within a cluster becomes the cluster-master, it starts multicasting its status packet (described above) to a "global multicast address" (01-0D-94-00-00-01). You should configure the Ethernet switch fabric to pass this multicast packet to all the clusters. All cluster-masters receive these status packets and decide which one among them becomes the clock-master. The selection criteria is identical to the one used to select the cluster-master: the unit with the highest serial number becomes the clock-master, unless another unit is already performing that function.

Once a radio assumes the clock-master function it multicasts (to the global multicast address) a **heartbeat** packet once per cycle that includes the clock-master time when the packet was sent. All the other hubs (clock-slaves) receive this packet and latch their local time when this packet arrives. The clock-slaves then use both the transmit and receive times, together with their knowledge of the Ethernet transit time, to keep statistics on the offset of their local timer and adjust it to cancel out the error.

The Ethernet transit time depends on the number of Ethernet switches that heartbeat packets have to go through and whether there was additional delays due to other Ethernet traffic. Each clock-slave measures the Ethernet transit time by exchanging "delay request/response packets" with the clock-master every 3 to 4 seconds. They also discard any heartbeat packets that show excessive transit times. Finally, by keeping a running average of the timer errors they are able to keep their local timers synchronized to the master timer with errors of just a few microseconds.

In spite of the precautions listed above, the Ethernet switch fabric for large networks needs to be carefully designed, configured, and making use of good performance Ethernet switches capable of running at least at 100 MHz full duplex. In a multi-cluster network a preferred approach would be to use a separate switch to connect all radios in each cluster. Then connect those switches to a next higher level managed switch, possibly with those connections running at 1 GHz. This higher level switch needs to be configured to block packets addressed to the Afar "local multicast address" (01-0D-94-00-00-02) but pass the "global multicast address" (01-0D-94-00-00-01).

With all hub radios synchronized, the synchronization of remote radios is achieved as follows:

During the outbound phase, each hub radio that was assigned a transmit slot, broadcasts, as the very first packet, a schedule of the inbound slot assignments. This packet includes the time offset within the cycle when this packet is transmitted. The remote radios latch the arrival time of every packet over RF. They then compute an average of the cycle timer error and adjust their cycle timer to stay in sync with the master.

2.4.5 Inbound Packet Flow

A remote radio operates its Ethernet port in promiscuous mode and therefore receives all Ethernet packets. The radio runs a self-learning transparent bridge algorithm, discarding any local traffic packets, and forwarding other packets to the RF port. Any packets generated by the mobile user station addressed to the base-station fall into this latter category and get queued for RF transmission.

The remote radio adds a header to these Ethernet packets that includes a packet sequence number. When the radio has an opportunity to transmit it sends all packets in its RF queue that fit within the slot allocation. If the slot allocation is not enough to transmit all packets, the last packet may be fragmented to fill all of the transmit time available. All RF transmissions from a remote radio are sent to the "cluster address" so that they are picked up by any of the cluster hub radios.

Multiple hub radios may receive the inbound transmissions. These radios forward all received packets to the cluster-master radio over the Ethernet. This master radio discards the repeated packets or fragments and, for fragmented packets, it reassembles them into a single packet. Once a packet is fully reassembled it forwards a single copy to the user base-station.

When the non-master radios forward the inbound packets to the master, they include the information about the RSSI associated with those packets. The cluster-master uses this information in the distribution of the outbound packets as explained in the next section.

2.4.6   Outbound Packet Flow

The cluster-master operates its Ethernet port in promiscuous mode and therefore receives all Ethernet packets in the LAN. It runs a self-learning transparent bridge algorithm, discarding any local traffic packets and processing all others. As part of the bridge algorithm the master keeps a **bridge table** with the addresses of all the user mobile stations that are currently in the RF coverage area. For each entry this table includes the following information:

- Ethernet address of the user mobile equipment

- Identity of the remote radio associated with that equipment

- Time of last message heard from this remote radio

- List of hub radios that received this last message and respective RSSI

The user base-station generates outbound packets addressed to mobile user equipment attached to remote radios. The cluster-master receives these packets and looks up in the bridge table for the identity of the remote radio associated to the destination address.

The cluster-master then adds a header to the outbound Ethernet packet, which includes a packet sequence number and a list of the N hub radios that have the strongest RSSI associated with this remote radio. The cluster-master sends this packet on the Ethernet to the "local multicast address" which is received by all non-master hub radios in this cluster.

The selected hub radios retrieve the outbound packet (including the sequence number) and queue it up for transmission over RF. All other hub radios that receive this multicast, discard the outbound packet.

As each hub radio has a chance to transmit over RF, it transmits its copy of the outbound packet addressed to the specific remote radio. In this transmission the outbound packet may be fragmented and transmitted across multiple cycles. The remote radio reassembles the outbound packets, discards repeated packets, and sends a single copy of the outbound packet to its Ethernet port. If fragments from different hub radios are lost the remote radio still attempts to piece together a complete packet from the fragments received.

Because of the multiple transmissions of the same packet by different hubs it is possible for the remote radio to receive packets out of order. The remote radios will reorder the packets before sending them out on the Ethernet, such that the original order of the packets is preserved.

You can configure the number of outbound redundant transmissions. As a vehicle moves across the coverage area, only a subset of hub radios (closest to the vehicle) is likely to receive the inbound transmissions. By using the RSSI information as described above the cluster-master automatically selects the subset of the most favorable hub radios.

The cluster-master periodically purges inactive entries in the bridge table (there is a configurable inactivity timeout). Therefore, once a vehicle leaves the coverage area, its radio will disappear from the bridge table.

Outbound Packet Latency: Since multiple hubs may transmit each outbound packet at different times, a remote radio may receive packets out of order. When that happens the remote radio must wait to see if the missing packet, transmitted by a different hub, arrives. After a "reasonable" timeout, if the missing packet is not received, the remote assumes that all transmissions of that packet were lost. Subsequent packets that had been queued and waiting are now sent to the host.

When the links are marginal and packets are being dropped, this may introduce an outbound latency of as much as 0.5 second. If there is congestion in the network the total delay may be greater.

Note that even when the outbound transmit redundancy is set to one the remote radios still need to wait for a missing packet arriving out of order. This is because the hub covering that remote may change and a packet transmitted by a new hub may arrive before the last packet (or fragment) transmitted by the previous hub.

This missing packet timeout value is 250 ms when you set the transmit redundancy to one, and increases by 100 ms for each additional hub added to the transmit redundancy.

2.4.7 Dynamic Bandwidth Allocation

The inbound transmissions by a remote radio always start with a short **bandwidth request** packet. This packet includes a field with the number of bytes currently queued for RF transmission. Hub radios that receive these packets forward them to the cluster-master radio over the Ethernet.

With this information the cluster-master keeps a tally of the total inbound traffic waiting to be transmitted by all the remotes. The cluster-master also has the same information about outbound traffic, since it processes all the outbound packets generated by the base-station. The total RF outbound traffic is actually the product of all these packets multiplied by the current number of redundant outbound transmissions.

Based on this current demand the cluster-master first computes the ideal split of the TDD cycle between outbound and inbound (if the TDD split is set to "auto"). Then the cluster-master allocates slots for the upcoming cycle, first for the inbound phase and then for the outbound phase. The allocation of the slots is based on a number of rules:

Inbound Slots:

1. First allocate one or more contiguous slots for remote radios that have non-zero bytes queued. Since each RF transmission requires a preamble that occupies a significant air-time, the cluster-master typically allocates multiple slots to each radio in order to improve efficiency. This may

result in some remote radios not being allocated slots in a particular cycle. However those radios will then be allocated their fair number of contiguous slots in a subsequent cycle.   Reducing the total number of remote radios that transmit in a given cycle helps the efficiency of the outbound phase as well.

2. Remote radios with zero bytes in their transmit queue are allocated the minimum number of slots every once in a while in order to give them a chance to update their bandwidth request. The frequency for polling idle remote radios is dynamic and depends on current traffic load.

Outbound slots:

1. For each remote radio that got allocated in the inbound phase, allocate the minimum number of slots for each of the N hub radios that currently cover that remote. This provides full redundancy in transmitting the schedule to the intended remote radios.

2. Increase the number of slots to each of the selected hubs based on the outbound traffic that that specific hub must transmit.

3. Allocate any remaining slots to other hub radios that have outbound traffic.

4. Once in a while the cluster-master also reserves the first slots of the inbound phase for new remote radios to attach to the network.   In those cycles every hub radio is assigned to transmit the cycle schedule. This guarantees that this "invitation to join" is heard everywhere in the network.

After assigning the outbound slots the cluster-master multicasts on the Ethernet the outbound packets that must be transmitted by the various hubs. This is done carefully with the goal of giving the various hubs enough data to completely fill the allocated slots, but no more. Keeping the outbound queues of the various hub radios shallow allows the cluster-master to respond quickly when a vehicle moves and is covered by different hubs.

Finally, prior to the beginning of a new cycle the cluster-master multicasts a packet on the Ethernet containing the complete schedule for the upcoming cycle. All the hub radios receive this packet and setup their cycles to start transmitting in the allocated slot. In addition these hub radios retrieve the inbound schedule and format a short RF packet with this information. This **inbound schedule packet** is always broadcast in front of any packets in the RF queue.

The remote radios may receive the inbound schedule from several hub radios. Once they receive this schedule they setup their cycles to transmit in the allocated slots. There is a short dead time between the outbound and inbound phases which allows the first remote radio to get ready to transmit if it received the schedule from the last hub radio.

2.4.8   New Remote Radio Acquisition

Once in a while the cluster-master allocates the first slots in the cycle for new remote radios to attach to the network.

A remote radio that is not currently attached first synchronizes its cycle to the transmissions from the various hub radios. It then transmits an **attach request** packet the next time that a slot is available for a new node acquisition.

The hub radios that receive this transmission forward the packet to the cluster-master. The master sends an **attach acknowledge** packet to the remote radio through the N hub radios with the strongest

RSSI. The cluster-master also adds the remote radio and any associated stations to its bridge table. That way the fixed base-station will now be able to send packets to this mobile station.

The remote radios also implement a back-off algorithm allowing two new nodes to get attached even if there is a collision in their attach request packets.

2.4.9   Packet priorities

As packets arrive into a radio from any port, the bridging algorithm determines if the packets need to be transmitted over RF. If so the radio queues the packets into one of several priority queues. Starting with the highest priority the packets are classified as follows:

- Vital packets: These are UDP packets with a specific destination UDP port number. This port number is part of the field programmable radio configuration (see command **>udp**).

- NetCrossing Gateways Serial packets: These are SNAP encapsulated packets containing synchronous serial data generated by the Afar NetCrossing Gateway devices.

- High-Priority: These includes network management packets for "ECON" command sessions, and also IP packets with a value in the "Type-Of-Service" indicating high priority. The radio interprets the IP TOS field per the IETF *differentiated services (DS)* definition as shown below:

0	1	2	3	4	5	6	7
Codepoint						Unused	

When the codepoint field has the value **xxx000**, the three most significant bits are interpreted as **precedence** bits.   The radio gives high priority to packets with a precedence field of 6 or 7. In hexadecimal notation this translates into TOS values of E0 and C0.

- Low-priority: All other packets

When the time to transmit over RF arrives, the software always takes packets from the higher priority queues first.

2.4.10   Ethernet Packet Drops

With the various hubs in the cluster distributed over a large geographic area the wired Ethernet network connecting all hubs can become large and complex. This frequently involves an optical fiber network with media converters (Ethernet/Fiber) installed between the radio and the fiber network. There has been installations where faults in the media converters introduce an intermittent connectivity between a hub and the network resulting in a random number of Ethernet packets being dropped. This in turn could affect the negotiation of the hub master role selection, and in some cases resulting in having two hubs trying to assume the master role at the same time.

Version 3.30 of the firmware introduced several features to make the system tolerant to failures in the wired Ethernet. The hubs now must be "master-capable" in order to attempt to become the master of the cluster (prior to this version every hub was considered master-capable). In order to become "master-capable" the following conditions must be true:

1. The number of hubs in the cluster must equal or exceed the "min-cluster-size" specified in the ">node" command.

2. The Ethernet packet drops experienced by the hub must not exceed a certain threshold.

Condition 2 requires the hubs to measure the packet drop percentage on their Ethernet receive ports. They compute this from the number of status packets received over each second (status packets are multicast, once per second, by every hub in the cluster). This computation is a running average since packet drops can be random and, in a small cluster, there is not enough status packets to get an accurate number within one second.

If or when a media converter fails suddenly, the running average of Ethernet packets being dropped will take some time to rise and make the hub not "master-capable". Under those conditions, having two masters on a cluster is still possible for a short period. All hubs now detect when a second hub attempts to become a master and, if there are two masters in the cluster, they ignore the new one. This allows the system to continue to work until the hub experiencing Ethernet packet drops becomes not "master-capable".

There is also a "slave-capable" feature introduced in this version. If the Ethernet packet drop percentage exceeds a higher threshold, the hub declares itself as not "slave-capable". When not "slave-capable" the master will not assign that hub to transmit any packets to the train radios. Otherwise, a train that is being covered by an affected hub might lose communications with the wayside.

The current percentage of Ethernet packet drops is now displayed in the "show" command. The "show radios" command, at the master, indicates the Master and Slave capable status of every hub.

The packet drop thresholds for a hub to change its "master-capable" or "slave-capable" status have a built-in hysteresis to avoid the status to change back and forth. The thresholds are 15 ± 5% for master-capable and 25 ± 5% for slave-capable.

2.5 Network size and performance

The maximum size of each cluster is 32 hubs and 29 remotes although most deployments use significantly fewer radios per cluster. As the cluster size increases and more radios share the total throughput available, the network may become congested. If you use the slower radio models the network capacity will be lower and you may need to limit the cluster size further. You can break the network into multiple clusters up to a maximum of 16 synchronized clusters.

There are four configurable parameters, listed in the table below, that directly affect the cluster capacity. You only need to configure these parameters at the cluster-master, all other radios will change their configuration automatically to match the settings of the master. When you change any of these parameters the software computes, among other things, the resulting maximum number of hubs that can be supported. If that number is less than 3 the software does not accept the new value and gives you a warning. The "show" command lists how many hubs and remotes are currently in your cluster and also the maximum number of hubs allowed. Whenever you change one of these four parameters it is a good idea to check that the maximum number of hubs allowed is larger than your intended cluster size.

Parameter	Command	
RF transmit speed	rf-transmit speed=xx	The higher the speed the higher the capacity of the RF network which increases the maximum number of hubs allowed.
Cycle period	tdd cycle=20,40,60,80	Increasing the cycle period increases capacity and the maximum number of hubs allowed. However it will also increase packet latency.
Cycle split	tdd outbound-transmit= auto,20..80	For a single cluster network the auto setting is recommended, which lets the cluster-master choose the split depending on traffic patterns. Depending on the values of the other parameters the range for the split value may be narrower than the nominal 20..80. The "tdd" command echoes the current setting and range allowed.
		In deployments consisting of more than one cluster you should use a fixed split to take advantage of the inter-cluster synchronization features and avoid self-interference where multiple clusters overlap.
Tx Redundancy	node redundancy=1..4	With redundancy greater than one the hubs transmit all the outbound packets multiple times sequentially. Higher redundancy values force the cycle split to favor outbound traffic which reduces inbound traffic capacity.

Network performance is also affected by broadcast traffic. Broadcast packets get transmitted, in turn, by every hub that is currently covering one or more remotes. In large networks, with multiple scattered remotes, a broadcast packet may have to be transmitted by many hubs which will contribute to congestion in the network. You can use the "monitor-coverage" command to check how many hubs are currently being used for broadcast. However this number changes as remotes move around. If your system never requires communication between remotes, you can turn on a filter that stops the hub from transmitting downstream any broadcast packets that it receives from a remote (see **ethernet** command)

The LAN traffic in a cluster can be quite heavy at specific times in the cycle. Some of that traffic are multicast packets originating at the cluster-master, as follows:

- All outbound data packets

- Inbound schedule packet: muticast once per cycle

- Outbound schedule packet: multicast once per cycle.

In addition, once per second, all hubs muticast a sync status packet.

You should ensure that the Ethernet switch fabric is configured to block packets addressed to the "local multicast address" (01-0D-94-00-00-02) from flowing between clusters. The hub radios will still work with these mingled packets, however the increased traffic can cause congestion on the LAN and overload the radio software leading to performance problems. The "show" command at any hub will display a warning if it sees local multicast packets originating from hubs in different clusters.

2.6 Encryption

The radios have the capability of encrypting the payload data transmitted over the air. You can select the encryption algorithm between DES, Triple-DES and AES-128, and enter a unique key to encrypt and decrypt the data. Refer to the encryption command in section 4.4 for complete details.

Turning encryption on has the following impact on the link performance:

1. Increase in the packet size. Block encryption algorithms require the packet length to be a multiple of 8 bytes for DES or Triple-DES, of 16 bytes for AES-128, and 32 bytes for AES-256. The radio uses one of those additional bytes to control the truncation of the padded field on the receive side, so there is always at least one added byte. For very long packets this padding may be negligible, but for short packets it can add significant overhead. A worst case scenario would be an ethernet packet of 64 bytes which, with AES-128 encryption will be padded to 80 bytes, and with AES-256 to 96 bytes.

2. Increase in latency. There is a small delay introduced by the additional processing to encrypt and decrypt data packets. The encrypt + decrypt time for a 100 byte packet is 0.28 ms, for a 1,000 byte packet is 0.62 ms irrespective of the algorithm. The increased packet size referred above can have a larger impact on latency, depending on how many bytes were added and the RF transmit speed.

3   <u>INSTALLATION AND SETUP</u>

NOTE

Appendix E contains a quick set up diagram showing the minimum configuration and commands necessary to put up a point to multipoint network.

3.1 Bench Check Out

It is recommended that an initial check be performed on the bench before a field installation.

For this bench check out you need two *pulsAR* units. Radio 1 will be configured as the hub and radio 2 will be configured as a remote. The first approach described below uses the "Ethernet Console Program" to emulate the terminal across an Ethernet connection. The second approach uses two terminals connected to the auxiliary port of the radios.

3.1.1   <u>Using the radio Ethernet connection</u>

In order to use the Ethernet connection you need the "Ethernet Console" (Econsole) utility provided in the CD or at the Afar website. Refer to the separate Ethernet Console User's Manual for installation instructions. Once Econsole is installed (version 4.xx or later), perform the following steps.

3. Connect the "To LAN" connector of the Power Inserter Unit of radio 2 to your PC Ethernet port. If the PC Ethernet is connected to a switch go to the switch instead. The radio auto-senses and crosses the Ethernet lines if necessary.

4. Connect each radio Antenna A port (N type connector) to an appropriate 2.4 GHz band antenna using an RF coaxial cable.

5. Connect each Power Inserter Unit "To Radio" connector to the respective *pulsAR* radio using the special CAT 5 cable as defined in section 1.

6. Connect the two Power Inserter Units to a power outlet of the appropriate voltage.

7. At the PC open a DOS window and invoke the Econsole program by typing:

   > **econ**

   If you have multiple network ports in your PC the Econsole program will first ask you to select the one connected to the Afar radio. If you don't know this information just try each one in turn until you get a list of one or more Afar devices followed by the Econsole> prompt. At the prompt type:

   Econsole> **connect 1**   (to establish a connection to the first device on the list)

   Once a connection to the radio is established, the radio outputs a prompt with the following format:

   rmt-nnnnn #>

where nnnnn are the last five digits of the radio serial number. If the radio had previously been configured the prompt will be the radio **name.**

8. Set radio 2 to its factory default configuration by typing the commands:

> > **load factory**
> > **save-configuration**
> > **logout**

9. You should now see the Econsole> prompt again. Move the Ethernet cable from the radio 2 power inserter to the power inserter connected to radio 1. At the Econsole> prompt type the command:

> Econsole> **discover**

which causes Econsole to go out and identify radio 1. Connect to this radio with the command:

> Econsole> **connect 1**

10. At the prompt from radio 1 type the commands:

> > **load factory**
> > **node type=hub**
> > **save-configuration**

11. Once radio 1 is configured as the hub it will establish a RF communication with radio 2. To verify this connection type:

> > **show**

Check that under MY CLUSTER there is a line indicating "Remotes: 1". You may also type **>show radios** to see various statistics of the link with radio 2.

12. Once the link is established you can use Econsole to further configure either of the two radios. But Econsole must first perform its discovery again to find both radios:

> **> logout**
> Econsole> **discover**

Econsole should now list the two radios. Use the >**connect n** command to establish a command session to either. To logout from one radio and get the list of radios again press the key [F4].

Section 4 describes the command language used to further modify the radio's operating parameters.

3.1.2   Using the radio auxiliary port

1. Connect each *pulsAR* Console Port to a terminal, or a PC running a terminal emulation program. Configure the terminal settings as follows:
     Baud rate: 9600
     Word length: 8 bits
     Parity: none
     Stop bits: 1

2. Connect each Power Inserter Unit to the respective *pulsAR* radio using a CAT 5 cable as defined in section 1.

3. Connect each radio Antenna A port (N type connector) to an appropriate 2.4 GHz band antenna using an RF coaxial cable.

4. Connect the two Power Inserter Units to a power outlet of the appropriate voltage.

5. The radios output a banner identifying the software and hardware versions and serial number, followed by the command prompt with the following format:

   rmt-nnnnn #>

   where nnnnn are the last five digits of the radio serial number. The first three letters may read **hub** or **rmt.** If the radio had previously been configured the prompt will be the radio **name.**

6. Set radio 2 to its factory default configuration by typing the command:

   > **load factory**
   > **save-configuration**

7. Configure radio 1 by typing the commands:

   > **load factory**
   > **node type=hub**
   > **save-configuration**

8. Once radio 1 is configured as the hub it will establish a RF communication with radio 2. To verify this connection type:

   > **show**

   Check that under MY CLUSTER there is a line indicating "Remotes: 1". You may also type **>show radios** to see various statistics of the link with radio 2.

9. The terminal connected to each radio can be used to further modify the radio's operating parameters. Section 4 describes the command language used to perform those functions.

3.2 Field Installation

3.2.1   Mounting Bracket installation

The radio is shipped with mounting hardware designed to easily mount the unit onto a pole outdoors. You can secure the radio to poles of up to 2.5 inches (6.3 cm) in diameter.

Before taking the radio into the field, assemble the mounting hardware as follows:

1. Using the two screws provided, secure the flat aluminum plate into the recessed channel on the back of the unit. Also install the provided ground lug for connection to the earth ground as described in step 3 of the section below.

2. Thread the L shape bolt into the hole of the V shape bracket. The non-threaded segment of the bolt should be outside of the V bracket.

In order to secure the radio outdoors place the radio against a pole with the RF connectors facing up (see Figure 1.1). The back of the radio enclosure has four guiding feet that prevent it from sliding from side to side. Place the V bracket around the pole, sliding its two grooves up into the aluminum plate on the back of the radio. Once the grooves reach the stops, manually tighten the L shaped bolt so that it "bites" into the pole.

Afar also provides a different bracket for mounting the radio against a flat surface.

3.2.2   Earth Grounding

For an outdoor installation you must provide a solid ground connection between the *pulsAR* metal enclosure and the Earth ground. This will minimize possible damage due to static buildup or nearby lightning.

In locations where it is warranted, you may also want to install a lightning arrestor device at the N type connector of the radio leading to the antenna (Afar part no SUP-0201). This is particularly recommended if the coaxial cable between the radio and antenna is of considerable length (greater than 2 meters or 6 ft). If you install the lightning arrestor, follow these same directions but connect the grounding cable to the appropriate screw/lug of the arrestor rather than the radio.

Each radio is shipped with a small ground lug (part no. SLU-35), and a lock washer to facilitate the installation of the ground connection.

You will require some additional supplies that are easily found at a hardware store, namely:

- AWG #6 copper grounding cable (4.1 mm diameter).

- Grounding lug, nut, bolt, lock washer (as required) for attaching the cable to the metal tower or structure.

- Anti oxidizing paste

- Outdoor cable ties (as required)

The following steps describe a procedure for a proper Earth ground connection:

1. Select an adequate grounding point on the tower or structure near the radio. This point should be below the unit and must not be inside the building. If you must drill a hole make sure it is NOT in the tower supports or cross braces. If several outdoor units are installed in the same area you may use the same grounding point.

2. Apply a thin film of anti oxidizing paste to both sides of the supplied grounding lug blade, as well as the threads of the screw used to secure the lug.

3. Install this grounding lug onto the radio enclosure with one of the two screws used to secure the mounting plate. This screw must go through (i) the lock washer, (ii) the grounding lug blade, (iii) the radio mounting plate and finally into the enclosure, in that order. Insure that the cable connector of the grounding lug is pointing downward.

4. Prepare the grounding cable by stripping an adequate amount of insulation from both ends and apply anti oxidizing paste to the exposed copper.

5. Insert one end of the exposed cable into the radio ground lug and tighten the screw on the lug.

6. Use steel wool or sand paper to clean the grounding point on the metal tower or structure.

7. Apply a thin film of anti oxidizing paste to this grounding point surface.

8. Fasten the cable to the grounding point using a lug, bolt and nut as required.

9. If required secure the cable to the tower or structure with cable ties or clips. DO NOT bundle this grounding cable with any other cable used for data, power or RF.

<u>Cautions</u>

When using the anti oxidizing paste read and follow the instructions and warnings for the selected product. In addition you should note the following general guidelines:

- The paste will act as a lubricant, therefore always use lock washers.

- DO NOT apply the paste to RF and data cable connections: the anti-oxidizing paste is conductive and may degrade the performance or damage the equipment.

- DO NOT use electrical or other tape for sealing the grounding connections when using anti oxidizing paste

- DO NOT use thread-locking compound on the same screw with anti oxidizing paste.

Inspect the grounding connections on a regular basis as well as after a lightning strike. Look for cables that may have been damaged or connections that may have loosen up or oxidize over time. Replace any damaged cables or connectors and tighten any loose connections.

3.2.3 <u>Power/Ethernet cable</u>

Connect the outdoor cylindrical connector of the CAT5e cable to port D of the radio. The other end of this cable (with an RJ45 connector) plugs into the indoor Power Inserter Unit.

You can optionally install the Ethernet/Power Surge Suppressor module (SUP-0202) at the point where the CAT5e cable enters the building. This protects your indoor equipment against surges induced by nearby lightning on the outdoor CAT5 cable. The surge suppressor has two RJ45 connectors and a ground wire, which you must connect to an earth ground.

If you use a DC source to power the radio, make sure you do not exceed the CAT5e cable length specified in the table below. At port D the radio requires a minimum of 9.5 VDC (and a maximum of 58 VDC). With the DC voltages shown at the power inserter, the maximum cable length results in an input voltage at the radio of 9.5 VDC.   The radio includes a voltage monitor which you can read with the **>show** command. This can be useful to determine the status of your battery for a battery-powered installation.

DC voltage (at power inserter)	Maximum CAT5e cable length (feet)	(meters)
10	51	16
11	153	47
12	255	78
13	358	109

3.2.4   Antenna Installation

NOTICE

The antennas for the *pulsAR* radios must be professionally installed on permanent structures for outdoor operations. The installer is responsible for ensuring that the limits imposed by the applicable regulatory agency (FCC, IC, or CE) with regard to Maximum Effective Isotropic Radiated Power (EIRP) and Maximum Permissible Exposure (MPE) are not violated. These limits are described in the following sections.

The *pulsAR* radio is typically attached to a pole (with the clamp provided) with the antenna connectors facing up. For optimum performance the radio must be mounted in close proximity to the antenna with a cable run typically under 2 meters (6 feet). Afar carries several antennas for operation at either 900 MHz or 2.4 GHz as shown below:

Band	Antenna Type	Gain	AFAR Model Number
900 MHz	Omni-directional	5 dBi	ATO-0905
	Dish Reflector	15 dBi	ATD-0915
2.4 GHz	Omni-directional	9 dBi	ATO-2409
	Dish Reflector	24 dBi	ATD-2424

Antennas at each end of the link must be mounted such that they have the same polarization, and directional antennas must be carefully oriented towards each other. The choice of polarization (horizontal vs. vertical) is, in many cases, arbitrary. However, many potentially interfering signals are polarized vertically and an excellent means of reducing their effect is to mount the system antennas for horizontal polarization. Of those antennas listed above, the directional antennas can be mounted for horizontal or vertical polarization, while the omni-directional antennas can only be mounted for vertical polarization.

Proper grounding of the antenna is important for lightning protection as well as to prevent electrical noise interference from other sources. The antenna should be mounted to a mast or tower that is well grounded to Earth. Use weatherproof connectors in all outdoor couplings. Also use the "coax-seal tape" (included with the radio) to further weatherproof outdoor connections.

The radio antenna ports come equipped with a quarter-wave short to ground which provides adequate surge protection of the RF front-end circuitry when you install the radio close to the antenna using a coaxial cable of less than 10 ft (3 m). If the coaxial cable between the radio and antenna exceeds that length you may also want to install a lightning arrestor device at the N type connector of the radio (Afar part no SUP-0205).

3.2.5   Antenna Alignment

When mounting the high gain antenna (24 dBi), the proper antenna alignment is extremely important since the beam-width of the antenna is very narrow. Once you perform a rough alignment and the link is in operation, you can use the "monitor-link" and "antenna-alignment-aid" commands. Type:

> **monitor-link**

in order to update, every half second, the link statistics including the RSSI level. The antenna can then be aligned so that the RSSI is maximized. In the PmP topology, the hub antenna is typically an omni and dose not need to be carefully aligned. But if you need to align a hub radio antenna for maximum signal from a particular remote use the command:

> **monitor-link node=N**

where N identifies the remote per the table displayed with the **show** command

Since in many applications the antenna is on a tower where it is not practical to have a terminal nearby, the *pulsAR* has an additional "antenna alignment aid" available at the outdoor unit. This feature uses the three pin "Auxiliary port" connector to output an audio signal with a pitch proportional to the receive signal strength. AFAR provides a special cable adapter that converts the three-pin connector into a standard female audio jack. Use this cable to connect the three-pin connector to a pair of standard headphones while aligning the antenna. At a terminal session issue the command:

>**aaa audio**   (aaa is an abbreviation for "antenna-alignment-aid")

and then align the antenna until you hear the highest audio pitch. Once the antenna is aligned you may type the command:

>**aaa off**

to turn off the audio signal and revert the auxiliary port connector to console mode.

3.2.6   Radio Configuration

The *pulsAR* units are shipped pre-configured with a factory default configuration. If the unit configuration has been altered, you can always reload it with the command:

> **> load factory**

In order to deploy an RF network between two or more radios you need choose one radio to be the "hub" and configure it with the command:

> **> node type=hub**

All other radios may be left configured with the factory configuration. As you turn them on with antennas pointing at the hub they will automatically join the network. Use the **>show** command to see the status of the radio, or the **>show radios** command at the hub for a complete list of all the radios in the network.

In most installations you may want to change several other parameters. The table below shows the most common ones and the associated commands to change them. Refer to section 4 for a complete description of each command.

Parameter	Description	Command
RF channel	You may need to change the RF channels if there is interference on the default channel (12). You can configure the RF transmit channel independently from the RF receive channel. Refer to section 3.2.7 for the procedure for choosing new channels.	rf-receive rf-transmit
RF transmit power	The factory default is 18 dBm. You can configure this parameter in 1 dB increments from 0 to 27 dBm. Take care not to exceed the maximum power limits as described in sections 3.2.7 or ??	rf-transmit
Network ID	The default value is 0. Change this value in all radios to a unique number to avoid unauthorized radios from joining the network	node

3.2.7   Spectrum Analysis and channel selection

Radio operation in unlicensed bands has the potential of suffering from interference from other equipment operating in the same band. The use of directional antennas greatly reduces the potential for interference. In addition, the p*ulsAR* radio includes several features, described below, to identify and overcome sources of interference.

The radio can be commanded to perform a spectrum analysis of the ISM band and report the results in either a graphical or tabular form. The command:

> **>spectrum-analysis antenna=a dwell=xx**

instructs the radio to scan the entire band, dwelling on each channel for a programmable amount of time, and record the highest signal level in that channel. This feature can be used to perform a site survey and identify the best receive channel.

Note that the RSSI value reported for each channel represents the total energy within the radio RF bandwidth centered around that channel. The radio RF bandwidth depends on the pulsAR model and can be 1.7, 4.6, or 17 MHz (see specification in appendix B). When you do a spectrum analysis any single channel sample that shows a low "noise" level, is a good candidate to select as a receive channel.

Once you identify a potential receive channel using the spectrum analysis tool, you may then use the "timing analysis" feature to confirm that the selected channel is indeed clear. The command:

  >time-analysis channel=xx antenna=a dwell=xx

instructs the radio to dwell on the specified channel for the specified amount of time. After taking several samples the radio displays the signal level detected in that channel over time.

3.2.8   Output Power Limits (FCC)

The Federal Communications Commission (FCC) regulations limit the maximum Effective Isotropic Radiated Power (EIRP) for spread spectrum systems operating in the 900 MHz or the 2.4 GHz band. The tables below show the maximum allowed output power using the various antennas.

Maximum Output Power (dBm) – 900 MHz models

	Antenna Gain	
	5 dBi	15 dBi
AR-9010E	27	19
AR-9027E		

\

Maximum Output Power (dBm) – 2.4 GHz models

	Antenna Gain	
	9 dBi	24 dBi
AR-24010E		
AR-24027E	27	24
AR-24110E		

3.2.9   Output Power Limits (CE)

At 2.4 GHz the European Telecommunications Standards Institute (ETSI) imposes a limit of 20 dBm as the maximum Effective Isotropic Radiated Power (EIRP) for direct sequence spread spectrum systems. In addition the maximum spectral power density is limited to 10 dBm per MHz maximum EIRP.

Because of these limits only two of the radio models (AR-24027E and AR-24110E) are available for deployment in the European Community countries. When using those two models you must reduce

the output power such that the EIRP of the installation does not exceed the values shown in the table below. In calculating the output power from the radio you must take into account the antenna gain, cable and connector losses.

Maximum EIRP (dBm) – 2.4 GHz models

	Maximum EIRP
AR-24027E	14
AR-24110E	20

3.2.10   Maximum Permissible Exposure (MPE) Limitations

The installer must mount all transmit antennas so as to comply with the limits for human exposure to radio frequency (RF) fields per paragraph 1.1307 of the FCC Regulations . The FCC requirements incorporate limits for Maximum Permissible Exposure (MPE) in terms of electric field strength, magnetic field strength, and power density.

Antenna installations must be engineered so that MPE is limited to f/1500 mW/ cm^2 (at 900 MHz) or 1 mW/cm^2 , (2.4 GHz) the more stringent limit for "uncontrolled environments". The table below specifies the minimum distance that must be maintained between the antenna and any areas where persons may have access, including rooftop walkways, sidewalks, as well as through windows and other RF-transparent areas behind which persons may be located.

**900 MHz - Minimum Distance calculation to
avoid Antenna Radiation Hazard (exposure of 0.610 mW/cm^2)**

Antenna Gain (dBi):	5	15
Max. Output Power	27	19
MPE safe distance (cm)	20	20

**2.4 GHz - Minimum Distance calculation to
avoid Antenna Radiation Hazard (exposure of 1 mW/cm^2)**

Antenna Gain (dBi):	9	24
Max. Output Power	27	24
MPE safe distance (cm)	25	25

*NOTE: For fixed location transmitters, the minimum separation distance is 2 m, even if calculations indicate a lower MPE distance. For mobile transmitters the minimum is 20 or 25 cm (shown on the tables)

3.3 Recording the Network Configuration and Performance

Once you finish a deployment and all links in your network are operational, you should record the configuration of each radio and the performance of every RF link. Then at a later time, if you need to replace a radio, or you suspect the performance of a link has degraded, you will have easy access to the original configuration and RF performance at the time the network was deployed.

Our utility program Econsole provides an easy way to achieve this record-keeping. From a single location you can log onto every radio in the network and record the command session into a file. Below are the steps we recommend you use to keep a record of your network:

1. Start the Econsole program in a PC connected over the Ethernet to one of the radios in the network. Econsole performs a "discovery" and displays a list of all the radios it reached. Verify that every radio in the network is in that list.

2. Create a script command file as follows:

    Econsole> **edit cmd.txt**

    a new window opens where you can type any radio commands. We recommend you type the following:

    > display-config
    > show
    > show radios
    > logout

    then Save the file and close the window.

3. At the Econsole> prompt type:

    Econsole> **connect all command=cmd.txt output=my_network.txt**

    The Econsole program now will log onto each radio in turn, and perform the commands in the cmd.txt file. The output, besides going to the screen, is also being written into the file "my_network.txt".

4. Once Econsole completes and you get its prompt (this may take some time), use any text editor to open the file "my_network.txt". The file should contain the configuration of each radio, and the RF performance (RSSI, distance, and other statistics) of each RF link.

3.4 Upgrading the Firmware.

3.4.1   Description

The operational firmware for the *pulsAR* radio is stored in Flash PROM and can be easily updated. The Flash PROM can hold multiple versions of the firmware simultaneously. The table below lists some of the "File Utility" commands used to download and manage the various files stored in Flash PROM.   A more detailed explanation for each command can be found in section 4.

File Utility command summary

Command	Description
directory	Lists all files stored in Flash PROM
delete-file filename	Deletes the specified file from the directory
download-file path/filename	Downloads the specified file from the PC path/filename into the Flash PROM
set-default-program filename	Sets the indicated filename as the default program to run after power up
run-file filename	loads the indicated program into RAM and executes it.

New firmware versions are made available from time to time at the following page in our website:

> http://www.afar.net/support.htm

The firmware files are named:

> clh0x_xx.bze   (binary zipped file for downloads through the Ethernet port)
> clh0x_xx.dwe   (ascii file for download through the serial port, or via Telnet)

where 0x_xx is the firmware version number. The website contains instructions for transferring the files into your PC.

A new file can be downloaded into the radios in one of three ways:

1. Using the Econsole program running in a PC connected to the same physical LAN as one of the radios. This is the fastest method and allows you to download to multiple radios from the same PC.

2. Using a Telnet session from anywhere on the Internet. This requires the radio to have been pre-configured with an IP address.

3. Using a terminal emulator program (e.g. HyperTerminal) running on a PC connected through the serial port to the radio RS-232 auxiliary port. This method only allows you to download to that specific radio.

The next three sections explain in detail how to download a new file using each method.

3.4.2   Installing new firmware through the Ethernet port

This procedure assumes that the new firmware needs to be installed in all radios of a working network. The upgrade is performed from a single PC connected via Ethernet to one of the radios. Note that new firmware does not need to be compatible with the firmware currently running. You can still download incompatible firmware and restart the network from a single location.

1. If you have not done so, install the utility program Econsole in the PC (version 4.xx or later). This utility program is distributed with the radios and can also be downloaded from the website. Please refer to the separate Econsole User's Manual for instructions on how to install it.

2. Make sure the file with the new firmware (file clh0x_xx.bze) is available in the PC.

3. Start the Econsole utility by typing "econ" at a DOS command window. Econsole will send a "discovery" message and display all the radios that can be seen. Verify that all radios in the network are listed.

4. Establish a command session with one of the radios in the list with the command:

     Econsole> **connect n** (where "n" is the number of the desired radio in the radio list)

5. Once you get a command prompt from that radio type:

     >directory

   to view a list of files stored in Flash PROM as well as the available free space. Verify that the free space in flash PROM is larger than the size of the clh0x_xx.bze file in the PC. If there is not enough space in Flash PROM delete one of the program files to make up space (use command >delete filename).

6. If the radio configuration has been password protected, you must first unlock the protection with the command:

     >unlock enable-configuration=*password*

   (when the configuration is unlocked, the radio prompt ends with the characters '#>. In locked mode the prompt does not include the '#' character).

7. Issue the command:

     >download *path/***clh0x_xx.bze**

   where *path/* is the directory in the PC where the clh0x_xx.bze file is stored. The *path/* extension is not required if the file is in the same directory as the Econsole program. As the download proceeds Econsole displays a line showing the current percentage complete.

8. Once the download is complete, issue the command:

     >set-default-program clh0x_xx

   in order to make the new file the default program to run after a reset.

9. Issue the command:

     >directory

and verify that the new file is in flash PROM, has the expected size, and is identified as the default program. Note that until you reboot the radio (below) the older version is still running.

10. Depress the "**F4**" key to log-off the session with the current radio. Econsole displays the list of all radios from the initial discovery phase. Repeat steps 4 through 9 for each of the radios until all radios have the new firmware version.

    You can also use a script file to have Econsole send the set of commands above to all radios sequentially, instead of doing this manually as explained above. Refer to the Econsole User's Manual for details.

11. Once all radios in the network have the new program in memory you must log onto each one in turn and reboot it with the command:

    > **>reboot**

    which causes that radio to restart using the new firmware. However, if new firmware is NOT compatible with the existing one, you must choose the order of the radios that you reboot very carefully. Always reboot the radios that are further away (in number of hops) from your current location first, and move to the closer radios. The local radio should be the last one to reboot.

12. Once you reboot the local radio, wait a few seconds, then, at the Econsole> prompt type:

    Econsole> **discover**

    you should now see the complete list of radios and on the right hand column the current version of the firmware should be listed. Verify that all radios are running the latest version.

3.4.3   Installing new firmware using Telnet

Telnet is a protocol that allows you to conduct a remote radio command session from a local host. The radio must have been pre-configured with an IP address and be reachable, over the network, from the local host. Refer to section 5 for details on how to configure a radio IP address and initiate a Telnet session.   The Telnet terminal emulation must have the capability of sending an ASCII file to the remote machine. The following description assumes you are using Hyperterminal as the local Telnet terminal emulation.

1. Verify that the new software is available in the local machine. The download software for upgrade via Telnet must have a ".dwe" extension, e.g., clh01_22.dwe.

2. Initiate a Telnet session with the radio as described in section 5.

3. If the radio configuration has been password protected, you must first unlock the protection with the command:

    >**unlock enable-configuration**=*password*

    (when the configuration is unlocked, the radio prompt ends with the characters '#>. In locked mode the prompt does not include the '#' character).

4. Issue the command:

    >**directory**

to view a list of files stored in Flash PROM as well as the available free space. Verify that there is enough free space in flash PROM for the new file. The space required will be the size of the clh0x_xx.dwe file divided by 2.5. If there is not enough space in Flash PROM delete one of the program files to make up space (use command >delete filename).

5. Start the download process by typing:

> **>download-file destination=clh0x_xx method=inline**

where 0x_xx file is new version of software being installed.

6. The radio will return with the following:

> "*Send the file ... if incomplete, end with a line with just a period*"

When you get this prompt, go to "Transfer-Send Text file…" in Hyperterminal and select the file to be installed. The file must have a ".dwe" extension.

7. After the file is successfully installed issue the command:

> **>directory**

to insure that the file has been loaded into memory.

8. Issue the command:

> **>set-default-program clh0x_xx**

where 0x_xx file is new version of software being installed.

9. Issue the command:

> **>reboot**

to restart the radio with the new software. Close the Telnet session, wait a few seconds and open a new session with the same radio.

10. Issue the command:

> **>version**

to insure the radio is running the latest version.

3.4.4   Installing new firmware using the RS-232 serial port

On occasion, it may be necessary to install new firmware using the RS-232 port. This is generally a less desirable method as the download time is much longer and you can only update the radio that is directly connected to the PC, i.e., remote updates are not possible.

The serial upgrade uses a PC with a terminal emulator. Any emulator can be used, however, it must have the facility to download a text file on demand. In the example below, the emulator used is Windows Hyperterminal.

1. Connect the *pulsAR* Auxiliary Port (3 pin circular connector) to a terminal, or a PC running a terminal emulation program. A special adapter cable is supplied by AFAR. Configure the terminal settings as follows:
    Baud rate: 9600
    Word length: 8 bits

> Parity: none
> Stop bits: 1

2. Verify that the new software is available in the PC. The download software for the serial upgrade must have a ".dwe" extension, e.g., clh01_22.dwe.

3. To have the shortest download time possible, set the radio to use the highest RS-232 speed allowable on the PC. In this example, a download speed of 115200 baud will be used. Set the console speed of the radio to 115200 baud by issuing the command:

    >console-speed-bps 115200

4. Change the baud rate of the PC to match the radio. Remember that with Hyperterminal, you must disconnect the session and re-connect before the changes will take effect. Verify the PC communicates with the radio again.

5. If the radio configuration has been password protected, you must first unlock the protection with the command:

    >**unlock enable-configuration=***password*

    (when the configuration is unlocked, the radio prompt ends with the characters '#>. In locked mode the prompt does not include the '#' character).

6. Issue the command:

    >directory

    to view a list of files stored in Flash PROM as well as the available free space. Verify that there is enough free space in flash PROM for the new file. The space required will be the size of the clh0x_xx.dwe file divided by 2.5. If there is not enough space in Flash PROM delete one of the program files to make up space (use command >delete filename).

7. Start the download process by typing:

    >download-file destination=clh0x_xx method=inline

    where 0x_xx file is new version of software being installed.

8. The radio will return with the following:

    "*Send the file ... if incomplete, end with a line with just a period*"

    When you get this prompt, go to "Transfer-Send Text file…" in Hyperterminal and select the file to be installed. The file must have a ".dwe" extension.

9. After the file is successfully installed issue the command:

    >directory

    to insure that the file has been loaded into memory.

10. Issue the command:

    >set-default-program clh0x_xx

    where 0x_xx file is new version of software being installed.

11. Issue the command:

    >**reboot**

    to restart the radio with the new software. Remember to change the PC Hyperterminal settings back to 9600 baud and disconnect/re-connect the session.

12. Issue the command:

    >**version**

    to insure the radio is running the latest version.

3.4.5   Feature upgrades

The *pulsAR* radios have the ability to turn ON or OFF optional features and capabilities. This is done via the use of the "license" command. This command requires a "key" that is specific to a particular radio serial number and capability. To obtain a feature key, you must supply the specific model number, the serial number, and the feature desired. Please contact your local distributor for a list of optional features available for your radio.

4   <u>COMMANDS</u>

4.1 Configuration techniques

You can establish a command session with an Afar radio in any of four different interfaces:

1. **Serial Console** through a 3-pin RS-232 port.

2. With the Afar **EConsole** program running on a PC connected to the radio Ethernet port.

3. Using **Telnet** from anywhere that can reach the radio IP address.

4. Using a **UDP/IP interface** for programming using a host computer.

Serial Console: To establish a command session on this port all you need is a terminal or PC directly connected to the radio 3-pin cylindrical connector. Afar provides an adapter cable (CBL-0403-003) to convert this connector to a DB9 female. By default this port is set as follows:
> Baud rate: 9600
> Word length: 8 bits
> Parity: none
> Stop bits: 1

This port allows you to configure and monitor only the local radio, i.e. you can not reach any of the remote radios through RF. It is often used for bench testing and for setting up device parameters prior to installation.

EConsole: This is an Afar program, available on the distribution CD or downloaded from our website, that runs on a PC Windows or a Linux platform connected to the same Ethernet LAN as the radio. With Econsole you can reach any local radios and also remote radios across multiple RF hops. However, EConsole does not cross an IP router. Refer to the separate Econsole User's Manual for instructions on its installation.

Telnet: Lets you establish a command session with a radio from anywhere on the Internet. The only requirement is that the radio must have been pre-configured with an IP address using one of the previous two interfaces (see **ip-configuration** command). Telnet is explained in more detail in section 5.

UDP/IP Interface: This is intended to allow a host computer to issue all the same text commands available through the other interfaces. Refer to the **udp-configuration** command and section 5.3 for details.

On power up the radio performs several diagnostic and calibration tests. At the end of these tests it outputs the command prompt. The default prompt has the following format:
  rmt-nnnnn #>

where nnnnn are the last five digits of the radio serial number. The first three characters are an abbreviation of the **node type** in the network, which may be hub or rmt. If a node "name" has been assigned to the node, the prompt will be that name.

The "help" command provides a list of all the commands available. To get more detailed help for a specific command, type "help command-name".

The radio keeps a history of several of the previously issued commands. Those commands can be viewed by pressing the up-arrow and down-arrow keys on the keyboard. Any of those previously issued commands can then be edited and reentered by pressing the <Enter> key.

4.2 Command syntax

The command interpreter in the *pulsAR* radio is designed to accommodate both a novice as well as an expert operator. All commands and parameters have descriptive names so that they are easily remembered and their meaning is clear. In order to be descriptive however, those commands are sometimes long. As the operator becomes familiar with the command language, typing the complete words could become cumbersome. The *pulsAR* radio command interpreter recognizes any abbreviations to commands and parameter names, as long as they are unambiguous. If an ambiguous command is entered, the radio will output all possible choices.

Commands have the following generic form:

command   parameter=value   parameter=value

You can enter multiple commands in one line by separating them with a semi-colon. If one of the commands has a syntax error the radio executes all commands up to the one with the syntax error and discards the remaining commands.

Following is a brief list of syntax rules:

- Words (for commands, parameters, or values) can be abbreviated to a point where they are unambiguous.

- Some commands or parameters consist of compound words separated by an hyphen. With compound words, the hyphen is optional. Additionally each word in a compound word can be abbreviated separately. For example, the following are all valid abbreviations for the command "save-configuration": "save", "savec" s-c" "sc".

- The parameter and value lists are context sensitive, i.e., in order to solve ambiguities the command interpreter only considers parameters valid for current command, or values valid for the current parameter.

- The arguments "parameter=value" must be entered with no blank spaces on either side of the '=' sign. Those arguments (parameter/value pairs) can be listed in any order.

- Even though parameters can be listed in any order, there is a "natural" order known by the command interpreter. This allows the user to specify parameter values without having to type the parameter names. For example the command

  >**spectrum-analysis antenna=a display=table**

  can be entered as (using abbreviation rules as well):

  >**spa a t**

- Using the preceding rule, for commands that have a single argument, the "parameter name" part of the argument is always optional, i.e., you can enter:

  >*command value*

  For example the command:
  >**save-configuration destination=main**
  can be shortened to any of the following:
  >**save-configuration main**
  >**save main**
  >**save**

- Not all parameters associated with a command need to be specified. Depending on the command, when a parameter is omitted it either assumes a default value or keeps the last value assigned to that parameter.

- For all parameters that accept a numeric value, the number can be entered in decimal or hexadecimal notation. To enter a number in hexadecimal notation precede it with a 0x or 0X. All other numeric values are interpreted as decimal. Example:

  >**rf-transmit channel=0x1a**   (hexadecimal)

  >**rf-transmit channel=14**   (decimal)

The following sections describe the various commands grouped according to their functionality. A summary list of all commands are contained in Appendices A and B.

4.3 Configuration Management Commands

A **radio configuration** consists of a set of programmable parameters that define the radio operation with regard to a variety of operating modes. There are five different configurations identified as **current, main, alternate, factory** and **basic**.

The **main** and **alternate** configurations are both stored in non-volatile memory. They can be loaded into the **current** configuration with the **load** command. On power up the radio loads the **main** configuration from non-volatile memory into the current configuration.

The **current** configuration is the set of parameters currently being used and can be modified by the operator through several commands. This configuration is volatile. If the current configuration has been modified it should be saved using the **save** command. Otherwise the modifications will be lost if power is removed.

The **factory** configuration can not be modified by the operator and is used to return the radio to the factory default condition. It is useful as a starting point to create a customized configuration.

The **basic** configuration is similar to the factory configuration with the exception that a few parameters are left unchanged when you issue the **load basic** command. The parameters left unchanged are the RF and the IP configuration. This is useful when you are logged on to a remote unit and need to start from a known configuration. If you were to issue the **load factory** command you might lose contact with the remote unit if, for example, it changes the antenna of the remote radio.

The access to change the radio configuration can be password protected. This password is set by the user with the **change-password** command. Once a password is set, issue the **lock** command to prevent any unauthorized changes to the configuration. Once locked, the configuration can only be modified by issuing the **unlock** command with the correct password.

When the configuration is unlocked, the radio prompt ends with the characters '#>' to remind the user that the configuration is unlocked. In locked mode the prompt does not include the '#' character. Once a password is set, the radio will automatically lock the configuration after 10 minutes without any commands being issued.

The configuration management commands are listed below:

change-password

enable-configuration="ASCII string"

This command allows the user to set or change a password used to "lock" and "unlock" access to the commands that change the radio configuration. The *pulsAR* radio is shipped with no password which allows access to all commands. Once a password is set and the configuration is locked, the password is needed to unlock the access to those commands. After changing the password you should also issue the "save-configuration" command to save the new password in non-volatile memory.

If you want turn off the password protection change the password to the "null string" as shown below (note the double-quotes):

>**change-password enable-configuration=""**

Another alternative is the >**load factory command** which restores the complete configuration to the original factory values (with no password).

Examples:

>**change-password enable-configuration=bh7g8**

WARNING

The p*ulsAR* radios are shipped with no password. If you set a password make sure you do not forget it. Once locked, without a password, you need to contact the factory to have the radio unlocked.

---

display-configuration

source= current or *main* or *alternate* or *basic* or *factory*

Displays all the parameter values for the specified configuration.   If the source is not specified it defaults to "current".

Examples:

> **display-configuration factory**

> **disco**

load-configuration

source=main or *alternate* or *basic* or *factory*

Loads the specified configuration into the current set of parameters controlling the radio operation. If no source is specified it defaults to the "main" configuration.

Examples:

> **load-configuration source=factory**
> **load**

lock

This command locks the access to all the commands that can alter the radio configuration. Once locked use the "unlock" command to regain access to those commands. Note that a password must be set prior to the "lock" command being issued (the radios are shipped with no password), otherwise the lock command has no effect. If a password is set, the radio automatically "locks" the configuration at the end of 10 minutes with no command activity.

save-configuration

destination=main or *alternate*

Saves the current set of radio operating parameters into one of the two non-volatile configurations. If the destination is not specified it defaults to "main".

Examples:

> **save-configuration destination=alternate**
> **save**

unlock

debug-mode="ASCII string"
enable-configuration="ASCII string"

This command unlocks the access to various commands. The **enable-configuration** password (set with the change-password command) unlocks the various commands listed in this manual that alter the radio configuration. The **debug-mode** is a factory mode used for troubleshooting by customer support.

Examples:

> **unlock enable-configuration=bh7g8**

4.4 Major Configuration Parameters

These commands change several operating parameters of the radio that are part of the radio configuration. When entering commands with multiple parameters, if a parameter is not included, that parameter keeps its current value.

distance

maximum=10..120
units=km or **miles**

Sets the limit for the maximum distance of any RF link in this network. You need to set this maximum distance to the same value on all hub nodes. Remote radios will automatically configure the maximum distance to that of the hub radios.

In general you should leave the maximum distance set to the default value of 80 km (50 miles). But if you are deploying a network where one or more links exceed this distance you must change this parameter to a value that is equal to or greater than the maximum link distance.

Increasing the maximum distance results in a slight decrease of the network capacity.

Examples:

> **> distance 100 km**

> **> distance units=miles**

encryption

mode=off or **des-56** or **3-des-112** or **aes-128** or **aes-256**

Selects the encryption algorithm applied to all user data packets transmitted over-the-air. All units support the **des-56** mode. The other modes may be blocked, you can use the ">help encryption" command to find which modes are available in your unit.

When using encryption you must set all units in the network to the same mode and enter the same key. The number at the end of each mode name is the length, in bits, of the key used in that encryption mode.

key=XXXX-XXXX-XXXX-XXXX-…
key-phrase=<string>

You can enter the key using hexadecimal digits in groups of 4 separated by optional dashes. The table below shows the number of hexadecimal digits required for each mode.

Table 4.1 – Encryption key lengths

	DES-56	3-DES-112	AES-128	AES-256
Key length (bits)	56	112	128	256
Hexadecimal digits	16	32	32	64

In the DES modes the least significant bit of each key byte is a parity bit. Therefore each byte contributes only 7 bits to the key length. You do not need to enter the key with the correct (odd) parity, the software will enforce that and echo back the key with the correct parity.

The **key-phrase** parameter provides an alternate way for entering a key. You can enter any ascii string of up to 80 characters and the radio will generate a pseudo-random key of the appropriate length. The key phrase may have spaces but you need to put it in quotes. Note that the key-phrase is not stored in the radio configuration, only the generated key.

Example:

> **> encryption aes128 key-phrase="Acronym For Afar Radios"**

ethernet

speed=auto-10 or *10hdx* or *10fdx* or *100hdx* or *100fdx* or *auto* or *off*

Sets the ethernet port speed to a combination of 10 or 100 Mbps, half or full duplex, or auto negotiate.

In installations requiring a very long outdoor CAT5 cable, operation at 100 Mbps may become unreliable. For this reason the **auto-10** setting forces the speed to 10Mbps but negotiates the half vs full duplex setting. The **auto** setting (default) negotiates both the speed and duplex to the fastest configuration supported by the other device on the Ethernet. With either of the **auto** settings the radio also detects and crosses over the Tx and Rx signal pairs, if necessary. This automatic cross-over feature is disabled in the non-auto settings.

You can also turn **off** the ethernet port, but only if your command session is over the console port, or remotely over an RF link. This can be useful for test purposes if you suspect that you created a loop in the network and want to shut down this port without turning off the radio.

station-timeout-sec=5..10000

Sets the time the radio will retain, in its internal table, Ethernet addresses obtained from the network.

multi-cast-timeout-sec=5..10000

Sets the time the radio will retain, in its internal table, Ethernet multi-cast addresses obtained from the network. This can not be set to a value below the station-timeout.

block-remote-broadcast=on or *off*

When "off" (default) broadcast packets are sent out to reach every station. If "on" then the master-hub will NOT re-transmit (to other remotes) broadcast packets received from a remote. If your system never requires remote to remote communications, this prevents the unnecessary broadcast of packets over RF to reach every remote.

vlan-mode=reply-same or *strip*

Determines how the radio processes packets addressed to the radio itself that are wrapped in a VLAN wrapper. With the default setting (reply-same), any replies to those packets will be wrapped in a VLAN wrapper with the same VLAN tag. With the strip setting, no VLAN wrapper will be put on those replies.

The "reply-same" setting allows the user to connect to the radio using ECON or telnet in deployments where radios are used to provide the link between switches that carry multiple VLANs between them, even if the user's PC is not on that link but on a switch port connected to only one VLAN and not using VLAN tags on its packets.

Examples:

> **ethernet speed=10fdx station-timeout=100**

node

type=master-hub or *hub* or *remote*

In the cluster-hub network configure all hubs with node type set to **hub** and all other radios set to **remote**. When you have multiple hub radios the cluster will automatically select one as the master-hub. Use the **>show radios** command at any of the hubs to find which one is the current master (index zero in the cluster hub table).

The **master-hub** setting allows you to pre-select one of the hubs to always be the cluster-master, whenever it is present. If it is turned off then one of the other hubs assumes the cluster-master role.

max-remotes=1..29

At the cluster-master radio this value specifies the maximum number of remotes that will be allowed to join in. Once the network has this many remotes it stops allocating a slot for new nodes to join in. This increases the inbound throughput slightly, specially if the number of remotes is small.

redundancy=1..4

Selects the total number of separate transmissions by different cluster-hubs for each outbound packet. As you increase the number of redundant transmissions, the robustness of the wireless network improves at the expense of total throughput capacity. If there are fewer hubs than the selected number of transmissions, all hubs will transmit the same packet in turn.

name="ASCII string"

Gives the node a meaningful name for further reference. This name will be used as the command prompt. It is also used to identify the node in a variety of commands and displays. The name field can be up to 23 characters with no spaces. If spaces are desired, you may include the whole name in quotation marks.

network-id=0..65,535

For a link to get established, the network-id value of the radios involved must match. Setting unique network ids on each network prevents a radio from connecting to the wrong hub or peer if it happens to be within RF range and on the same channel.

The value of the network-id is only displayed if the configuration is unlocked.

cluster-id=1..16

In a multi-cluster network you must assign a different ID to each cluster and configure each of the hubs with this cluster-id. All hubs in the same cluster must be configured with an identical cluster-id value which must be different from all other clusters. The system supports up to 16 different clusters.

min-cluster-size=0..32

This is the minimum number of hubs in a cluster for hub radios to elect a master and start operating as a cluster. Typically you would set the same value on all hubs. While there are not enough hubs none of them is "master-capable" and with no master-hub there will not be any RF transmissions. This is useful if, for example, one hub becomes disconnected from the LAN. That hub would become a separate cluster of size one, it would become his own master, and initiate transmissions over RF. Those transmissions could collide with the transmissions from the other hubs. Setting the min-cluster-size to 2 will disable that single hub from becoming a master and it will stay quiet until it joins the rest of the network. You may want to set it to a larger number than 2 specially if, depending on the switch network connecting all the hubs, there is the possibility that a failure in a switch would break the network into two or more separate networks of various sizes (half of the expected cluster size may be a good approach).

The value of 0 turns this feature off: a single hub radio, even with no Ethernet connection, would still become a master hub and transmit over RF. This may be useful in the lab where a single master hub may provide a connection between two or more remotes.

The value of 1 requires that the Ethernet port be up for a single hub to elect itself as a master. This is useful in a situation where the cluster is made of only two hubs. If the LAN connection to one of the hubs fails, that hub shuts down while the other hub continues to operate.

location="ASCII string"

Optional parameter to define the location of the node. This field is displayed in the "Display-configuration" output and also reported through SNMP. This field is used for information only. The location string can be up to 25 characters with no spaces. If spaces are desired, you may include the whole string in quotation marks.

contact="ASCII string"

Optional parameter to define the contact for maintenance purposes. This field is displayed in the "Display-configuration" output and also reported through SNMP. This field is used for information only. The contact string can be up to 25 characters with no spaces. If spaces are desired, you may include the whole string in quotation marks.

Examples:

> **>node name=bank location="wall street" contact=964-5848**

rf-receive-setup

channel=<channel-number>
antenna=a, b
disconnect=0 or *1*
forward-all-packets=0 or *1*

This command configures the channel, and antenna used for the RF reception.

For a remote radio to join the network, the channel selected by this command must match the transmit channel selected for the hub radio in that cluster.

The **disconnect** parameter is only applicable at a remote radio. When set to 1 (default), and the channel or antenna changed values, the remote radio disconnects from the current cluster right away and start looking for a new parent. When set to 0 a remote radio changes the channels or antennas but stays attached to the current cluster. This is useful if that one cluster has hubs set to transmit on two channels, in which case the radio stays attached. If there are no hubs in the same cluster transmitting on the new channel, the remote radio times out after 1 second, only then tries to attach to a new cluster.

The forward-all-packets parameter is only applicable at the hubs. You only need to set it at the hub-master, its value will propagate to all other hubs. When set to off (default) only the 4 strongest slave hubs will forward to the hub-master inbound packets received from a remote. This limits the total number of repeated packets seen by the hub-master. Turning the parameter on is useful during the commissioning of a new cluster to verify the true coverage of the track. This coverage is reported in the "monitor-link" command under the "Rd" (redundancy) column.

Table 4.2 shows the valid ranges for the **channel** parameter which depend on the radio model you are using. Refer to appendix C for a mapping of the channel numbers to actual RF frequencies. You can also use the command >**help rf-receive** to find the ranges of the various parameters.

Example:

> **> rfre ch=15**

rf-transmit-setup

channel==<channel-number>
antenna=a, b
power-dbm=0..27
speed-kbps= <rf-speed>

This command configures the channel, antenna, transmit power and speed used in the RF transmissions.

You only need to configure the transmit channel of the hub radios. The remote radios will automatically set their transmit channels to match the receive channel of the hubs.

The following table shows the valid ranges for the **channel** and **rf-speed** parameters which depend on the radio model you are using. Refer to appendix C for a mapping of the channel numbers to actual RF frequencies. You can also use the command >**help rf-transmit** to find the ranges of the various parameters.

The rf-speed for the complete cluster driven by the setting at the cluster-master. All other radios will modify their configuration to match that value. Lower speeds may restrict the maximum number of hubs in a cluster. You can use the "show"command to find out the current maximum number of hubs allowed.

The clustered hub topology can generate a lot of over-the-air traffic, specially as you increase the value of transmit redundancy. To avoid congestion we recommend you always use the highest rf-speed available.

Table 4.2– RF parameters ranges

	AR-9010E	AR-9027E	AR-24010E	AR-24027E	AR-24110E
Channel ranges	3...27	5...25	1...40	2...39	5...35
Rf-speeds (mbps)	0.10	0.25	0.10	0.25	1.0
	0.20	0.50	0.20	0.50	2.0
	0.55	1.375	0.55	1.375	5.5
	1.10	2.750	1.10	2.750	11.0

single-node-reboot

timeout-sec=0,15..60000

After power up, radios attempt to get an RF link with one or more radios. If a radio fails to get a link up (or drops all existing links), it will perform a complete reset after the timeout specified in this command. A value of zero is allowed and turns this feature off.

This feature is useful if you issue a command to a distant radio (over an existing RF link) and the link drops as a consequence of the command. If that radio now has no other links up it waits for the "single-node-reboot" and then performs a reset. As a result, the radio reverts to the saved configuration, allowing it to reestablish the original link.

Examples:

> **snr 60**

time-division-duplex

cycle-period-ms= 20 or *40* or *60* or *80*

The network operates in fixed "cycles"as described in section 2. A cycle is then divided into an outbound phase (transmissions by the hubs) followed by an inbound phase (transmissions by the remotes). Lower cycle periods result in lower latencies in a network with low traffic. As the network and/or traffic increases, you may get better performance with larger cycle periods.

Short cycle periods may restrict the maximum number of hubs allowed. After changing this parameter you may check the resulting maximum number of hubs allowed with the "show"command.

The cycle period is set by the cluster-master radio. All other radios in the cluster will change their configuration to match that of the master.

transmit-percent= auto or *20* or *30* or *40* or *50* or *60* or *70* or *80*

This parameter defines the percentage of the cycle that is dedicated for transmission by the hubs. The remaining time is dedicated to receiving from the remotes. This parameter is set by the cluster-master radio. All other radios in the cluster will change their configuration to match that of the master.

In **auto** mode the cluster-master dynamically assigns a split based on the current traffic load in each direction. This split may be different from cycle to cycle. This is the recommended setting when you have a single cluster. In a multi-cluster deployment you need to use a fixed split

value, which must the the same in all clusters in order to avoid potential self-interference between co-located hubs from different clusters.

Example:

> **> tdd sync=auto transmit=30**

4.5 Internet Protocol (IP) Management Commands

The IP Management commands configure the radio IP protocol parameters which allow the radio to be monitored and configured through Telnet and SNMP. Refer to section 5 for a more detailed explanation on those two applications.

ip-configuration

address=<ip address>
netmask=<string>
gateway=<ip address>
dhcp-client=off or *on* or *local-only* or *radio-only*

This command configures the radio IP address, netmask and gateway. The IP configuration is optional and the radios are shipped with these parameters left blank. Once the IP configuration has been initialized, the radios will reply to "ping" packets. The IP configuration is also required in order to use the "ping", "snmp" and "telnet" features.

Alternatively you can enable the **dhcp-client** function. In that case the radio will attempt to configure its IP address parameters from a DHPC server in the network. You can control whether the radio should look for a DHCP server exclusively over the local LAN (**local-only**), exclusively over the RF port (**radio-only**), or on either port (**on**).

Since the two radios in a link are bridged together they are in the same "internet network".

Example:

> *>* **ipconfig add=207.154.90.81 netmask=255.255.255.0 gateway=207.154.90.2**

ping

destination=<string>
count=0..500
size-bytes=32..1472

This command causes the radio to "ping" the destination address and display the results. The "ping" packet consists of an ICMP packet with a length specified by the "size-bytes" parameter. The destination is any valid IP address. When the destination host receives the packet it generates a reply of the same size. Upon receiving the reply the radio displays the round trip delay. This process is repeated until the number of replies reaches the value specified by the "count" parameter (default to 4). A count of zero leaves ping running indefinitely until stopped by the user.

Example:

> **ping 207.154.90.81 count=10 size=100**

snmp

The radio runs an SNMP agent which allows up to four IP addresses to be specified as valid SNMP managers. This command configures those IP addresses and the type of access allowed. You can issue the command up to four times to specify each separate IP address manager. The radios are shipped with all entries blank. While no entries are specified, the unit accepts SNMP "get" requests from any IP address with the "public" community. Once one or more entries are specified, the radio only responds to requests from the specific IP addresses listed. This list of authorized managers is also used for validating Telnet requests.

Refer to section 5 for an overview of Network Management using SNMP and Telnet.

manager=<ip address>

Specifies one valid IP address where the SNMP manager or Telnet session will run.

community=<string>

Any string of up to 9 characters. For SNMP requests the "community" field in the request packet from this IP address must match this parameter. For a Telnet session the username entered when initiating the session from this IP address must match this string. If this parameter is not specified it defaults to "public". Note that you must always enter the "manager" IP address in the same command line that sets the "community" value.

access=g or *gs* or *gst* or *gt*

SNMP access type authorized *for* this IP manager. Specify as any combination of three letters: g (get), s (set) and t(trap). If this parameter is not specified it defaults to "get". Note that you must always enter the "manager" IP address in the same command line that sets the "access" value.

authentication-traps=yes or *no*

Specifies whether an "authentication trap" should be generated if a SNMP request is received that can not be honored (due to invalid IP address, community or access fields). When enabled, all IP managers that have "trap" access will receive this trap.

delete=1..4

Allows deleting one entry in the SNMP table. The number 1..4 refer to the entry number as listed in the "display configuration" report.

Example:

> **snmp manager=207.154.90.81 com=support access=gst**

udp-configuration

> *console=on* or *off*
> *vital-port-1=1..0xFFFF*
> *vital-port-2=1..0xFFFF*
> *command-port=1..0xFFFF*
> *max-response-bytes=400..65521*
> *socket-mode=1* or *2*
> *peer-address=<ip address>*
> *peer-command-port=1..0xFFFF*

The **console** parameter turns **on** or **off** the radio UDP interface. The factory default is off. You may turn it on for either of the following purposes:

1. To send and receive **vital packets** which the radio classifies as the highest priority (see section 2.4.9).

2. Send radio configuration text commands encapsulated in UDP/IP packets. This is useful when you want to configure the radio from a program running on an external computer

The **vital-port-1** and **vital-port-2** specify two different UDP port numbers. The radio examines the "source" and "destination" ports of any UDP encapsulated packets that the radio receives and queues for transmission over RF. If any of those two values match the vital-port-1 or vital-port-2, the packet is classified as **vital priority** and is transmitted ahead of all other packets.

All the remaining parameters are used for the purposes of issuing radio commands using UDP encapsulated packets. The formats of these UDP packets and radio replies are described in detail in section 5.3.

The **command-port** parameter is the UDP port number used by the radio to receive commands.

The **max-response-bytes** parameter limits the length of the response packets generated by the radio. If the response is longer than this value it gets truncated.

The **socket-mode=1** (default) is intended for applications where the controlling program allocates a single socket for packets in both directions, while **socket-mode=2** is used when the program must create separate sockets for sending to the radio and receiving from the radio.

In both modes the radio listens for UDP packets addressed to the specified **command-port** number. In **socket-mode 1**, if you do not specify a **peer-address** and a **peer-command-port** the radio accepts packets from any IP address and port and sends the responses to the same IP address and port from which the command was received. If you specify a **peer-address** and/or a **peer-command-port** the incoming packets must match these parameters, otherwise the packets will be ignored.

In **socket-mode 2**, the radio sends the UDP command replies to the IP address specified by the **peer-address** parameter and sets the destination UDP port to the value specified by the **peer-command-port** parameter. Additionally the IP address on incoming packets must match the **peer-address** parameter.

4.6 Installation and Link Monitoring Commands

These commands are useful as installation aids and also for monitoring link statistics after the link is established.

antenna-alignment-aid

mode=off or **a-antenna** or **b-antenna**

With the mode other than **off**, the radio outputs, through the auxiliary port, an audio signal with a pitch proportional to the Receive Signal Strength (RSS) level of packets received on the specified antenna. AFAR provides a special cable adapter that converts the three-pin auxiliary port connector into a standard female audio jack. Use this cable to connect the auxiliary port to a pair of standard headphones while aligning the antenna.

While the antenna alignment is on the RS-232 console output is not available. When the antenna alignment output is set to **off** the auxiliary port output reverts to RS-232 console.

The antenna alignment output setting can also be saved as part of the radio configuration. This is useful to take a pre-configured radio to an installation site with no need to turn the antenna alignment ON (through a terminal) after power up.

Example:

>**aaa a-antenna**

>**aaa off**

monitor-coverage

clear=0 or **1**

This command is only valid at the cluster-master. It continuously updates a list of all remotes and, for each remote, it displays which hubs are currently within range and the respective receive signal strength (RSSI) as seen by those hubs. The hub numbers correspond to the radios as listed in the **show radios** command.

The covering hubs for each remote are typically listed in order of RSSI. The only exception is if you set the transmit redundancy to one, the scheduling algorithm applies some hysteresis before switching covering hubs - in which case the first hub listed may not be the one with the strongest RSSI. In all cases the first N hubs listed (with N being the transmit redundancy) will actively transmit packets to that remote.

The last two columns in the table show how many polls were issued to that remote since the screen was last updated, and the maximum interval between consecutive polls to that remote since that value was cleared. You can clear this last number by using the **clear=1** argument

monitor-ethernet

header=0 or **1**
line-feed=0 or **1**

This continuously displays the total number of packets that the radio received and transmitted on the Ethernet over the previous second. It also breaks down the total number of packets

based on the destination address as Unicast, Broadcast, Multicast 1 (Global multicast address) and Multicast 2 (Local multicast address).

You can use the **header=0** parameter to eliminate all the lines and headers except for the last line. You can specify the **line-feed=1** to add a line feed character to the end of the line and have a record of the number of packets over previous seconds.

monitor-flow

At the master-hub this command shows the current data flow to and from each remote and updates this information once per second. At a remote unit this command shows the data flow statistics to the hub. Press the [space bar] to terminate the command.

display-link
monitor-link

node=0..31
clear=0 or *1*
header=0 or *1*
line-feed=0 or *1*

These commands output statistical information about one RF link. If you are at a hub and there are multiple remotes you can specify the remote **node** using the index assigned to that remote (use the **">show radios**" command to see the indexes). Or you can specify the value of 0 to see all links. Note that only the cluster-master has complete information about all the links; therefore when you issue this command at a non-master hub some of the information will be missing. If you are at a remote the node number is irrelevant, the command displays the complete statistics of the link from the hubs.

The **display-link** command outputs the information once and returns, while **monitor-link** keeps running, updating all the statistics once per second, until you press the space-bar.

The output at the cluster-master has the format shown below. At a remote the output has an identical format with the headers slightly different to reflect the perspective at the remote. The description of the fields below reflects the hub's perspective.

You can use the **header=0** parameter to eliminate all the lines and headers except for the last line. All values are output in ASCII, separated from each other by one or more spaces. The line terminates with the Carriage Return character. You can also specify the **line-feed=1** to add a line feed character to the end of the line.

```
>display-link node=3
```

```
CLUSTER HUBS (redundancy 3):
  #   S/N        Since       RSSI  Last Seen
 --  -----   ---------------  ----  ---------
  0  17001         00:20:39   -64     0.08
  1  15005         00:20:40   -64     0.08
  2  16335         00:20:46   -43     0.00


REMOTES:                                      % received by        Recent
                                       Total  N hubs (ever) (now)Hubs  RSSI
  #    Name     S/N       Since       Replies 3+  2   1   0    0 Rd Hi-Max Min
 --  --------- ----- ---------------  ------- --- --- --- --- -- -- -- --- ---
  3  rmt-17010 17010       00:20:40   45588 99. .01 .00 .00  0  3  2 -43 -65
```

Where:

CLUSTER HUBS: Table listing all the cluster hubs and for each of them the last RSSI level, and elapsed time since that RSSI was recorded. At a cluster-master these are the RSSIs at the hubs for the reception from the specified remote. At a remote this is the RSSIs at the remote on the last message from that hub. If more than 10 seconds elapsed since this hub was involved, then the RSSI is left blank.

Total Replies: Total number of MAC level packets transmitted by this remote since joining the network or since statistics were cleared with clear=1 parameter. The following percentages are with reference to this number of packets.

% received by N hubs (ever): Of the total replies, these fields indicate the percentage of packets that were received by more than 3 hubs, by 2, 1 or 0 hubs. The last value indicates the percentage of packets that were actually dropped.

% received by N hubs (now): Of the last 100 replies this numbers indicates how many packets were dropped (received by 0 hubs).

Hubs Rd: number of redundant hubs – how many different hubs received from this remote in the last half second. This number is affected by the "forward-all-packets" setting of the "rf-receive-setup" command. When the forward-all-packets is off (default), not all hubs forward the received packets to the master and this number is clipped at 4 or 5. You need to turn the forward-all-packets to on to see the true coverage (redundancy) of the cluster.

Hubs Hi: Current hub index with the highest RSSI.

RSSI: Min and Max RSSI of last message received from specified remote by the hubs "covering" that remote. The number of hubs covering the remote is controlled by the "node redundancy" parameter. If there is no Max or Min RSSI (no hubs received) the value will show as –99.

show-table

table=status or **radios** or **clusters** or **sync-delays** or **ethernet** or **econsole** or **ip-stack** or **properties**
format=counts or **times**

This command displays various tables in different formats as described below:

status table

This contains miscellaneous information including system start and run times, unit temperature, and input DC voltage. At the hub radios it also identifies the current clock-master, cluster-master, and current cluster size. The "format" parameter is not applicable for this table.

radios table

Displays a complete list of the cluster hubs followed by the remotes with different statistics for each group. When you issue this command at a hub, an asterisk identifies the hub radio that you are logged to. Also the first radio on the cluster list (with index 0) is always the cluster-master for that cluster.

Below is the format of the "show radios" output at a cluster-master. See the **display-link** command for a description of all the statistics. Note that at a non-master hub not all the fields are filled.

```
CLUSTER HUBS (redundancy 1):
                                    Capable      Qd Tx
    #    Name     S/N      Since     Mas/Sla     bytes
   -- --------- ----- --------------- --- ---   ---------
 *  0 hub-2     40754 04-May 17:06:37  yes yes          0
    1 hub-3     40760 04-May 17:06:36  yes yes          0
    2 hub-1     40749 04-May 17:06:36  yes yes          0

REMOTES:                                      % received by        Recent
                                     Total   N hubs (ever) (now)Hubs  RSSI
    #    Name     S/N      Since     Replies 3+  2   1   0   0 Rd Hi-Max Min
   -- --------- ----- --------------- ------- --- --- --- --- -- -- -- --- ---
    3 rmt-30041 30041 04-May 17:06:37  69020 100 .00 .00 .00  0  3  1 -45 -59
    4 rmt-30369 30369 04-May 17:06:39  68495 100 .00 .00 .00  0  3  1 -60 -73
```

clusters table

Shows all the cluster IDs present in the network, and for each cluster identifies the cluster-master and which of them is the clock-master.

sync-delays table

This is only available at the clock-master radio. It displays the Ethernet transit times as reported by each of the clock-slave radios in the latest "delay request packet" received. It groups them by cluster ID. In a multi-cluster deployment hubs in the same cluster will typically show similar transit times (depending on the Ethernet switch fabric).

ethernet-stations table

This table can be displayed in two formats, "counts" (default) and "times".

>show ethernet

```
                                     --Discard--        --Forward--
 #        MAC address    IP address     Radio    from      to      from      to
 --   ----------------   --------------  -----    -----    -----    -----    -----
 0   ff-ff-ff-ff-ff-ff                   Local       0        0        0      919
 1   00-0d-94-00-3a-9d                     me        0        0      388      361
 2-  01-0d-94-00-00-01                     me        0        0        0        0
 3   00-a0-cc-66-70-8e  207.154.90.161     4         0        0   197246    99568
 4   00-a0-cc-d7-06-76  207.154.90.173    Hub        0        0    99578   197133
 5   00-a0-cc-d6-fd-50                     6         0        0      122      148
```

>show ethernet times

```
 #        MAC address    IP address    Radio MC    Time added        Idle  VLAN
 --   ----------------   --------------  ----- --   -----------      -----  ----
 0   ff-ff-ff-ff-ff-ff                   Local     11-Jan 22:57:57          N/A
 1   00-0d-94-00-3a-9d                     me   X  11-Jan 22:57:57          N/A
 2-  01-0d-94-00-00-01                     me      11-Jan 22:57:57  5490.86  N/A
 3   00-a0-cc-66-70-8e  207.154.90.161     4       11-Jan 23:30:48          N/A
 4   00-a0-cc-d7-06-76  207.154.90.173    Hub      11-Jan 23:32:32          N/A
 5   00-a0-cc-d6-fd-50                     6       12-Jan 00:28:22          N/A
```

Both formats list all the ethernet stations attached to either this radio or other radios that have a direct link to this one. The tables list the MAC (Ethernet) address of the station, and, if known, the IP address.

The first row in the table tracks broadcast traffic while the second entry is always the address of the radio itself. The <u>Radio</u> column shows the radio where that station is physically attached. It may have a number 3 through N which identify one of the children radios as shown in the **show links** table. Or it may say: "**Local**" to indicate stations connected to the local Ethernet, "**me**" to identify this radio, **"Hub"** for the parent radio, and **"Bcast"** for addresses that are in an unknown segment (this radio broadcasts packets to these addresses through all ports).

The "counts" format shows the cumulative number of ethernet packets that have been seen with that MAC addresses in the source ("from") or the destination ("to") fields. The radios operate the Ethernet port in promiscuous mode and therefore look at all the packets in the Local Area Network. The radios discard the packets that are known to be local, but forward all other packets to remote radios. These are accounted separately in the report.

The "times" format indicates whether that entry is for a "multicast" (MC) address, shows the time when the station was added to the table, and how long since that address has been seen. When the "idle" time exceeds the time specified by the "ethernet" command, that entry is deleted from the table.

econsole table

The unit broadcasts an e-console discovery packet on both its ports: Ethernet and RF, and then reports all the replies. These include both gateways and radios that can be reached on either port.

properties

Displays the properties of the radio hardware including the hardware version, clocks speeds, CPU version, and RF characteristics.

spectrum-analysis

antenna=a or *b*
display=graph or *table*
dwell-time-ms=1..1000
post-scan-wait-ms=500..10000

This command switches the radio to receive mode on the designated antenna (defaults to **a**) and performs a scan of <u>all</u> the channels in the band, dwelling on each channel for the specified amount of time (defaults to 100 milliseconds). While on each channel it measures the RSSI for that channel and stores its peak value. It then displays the data collected in a graphical or table formats (defaults to **graph**).

Note that the RSSI value reported for each channel represents the total energy present in the radio bandwidth centered around that channel (see appendix B for the RF bandwidth of each model). Since adjacent channels "overlap" each other, a narrow band transmitter will show up in this spectrum analysis as a lobe with energy present in several adjacent channels. Conversely, you do not need to find a wide region in the spectrum analysis report to select a quiet channel, i.e., any single channel sample that shows a low "noise" level, is a good candidate to select as a receive channel.

Performing this function causes all RF links with this radio to drop momentarily. Once the scan is complete the links will be restored. If you invoke this command remotely through an RF link the radio waits, at the end of the spectrum scan and then attempts to send the report to your terminal. This wait defaults to 2000 ms which is usually adequate for the RF link to come back up. If you don't receive the report after this time out you may specify a longer wait with the **post-scan-wait-ms** parameter.

Examples:

>**spectrum-analysis antenna=b**

>**spa**

time-analysis

channel=0..50
antenna=a or *b*
display=graph or table
dwell-time-ms=1, 2, 5, 10, 20, 50, 100, 200, 500
post-scan-wait-ms=500..10000

This command switches the receiver to the specified antenna (defaults to A) and then measures the RSSI for a <u>**single**</u> channel over a period of time. Each "sample" consists of the maximum RSSI measured during the dwell time specified (defaults to 20 milliseconds). After collecting 60 samples the RSSI values are displayed graphically or numerically (defaults to "graph").

Performing this function causes all RF links with this radio to drop momentarily. Once the scan is complete the links will be restored. If you invoke this command remotely through an RF link the radio waits, at the end of the time analysis and then attempts to send the report to

your terminal. This wait defaults to 2000 ms which is usually adequate for the RF link to come back up. If you don't receive the report after this time out you may specify a longer wait with the **post-scan-wait-ms** parameter.

Example:

>**time-analysis antenna=b**

>**tia in=a dis=t dwell=500**

4.7 File Utilities

The *pulsAR* radio maintains a file system that allows multiple programs to be stored in either non-volatile flash PROM or volatile RAM. New programs can be downloaded into the *pulsAR* radio memory through the auxiliary port, through the Ethernet port, or to a remote radio across the RF link.

One of the programs in flash PROM is designated as the default program to run after reboot. On power up that program is copied from PROM into RAM and the code runs out of RAM.

Both sections of memory (non-volatile flash PROM and volatile RAM) are segregated into two "directories". The non-volatile flash PROM is called "flash" signifying the flash PROM and the volatile RAM is called "tmp" signifying the temporary status of the program. Use the "directory" command to view the programs loaded and whether they are in non-volatile or volatile memory.

Any program can be invoked with the command "run" without making it the default file. This is useful when upgrading the software over an RF link as a way to ensure that the new code is working correctly before making it the default.

console-speed-bps

baud-rate-bps=9600 or **19200** or **38400** or **57600** or **115200**

Sets the Auxiliary port of the radio to the specified baud rate. This setting is not saved in the radio configuration, the auxiliary port always reverts to 9600 baud on power up.

This command is useful to speed up the download process over the auxiliary port. Before issuing the download command, use this command to change the radio console speed to the highest baud rate supported by the PC. Then change the terminal settings to match the radio speed. Issue the download command described below and initiate the transfer at the terminal.

Examples:

>**console-speed-bps baud-rate-bps=115200**

copy-file

source=filename
destination=filename

Copies the input-file into the output-file. If the memory location is not defined (flash or tmp), the command assumes the flash directory.

Examples:

>**copy-file tmp/clh01_22 clh01_22**

delete-file

filename=filename

Deletes the specified file from RAM or Flash PROM. If the memory location is not defined (flash or tmp), the command assumes the flash directory.

Examples:

>**delete clh01_22**

directory

format=short or *full*

Lists all the files currently stored in flash PROM and RAM, their size, the sectors occupied and the MD5 checksum (full version). It also indicates which of the files is the default program. Files stored in flash PROM have the flash/ prefix. Files stored in RAM have the tmp/ prefix.

Examples:

>**dir**

download-file

source=path/filename
destination=filename
set-default-program=yes or *no*
method=inline or *binary*

Downloads a program file from a PC to the Radio.

To download a file through the Ethernet port or across RF links you need to be running the Econsole program on a PC attached to a radio through the Ethernet port. In this case the program file must be in binary zipped format (with extension **.bze**). The *path/* in the source parameter is the PC directory where the file resides. The program file is transferred to the radio and is stored in memory under the name specified by the destination parameter. If the destination parameter is omitted, the file will be stored in Flash PROM with the same name as the source. Note that the ".bze" extension is required in the command. The download "method" must be "binary" (which is the default).

Example:

>**download C:\load\clh03_12.bze**

download the file clh03_12.bze from the PC directory C:\load into the unit file flash/clh03_12

If the download is executed from a terminal connected to the Auxiliary port, the file is in ASCII format and has the extension .dwe. The download method must be "inline". The source parameter is not needed since, after issuing the command, you must initiate the transfer of the file from the terminal.

Example:

>**download destination=clh03_12 method=inline**

After issuing the command initiate the file transfer using the terminal facilities.

The **set-default-file** parameter allows you to make this the default program to use after the radio is rebooted. It defaults to **no.**

run-file

filename=filename

Executes the specified file. The file is first copied into RAM and then the program is executed out of RAM. If the radio is rebooted or power cycled, the radio reverts back to the program defined as the default program. If the memory location is not defined (flash or tmp), the command assumes the flash directory.

Examples:

>**run clh03_04**

set-default-program

filename=filename

Sets the specified file as the default program to be loaded upon reboot or power cycle. Since the default program must reside in flash memory, the "flash/" prefix is assumed and is not required for the command.

Examples:

>**sdp clh03_04**

4.8 Event Logging Commands

The *pulsAR* radio keeps track of various significant events in an "event log". This event log holds up to 500 events. The first 100 entries in the log are filled sequentially after power up and are not overwritten. The remaining 400 entries consist of the last 400 events recorded. All events are time-tagged with system time.

Events are classified in different categories from level 0 (catastrophic error) to 7 (information).

clear-log

region= all-events or *reboot-reasons*

This command clears the contents of the system event log from the specified "region". After a code upgrade it is recommended to clear the reboot reasons since the pointer in non-volatile memory pointing to the reason message may no longer be valid.

display-log

region=end or *tail* or *beginning* or *all-events* or *reboot-reasons*
length=1..500
id=0..1000
min-level=0..7
max-level=0..7

This command outputs to the terminal the specified **region** of the event log. The **length** parameter specifies the number of events to output (defaults to 10). The remaining parameters provide filters to leave out specific events. If the **id** parameter is specified, only the event identified by that id will be displayed. The **min-level** and **max-level** settings allow the user to display only the events with the specified category range.

When the region is specified as **tail**, the command displays the last 10 events followed by a blank line, then waits for more events and displays then as they occur. You can press the space bar to exit this mode.

The **reboot-reasons** region of the event log consist of the last four events that that caused the gateway to reboot. These events are stored in non-volatile memory. The time tag in these events is the time the gateway was up since it was rebooted, not the time of day.

Examples:

>**display-log region=all**

>**display-log region=all length=300 min-level=2 max-level=6**

max-event

Sets the event severity level that should be saved or displayed. These two parameters are saved as part of the configuration

save=0..7

Only events of the specified level or below will be saved in the event log.

print=0..7

Events of the specified level or below will be output to the console port as they occur.

Examples:

>**max-event print=6**

4.9 Miscellaneous commands

date

The *pulsAR* radio will set the internal radio date and time automatically by decoding Network Time Protocol (NTP) packets in the Ethernet LAN. The "zone" parameter specified with the

"date" or "time" command will then be used to display the date/time in local time. The "zone" value is saved as part of the radio configuration.

If NTP packets are not available, the user can initialize the radio date and time with either the "date" or "time" commands. The parameters for both commands are identical, but the parameter order is different. The date command can be entered as:

> **date 16-may-2000   10:32:06**

date=day-month-year

Sets the date used by the radio. The day / month / year parameter may be separated by any valid separator ('-' '/' etc.)

time=hh:mm:ss

Sets the radio time in hours, minutes and seconds. Use colons to separate the three fields.

zone=zone-code or *offset*

Sets the time zone to be used by the radio to translate the NTP time to local time. It can be specified by an offset from GMT (-0800 or +0200 for example), or as a "zone-code". The valid "zone-codes" and the respective offsets are shown below:

Zone	zone code	offset
Pacific Standard Time	PST	-0800
Pacific Daylight Time	PDT	-0700
Mountain Standard Time	MST	-0700
Mountain Daylight Time	MDT	-0600
Central Standard Time	CST	-0600
Central Daylight Time	CDT	-0500
Eastern Standard Time	EST	-0500
Eastern Daylight Time	EDT	-0400
Greenwich Mean Time	GMT	0000

help [command-name]

If no command is specified, displays the complete list of commands. If a command is specified it displays the valid parameter and corresponding values for that specific command.

Examples:

> **>help monitor-link**

history

Displays the previous commands entered.

license

key=< ASCII string>

The "license" command is used to turn ON or OFF a set of optional features or capabilities. The key is a 35-character string combination of ASCII letters, numbers, and hyphens. The key must be input with the syntax as shown in the example below, including hyphens, for the radio to accept it. The characters can be input as upper or lower case.

After entering the key you must reboot the radio for the feature, enabled by the key, to take effect.

Each key is unique for a particular radio serial number and capability, i.e. a key generated to turn ON a capability on one serial number will not work on another radio.

Example:
>**license key=02EL1-ZGZ42-G0000-00C54-81WAJ-C9BEK**

logout

Closes the current Econsole session.

reboot

Resets the radio causing the software to perform a complete start up sequence. This is equivalent to power cycling the radio off and on.

time

time=hh:mm:ss
date=day-month-year
zone=zone-code or offset

This command is identical to the "date" command explained above except for the order of the parameters. It allows the time and date to be entered as:

> **time 10:32:06 16-may-2000**

version

Displays the radio model and software version.

5   <u>NETWORK MANAGEMENT</u>

The radios operate as part of a network environment with many devices. Whether operated by an Internet Service Provider (ISP) or the Information Technology (IT) department of a business, there is often a need to supervise and manage the network from a central Network Operations Center (NOC). This chapter describes the features of the *pulsAR* radio that are useful for this purpose

5.1 Telnet

5.1.1   <u>General</u>

Telnet, which stands for Telecommunications Network, is a protocol that allows an operator to connect to a remote machine giving it commands interactively. Once a telnet session is in progress, the local machine becomes transparent to the user, it simply simulates a terminal as if there was a direct connection to the remote machine. Commands typed by the user are transmitted to the remote machine and the responses from the remote machine are displayed in the telnet simulated terminal.

5.1.2   <u>Starting a Telnet Session</u>

In order to start a telnet session with a radio you first need to configure the radio with a unique valid IP address. This is done with the ***ip-configuration*** command described in section 4. This initial configuration must be done using either the RS-232 console port or the ECON program.

Once the radio has an IP address, you must start the telnet application at the local machine and establish a connection with the IP address of the radio. If the local machine is a PC running Windows, you can start Telnet through Hyperterminal as follows:

1. Start the Hyperterminal application (in a typical Windows installation Hyperterminal can be found from the **Start** button under Programs/Accessories/Communications…)

2. From the **File** menu choose **New Connection**.

3. In the **Name** field enter any name you wish and press the OK button. This will open the "Connect To" window.

4. In the last field, titled "**Connect using**:", select **TCP/IP (Winsock)**. The fields above will change to **Host Address:** and **Port Number:**.

5. In the **Host Address** field, type the IP address of the radio, then press the OK button.

6. TCP will now attempt to connect to the specified device. If successful the radio will request a login name with the prompt **login:**

7. Type ***public*** followed by the Enter key

The radio will now display its prompt command and you may type any commands as described in section 4.

If after entering the ***public*** login name, the terminal displays the message "Login Failed", this may be due to the radio being configured to be managed from only some specific IP addresses. This is explained in the following section.

5.1.3   Telnet Security

The remote management capability through Telnet opens the possibility for an unauthorized user to login to any radio accessible through the Internet. The radio configuration can be password protected with the use of the **lock** and **unlock** commands. If further security is desired you can specify up to four source IP addresses that are authorized to initiate Telnet sessions with the radio. When configured in this way, the radio will reject Telnet requests from all IP addresses that are not in the authorized list.

The authorized source IP addresses for Telnet are the same addresses that are authorized to perform SNMP management. They are entered using the ***snmp*** command described in section 4 and can be viewed with the ***display-configuration*** command. When this list is empty, you can initiate a Telnet session from any IP address with the login name ***public.*** When this list is not empty, Telnet sessions can only be initiated from the listed hosts. Additionally, for each host, the login name must match the string listed for the ***community*** field.

If you wish to use this security feature you need to know the IP address of the local machine. On a PC running Windows, one way to find its IP address is to open a DOS window and issue the command:

>ipconfig

5.2 SNMP

5.2.1   Command Line Interface Versus SNMP

Configuration settings on the *pulsAR* radio are displayed and modified using a command line interface, which can be accessed using either the RS-232 console port, the ECONSOLE program, or via a TELNET session.

In a NOC environment, there is a need for an automated monitoring system to collect on an ongoing basis information from devices in the network for three purposes:

1) to build an inventory of all the devices of the network

2) to keep track of all devices on the network and raise alarms when any device becomes unreachable (device failed, link down, etc)

3) to maintain statistics on traffic levels in order to implement usage-based charging, or to determine where congestion exists in the network, so that the network can be expanded to accommodate growth

Command line interfaces are not very suitable for these purposes, and the *pulsAR* radio supports the Simple Network Management Protocol (SNMP) to assist in these tasks. SNMP is a simple, transaction-based (command/response) protocol, which allows a variety of third-party software products to query network devices and collect data for these purposes.

For a generic introduction to the SNMP protocol, we recommend the book "The Simple Book - An Introduction to Internet Management" by Marshall T Rose (P T R Prentice-Hall, 1994).

5.2.2   What is SNMP?

The SNMP protocol is described in the following documents:

- RFC1157 - Simple Network Management Protocol (SNMP) - ftp://ftp.isi.edu/in-notes/rfc1157.txt

- RFC1155 - Structure and identification of management information for TCP/IP-based internets - ftp://ftp.isi.edu/in-notes/rfc1155.txt

- RFC1213 - Management Information Base for Network Management of TCP/IP-based internets: MIB-II - ftp://ftp.isi.edu/in-notes/rfc1213.txt

SNMP is a specification for the interaction (*protocol*) between the **SNMP agent** embedded in a network device, and the **SNMP manager** software running on another machine in the network.

The data provided by the SNMP agent in a network device is described by a document called the MIB (Management Information Base). **MIB-II** describes the basic information provided by all devices, and additional documents describe optional extensions for components that may not exist in most devices.

Devices may also provide non-standard MIB groups. In order for a network management system to make use of these extended features, the MIB description must be obtained from the device manufacturer and loaded into the management station.

SNMP data travels in IP packets, using the UDP port 161 for the agent, so in order to use SNMP, the device must have an IP address.

5.2.3   Security Considerations in SNMP

SNMP was designed before the Internet grew commercial, and the original design was not secure. Later versions intended to provide security, but grew cumbersome and complex. As a result, most devices provide secure operation in a non-standard way.

The original SNMP design as embedded in the protocol, assigns network devices to named communities. Any transactions exchanged between the agent and the manager include the name of the community to which they both belong. The agent has a list of which access rights (set, get, trap) it will grant for each community of which it is a member.

In the *pulsAR* radio, this has been re-interpreted: The radio has a list of up to 4 management stations from which it will accept requests, and for each one - identified by its IP address - it is indicated what access rights it is granted, and which community string it must use. Requests from all other sources are ignored. Refer to the **snmp** command in section 4 for details on how to configure the radio for management using SNMP..

If no management stations are listed, **get**-requests with the community **public** will be accepted and responded to from any IP address.

5.2.4   Examples of Network Management Systems

Some of the most common network management systems are listed below. All of them provide many similar features, including network status displays showing key devices on a map, where the devices

change color if they have alarms, and with provisions for activating a remote paging device if there is a problem.

WhatsUp Gold (Ipswitch Inc)
    http://www.ipswitch.com/

    USD 800 (approx)

SNMPc (Castle Rock Computing, Inc)
    http://www.castlerock.com/

    USD 900 to USD 2700 (approx, depending on options)

OpenView (Hewlett-Packard)
    http://www.openview.hp.com/

    USD 3,000 to USD 10,000

    The OpenView product line has been revamped; HP is now positioning it not as a turnkey software product, but as a custom adapted application to be bought through a value-added implementation partner.

Multi-Router Traffic Graphing
    http://www.mrtg.org/

    This is a free, open-source software, capacity planning tool.

5.2.5   *pulsAR* radio Management Information Base (MIB)

The *pulsAR* radio implements only the core MIB-II. A management station will see three interfaces in the **interfaces group**:

1 - Bridge

2 - Ethernet

3 - Radio

The first of these represents the attachment of the SNMP agent to the bridged network. Only IP traffic seen by the embedded host is counted.

The ethernet device (**ifIndex=2**) represents the traffic passing through the radio's ethernet port. This is what should be tracked by MRTG.

The third device represents the wireless transceiver. If will appear as **down** if the radio does not have a working link to its peer. This is useful for confirming the loss of a link. The traffic counts show all packets to and from the radio, including handshaking between the two radios radios.

5.3 UDP Command and Data Interface

5.3.1   Purpose

The *pulsAR* radio firmware includes an optional command/data interface based on the UDP/IP protocol. This interface can be used for two purposes:

1. As a command interface allowing radio text commands and replies to be encapsulated in UDP/IP packets. This is useful when you want to configure the radio from a program running on an external computer

2. To send and receive **vital packets** which the radio classifies as the highest priority.

With the UDP Command Interface a host computer can issue all the same text commands available through the other interfaces and described in the radio Operator's Manual. The command text, in ASCII, must be encapsulated in an UDP/IP packet addressed to the radio. The radio replies to every command with text also encapsulated in an UDP/IP packet. This reply packet can be addressed to a pre-configured IP address or to the device that generated the command. See the **udp-configuration** command in section 4 for the options to configure this udp interface.

5.3.2   UDP Command Packet formats

Table 5.1 below shows the structure of the UDP command and reply packets. The host computer always initiates the command, and the radios reply to every command. The command sequence number field, in the reply, "echoes" the contents of the sequence number field in the command.

If the socket-mode is set to 2, the radio issues an "unsolicited reply" message on power up to the configured peer-address. This can be used to alert a host that the radio just rebooted. The command sequence number in this power up unsolicited reply is always zero.

The command and reply text is in ASCII. Refer to section 4 for a complete list of all valid commands. Prior to using the UDP interface you must initialize the radio IP and the UDP configuration (using commands **ip-configuration** and **udp-configuration**) through either the RS-232 console or the Ethernet Econsole ports.

Table 5.1. UDP Command / Reply Packet Format

Bytes	Host to Radio (Command)	Radio to Host (reply)	
0-5	Dest MAC address	Dest MAC address	Ethernet Encapsulation
6-11	Src MAC address	Src MAC address	
12-13	0x0800	0x0800	
14-33	IP header	IP header	UDP/IP encapsulation
34-35	Src port (any)	Src port: radio UDP cmd port	
36-37	Dest port: radio UDP cmd port	Dest port: UDP peer cmd port	RFC-768 (UDP) RFC-760 (IP).
38-39	Length of UDP payload (6-500)	Length of UDP payload (6-500)	
40-41	Checksum	Checksum	
42-45	Command Sequence number	Command Sequence number	Payload
46-47	Pad (all zeroes)	Reply code	
48-	Command text	Reply text	

The values of the "reply code" field are shown in the following table.

Table 5.2. Reply Code Field

Code	Mnemonic	Description
0	CMD_SUCCESS	Command executed successfully
1	CMD_RESTART	Unsolicited reply at startup. A **start** command must be given.
2	CMD_TRUNCATED	Response text overflow (truncated if over the value specified by max-response-bytes)
3	CMD_NOT_FOUND	Unknown Command
4	CMD_AMBIGUOUS	Ambiguous abbreviation
5	CMD_BAD_ARG_NAME	Illegal or ambiguous argument name
6	CMD_BAD_ARG_VALUE	Argument value out of range
7	CMD_ARG_MISSING	Required argument missing
8	CMD_FAILED	Command failed
9	CMD_DISABLED	A **start** command must be given

.

6   RF LINK DESIGN

6.1 Antenna Selection

The *pulsAR* radio comes equipped with two antenna ports to connect to external antennas. The two ports are typically used with the Mesh/Tree network topology described in section 2. Afar carries the following antennas which cover the needs of most typical applications.

Band	Antenna Type	Gain	AFAR Model Number
900 MHz	Omni-directional	5 dBi	ATO-0905
	Yagi	9 dBi	ATD-0909
	Dish Reflector	15 dBi	ATD-0915
2.4 GHz	Omni-directional	9 dBi	ATO-2409
	Panel	16 dBi	ATD-2416
	Panel	19 dBi	ATD-2419
	Dish Reflector	24 dBi	ATD-2424

The "gain" of the antenna is a measurement of how much it focuses its radiated energy in a specific direction or plane. An "omni-directional" antenna for example radiates its energy over 360 degrees in the horizontal plane but has a much poorer radiation in the vertical plane. In most applications you don't need to radiate vertically (into the sky or into the ground) so by focusing the energy in the horizontal plane you achieve a reasonable gain.

Omni-directional antennas are a good choice for a hub radio in a point-to-multipoint application when the remote radios are all around. If the remote radios happen to be all located in one particular "sector" when viewed from the hub location then you can use a "sectorial" antenna that focuses the energy in that general direction. There are antennas that cover sectors with different angles, for example, 30, 60, 90 and 120 degrees. The narrower the angle the higher the gain of the sectorial antenna.

At fixed remote radios, or in a point-to-point link, you should select high gain directional antennas that focus all the radiated energy in one specific direction. These antennas not only provide a much higher gain and therefore increased radio ranges and link margins, but also protect your link from unwanted interference coming from other directions.

In mobile applications you typically need omni-directional antennas on the moving vehicle so that the vehicle can change its orientation and stay connected to say, a fixed hub.

6.1.1   Antenna Polarization

The electro-magnetic waves radiated from an antenna are typically "polarized" meaning that the waves are constrained to oscillate in one specific direction. The most common polarizations are vertical (the waves oscillate up and down) or horizontal (right and left).

Note that this polarization is independent of the direction of wave propagation. For example the omni-directional antennas described above radiate the energy along the horizontal plane (waves propagate preferentially in that plane) but the oscillation of the electro-magnetic field can still be either vertical or horizontal (polarization).

In the case of directional antennas (yagis, panels, or parabolic reflectors), you can mount the antenna with either vertical or horizontal polarization by simply rotating the complete antenna assembly by 90 degrees. Most omni-directional antennas on the other hand consist of a vertical radiating element that can only be mounted for vertical polarization (although, as mentioned above, you can get omni-directional antennas with horizontal polarization).

It is essential that the two antennas at both ends of one RF link have the same polarization. Differences in polarization among antennas – called "cross-polarization" – will reduce the signal strength considerably.

The choice of polarization – horizontal vs. vertical – is in many cases arbitrary. However, interfering signals from such devices as cellular phones and pagers are generally polarized vertically, and an excellent means of reducing their effect is to mount your system antennas for horizontal polarization.

6.2 RF Path Analysis

6.2.1   Line-of-Sight Requirements

At UHF and microwave frequencies, when you deploy an RF link between two distant sites you need to make sure you have "line of sight" between the two antennas. But at these frequencies "line of sight" does not simply mean that from one site you can "see" the other.

For short ranges, a degree of obstruction may be acceptable. The radio has some ability to "penetrate" trees and other foliage, specially the 900 MHz models. On the other hand, geographical features (hills) and large buildings are likely to interfere with communications, and antennas should be elevated to see each other above such objects.

For links covering very long distances (exceeding 5 miles or 8 km) you also need to take into account the following factors:

- The curvature of the earth.

- Fresnel Zone clearance.

- Atmospheric refraction.

Figure 6.1 illustrates these concepts with an exaggerated representation of a long link. The following sections describe these effects. You can use our free "Fresnel Zone Calculator", shown in figure 6.2, to make all the computations for the RF path analysis and determine if you have adequate antenna height for your links. The calculator is available on our website at http://www.afar.net/fresnel-zone-calculator/
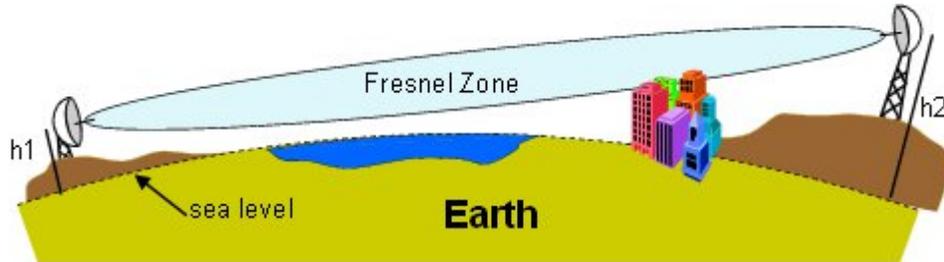
Figure 6.1 – Earth curvature, Fresnel Zone and antenna heights

6.2.2   Earth curvature

With long links the earth curvature can prevent the two antennas from seeing each other. This is illustrated in tables 6.2 and 6.3, which show the minimum antenna heights required, at both ends of the link, to simply clear the earth surface at various distances. As the distance grows the effect worsens requiring you to have access to high elevation points to deploy such links. The values in the table used a typical atmospheric refraction factor of 4/3 (see below).

Fresnel Zone Clearance and Antenna Height Calculator

Units:
- ⦿ miles, feet
- ○ km, metres

Input

Frequency: 2440 MHz

Atmospheric Refraction:

k factor: 1.33
(typical 1.33)

Percent of 1st FZ: 60 %
(typical 60%)

Link Distance: 20 miles

Antenna Heights:
Site 1: 140 ft

Site 2: 100 ft

At an Arbitrary Point P:
Distance from site 1: 5 miles

Distance from site 2: 15 miles

Height of obstruction: 0 ft

Output

Equivalent Earth radius: 5265 miles

Equal Antenna Height Solution:
Radius of 60% 1st FZ
at mid point: 61.8 ft

Height of both antennas
for FZ clearance: 112.0 ft

Minimum Clearance Point:
Distance from site 1: 11.2 miles

Clearance between Earth
and FZ: 7 ft

Clearance at Point P:
Radius of 60% 1st FZ: 53.5 ft

Clearance between obstruction
and FZ: 39 ft

Figure 6.2– Fresnel Zone Calculator

6.2.3   Fresnel Zone

The Fresnel zone is a long ellipsoid that stretches between the two antennas. The **first** Fresnel zone is such that the difference between the direct path (AB) and an indirect path that touches a single point on the border of the Fresnel zone (ACB) is half the wavelength (see figure 6.3).
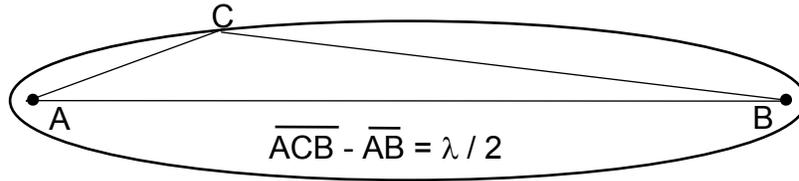
Figure 6.3– Fresnel Zone Definition

If a significant portion of the Fresnel Zone is obstructed the receive-signal-strength at the receiving antenna can be significantly attenuated. A rule of thumb is that you need at least 60% of the first Fresnel Zone clear of any obstructions in order for the radio wave propagation to behave as if it is in "free space".

Even though at 2.4 GHz half of the wavelength is only 2.4 inches (6.2 cm), at long distances the radius of this ellipsoid can be quite large. This is illustrated in tables 6.2 and 6.3, which show the radius of this (60%) ellipsoid at the mid-point for various distances.

Table 6.2 – Antenna heights (meters) to clear the earth and 60% of the Fresnel Zone (2.4 GHz)

Distance (km):	5	10	20	30	40	50	60	70
Antenna height to clear earth (meters):	0.4	1.5	6	13	24	37	53	72
60% Fresnel Zone radius at mid-point (meters):	7.5	10	15	18	21	23	26	28
Total antenna height required (meters):	7.9	12	21	31	45	60	79	100

Table 6.3 – Antenna heights (feet) to clear the earth and 60% of the Fresnel Zone (2.4 GHz)

Distance (miles)	5	10	20	30	40	50
Antenna height to clear earth (ft)	3	12	50	113	200	313
60% Fresnel Zone radius at mid-point (ft)	31	44	62	76	87	98
Total antenna height required (ft)	34	56	112	189	287	412

6.2.4   Atmospheric Refraction

Under normal atmospheric conditions radio waves do not propagate in a straight line, they actually bend slightly downward. This is due to "refraction" in the atmosphere that affects radio waves propagating horizontally. To take this downward bending into account, we perform all the RF path calculations using a larger value for the earth radius, such that we can then consider the radio waves as propagating in a straight line.

In the Fresnel Zone calculator you can change the earth radius multiplying factor (the "k factor") to take into account different atmospheric conditions. Under normal conditions the "k factor" is 4/3. However unusual weather conditions can cause significant changes to the refraction profile. For a high reliability link you may want to use a lower value for the k factor.

6.2.5   Clearing Obstructions

The calculator allows you to quickly determine whether you have enough clearance above a particular obstruction in the RF path, or alternatively, how high you need to elevate your antennas to clear the obstruction.

For each potential obstruction in the path you need to know its distance from one of your end points and the height of the obstruction. Drawing the path in "Google Earth" is a quick way of identifying buildings or structures that lay in the direct path and finding their distance from the end points. You may need to use a topographic map, draw the line between the end points, and create an accurate terrain profile. If there are buildings or trees in the path you need to determine or estimate their height and add it to the terrain elevation at those points.

For each of these potential obstruction points, enter its distance from site 1 and the height of the obstruction above sea level in the bottom left input "spinners" of the calculator.   On the right hand side the calculator displays the vertical separation between the top of the obstruction and the bottom of the Fresnel Zone. If this value is negative you can use the antenna height spinners to increase the height of one or both antennas until that clearance becomes greater than zero.

6.3 RF Link Budget Calculations

If you have radio-line-of-sight for your link (as explained in the previous section), then it is easy to compute the receive-signal-strength at the receiving radio and from there determine if you have an adequate "fade margin".

You can use our free "RF Link Budget Calculator", shown in figure 6.4, to make all the required computations and evaluate the trade-off between antenna gains, cable losses etc. The calculator is available on our website at *http://www.afar.net/rf-link-budget-calculator/*

RF Link Budget Calculator

Input

Frequency:	2440	MHz
Tx Power:	23	dBm
Tx Cable Loss:	0.4	dB
Tx Antenna Gain:	9	dBi
Distance:	12.2	miles
Rcv Antenna Gain:	24	dBi
Rcv Cable Loss:	0.9	dB
Rcv Sensitivity:	-90	dBm
Fade Margin:	19	dB

Compute:
- ⦿ Fade Margin
- ◯ Distance
- ◯ Tx Power

Units:
- ⦿ miles
- ◯ km

Output

Fade Margin: **18.6 dB**

Free Space Loss: 126.1 dB

Rcv Signal Strength: -71.4 dBm

Cable Loss Calculator

Input

Cable Type:	LMR 400	
Loss per 100 ft: (at 2440 MHz)	6.7	dB
Cable Length:	3	ft
No. of connectors:	1	

Total Cable Loss: **0.4 dB**

Apply to:

[Tx Cable] [Rcv Cable]

Figure 6.4 - RF Link Budget Calculator

Even though your link is bi-directional, in the calculator Site 1 is viewed as the transmitter and Site 2 as the receiver. If you configure both radios with the same transmit power the results for both directions are identical. If you configure the transmit power of the two radios to different values you should compute the link budget in each direction separately.

The RF link budget calculations are made a lot easier by using "deciBel" units (dB). The deciBel is a logarithmic scale that compares a parameter value against a specific reference. The advantage of working in dB is that you can simply add all the parameters that boost your signal and subtract the ones that attenuate it.

The following paragraphs follow an RF signal from the transmit radio to the receive radio, explaining the various parameters and how they apply to the *pulsAR* radio

Transmit Power

The RF signal starts at the output of the radio at Site 1 with a specific transmit power. In the *pulsAR* radio you can configure that power from 0 to 23 dBm (the "m" in the dBm unit indicates that this power is measured relative to 1 milliwatt).

Cable Losses

The radio is connected to the antenna through an RF coaxial cable. As the signal propagates through this cable it is attenuated. The total attenuation (loss) depends on the frequency, cable type, cable length and number of connectors. You can use the "Cable Loss Calculator" (at the bottom of the RF Link Budget calculator), which includes the characteristics for several RF cable types. If your cable is not listed you can also enter its "loss per 100 ft" (or loss per meter) at 2.4 GHz and the calculator computes the total loss. Note that each connector along the way introduces additional attenuation, typically around 0.2 dB per connection.

The p*ulsAR* radio is housed in a watertight enclosure so that you can mount it in very close proximity to the antenna. That way you can keep the RF coaxial cable very short and therefore reduce these losses.

Antenna Gain

The transmit signal is radiated through the antenna at Site 1. The antenna focuses the radiated energy in a specific direction or plane, boosting your signal strength in that specific direction. That boost is measured by the "antenna gain" in dBi (the "i" in the dBi unit indicates that the antenna gain is measured in relation to an **i**sotropic radiating element).

Distance and Free Space Loss

Once the signal is in the air it propagates towards the receiver but suffers attenuation as it radiates away from the transmitter. If there are no obstructions the total attenuation is called the Free-Space-Loss (FSL). This loss is a function of the frequency, f, and the distance, d. It can be computed, in dB, from the following expressions:

$$FSL = 32.4 + 20 \log \mathbf{f} + 20 \log \mathbf{d} \quad \text{(with } \mathbf{f} \text{ in MHz and } \mathbf{d} \text{ in km)}$$

or

$$FSL = 36.6 + 20 \log \mathbf{f} + 20 \log \mathbf{d} \quad \text{(with } \mathbf{f} \text{ in MHz and } \mathbf{d} \text{ in miles)}$$

The calculator computes this loss for you and displays it in the output panel. An easy rule to remember is that the free space loss increases by 6 dB every time you double the distance.

Receive Signal Strength

The signal is much weakened when it reaches the receiving antenna.   That antenna will give it a boost, measured by the antenna gain in dBi. The signal is then attenuated as it propagates down the RF coaxial cable that connects that antenna to the radio. The Receive Signal Strength (RSS) parameter refers to the strength of the signal that finally arrives at the RF connector of the receiving radio at site 2. With all the gains and losses measured in dB, this receive signal strength is computed with the following expression:

$$RSS = TxPower - CableLoss1 + AntGain1 - FSL + AntGain2 - CableLoss2$$

The RF Link Budget calculator always computes and displays this value in the output panel.

Receive Sensitivity

The radio Receiver Sensitivity is the receive-signal-strength at the input of the radio at which point its "Bit Error Rate (BER)" is at a specified value. Most manufacturers, including Afar, use a BER of $1x10^{-6}$ (1 bit error in one million bits) to specify the radio receiver sensitivity. However make sure you check the specifications when comparing the sensitivity in radios from different manufacturers.

You can configure the *pulsAR* radio to operate at four different RF speeds. Lower speeds give you a better receiver sensitivity. Appendix B lists the sensitivity for the various models and at the different RF speeds. Use the correct sensitivity value from the radio specification

Fade Margin

The Fade Margin is the difference between the Received Signal Strength and the radio Receiver Sensitivity. When you deploy a link you want to have a Receive Signal Strength that is sufficiently above the radio Receiver Sensitivity in order to survive signal fading due to a variety of factors. These factors might include slight misalignment of the antennas, losses due to fog and rain, etc. As a rule of thumb you should try to get at least 15 dB of fade margin in your links.

With the calculator you can select whether to compute the Distance, the Fade Margin or the Transmit Power. All these parameters are inter-related as described above. When you select one parameter to compute, its value in the input panel is disabled.

All the input values are controlled with "spinners". As you change any input the calculator instantly updates the output values. By seeing the results immediately you can quickly evaluate trade-offs between different parameters.

APPENDIX A – Command Summary

This appendix lists all commands organized in the respective functional groups. Parameters that are part of the radio configuration are identified by having an entry under the "Factory Configuration" heading.   When entering a command, if a parameter that is part of the radio configuration is omitted, the value for that parameter is not modified.

For commands that are not part of the radio configuration, if a parameter is omitted, the value for that parameter defaults to the value indicated in bold.

Configuration Management Commands

Command	Parameters	Values
change-password	enable-configuration	<string>
display-configuration	source	**current** main alternate basic factory
load-configuration	source	**main** alternate basic factory
lock		
save-configuration	destination	**main** alternate
unlock	enable-configuration	<string>

Major Configuration Parameters

Command	Parameters	Values	Factory Configuration
distance-max	maximum	10..120	80
	units	km or miles	km
encryption	mode	off, des-56, 3-des-112, aes-128, aes-256	off
	key	(hexadecimal)	
	key-phrase	ascii string	
ethernet	speed	auto-10, 10hdx, 10fdx 100hdx, 100fdx, auto, off	auto
	station-timeout-sec	5..10000	30
	multi-cast-timeout-sec	5..10000	30
	block-remote-brodcast	On, off	off
	vlan-mode	reply-same, strip	reply-same
node	type	master-hub, hub, remote	remote
	max-remotes	1..29	29
	redundancy	1..4	2
	name	(23 character string)	rmt-nnnnn
	network-id	0..65535	0
	cluster-id	1..16	1
	min-cluster-size	0..32	0
	location	(25 character string)	
	contact	(25 character string)	
rf-receive-setup	channel	min..max (appx C)	12
	antenna	a, b	a
	disconnect	0, 1 (default)	
	forward-all-packets	0, 1	0
rf-transmit-setup	channel	min..max (appx C)	12
	antenna	a, b	a
	speed-mbps	[speeds] (appx B)	2.75
	power-dbm	0..27	18

Command	Parameters	Values	Factory Configuration
single-node-reboot	timeout-sec	0, 15..60000	900
time-division-duplex	cycle-period-ms	20, 40, 60, 80	40
	transmit-percent	auto, 20, 30, 40, 50, 60, 70, 80	auto

Internet Protocol (IP) Management Commands

Command	Parameters	Values	Factory Configuration
ip-configuration	address	ip address	
	netmask	ip address	
	gateway	ip address	
	dhcp-client	off, on, local-only, radio-only	off
ping	destination	ip address	
	count	0..500 (def **4**)	
	size-bytes	32..1472	
snmp	manager	ip address	
	community	ASCII string (9 max)	
	access	g, gs, gt, gst	
	authentication-traps	0, 1	
	delete	1..4	
udp-configuration	console	on, off	off
	vital-port-1	1..0xFFFF	0
	vital-port-2	1..0xFFFF	0
	command-port	1..0xFFFF	422
	max-response-bytes	400..65521	512
	socket-mode	1, 2	1
	peer-address	ip address	
	peer-command-port	1..0xFFFF	0

Installation and Link Monitoring Commands

Command	Parameters	Values	Factory Configuration
antenna-alignment-aid	mode	off, a-antenna, b-antenna	off
monitor-coverage	clear	**0**, 1	
monitor-ethernet	header	0, **1**	
	line-feed	**0**, 1	
monitor-flow			
monitor-link	node	0,**3**,4,5…	
	clear	**0**, 1	
	header	0, **1**	
	line-feed	**0**, 1	
show-tables	table	**status,** radios, clusters, sync-delays, ethernet, econsole ip-stack, properties	
	format	**count** times	
spectrum-analysis	antenna	**a** b	
	display	**graph** table	
	dwell-time-ms	1…1000 (def: **20**)	
	post-scan-wait-ms	500..10000(def: 2000)	
time-analysis	channel	0..50	
	antenna	**a** b	
	display	**graph** table	
	dwell-time-ms	1, 2, 5, 10, **20**, 50, 100, 200, 500	
	post-scan-wait-ms	500..10000(def: 2000)	

File Utilities

Command	Parameters	Values
console-speed-bps	baud-rate-bps	9600, 19200, 38400 57600, 115200
copy-file	source	filename
	destination	filename
delete-file	filename	filename
directory	format	**short** full
download-file	source	path/filename
	destination	path/filename
	method	binary inline
run-file	filename	filename
set-default-program	filename	filename

Event Logging Commands

Command	Parameters	Values	Factory Configuration
clear-log	region	**all-events** reboot-reasons	
display-log	region	**end** tail beginning all-events reboot-reasons	
	length	1..500 (def **10**)	
	id	0…200	
	min-level	0…7 (def: **0**)	
	max-level	0…7 (def: **7**)	
max-event	save	0..7	5
	print	0..7	3

Miscellaneous Commands

Command	Parameters	Values	Factory Configuration
date	date	dd-mmm-yyyy	
	time	hh:mm:ss	
	zone	offset or code	GMT
help	command		
history			
license	key	<35 character string>	
logout			
reboot			
time	time	hh:mm:ss	
	date	dd-mmm-yyyy	
	zone	offset or code	GMT
version			

APPENDIX B – Specifications

RF Specifications	AR-9010E	AR-9027E	AR-24010E	AR-24027E	AR-24110E
RF Frequency Band (MHz)	902 to 928	902 to 928	2400 to 2483	2400 to 2483	2400 to 2483
Signal Bandwidth (-20 dBc)	1.6 MHz	4.6 MHz	1.6 MHz	4.6 MHz	17 MHz
RF Channels (non-overlap):	13	4	35	11	4
Transmitter Output Power:	0 to 27 dBm	0 to 27 dBm	0 to 27 dBm	0 to 27 dBm	0 to 27 dBm
Receiver Sensitivity (10^{-6} BER) and Data Rates	(dBm) (kbps) -103 @ 100 -100 @ 200 -98 @ 550 -95 @ 1100	(dBm) (kbps) -100 @ 250 -97 @ 500 -95 @ 1375 -92 @ 2750	(dBm) (kbps) -100 @ 100 -97 @ 200 -95 @ 550 -92 @ 1100	(dBm) (kbps) -98 @ 250 -95 @ 500 -93 @ 1375 -90 @ 2750	(dBm) (kbps) -94 @ 1000 -91 @ 2000 -89 @ 5500 -86 @ 11000
Maximum Receive Signal	-30 dBm (to stay in receiver linear region) +20 dBm (to avoid damage)				
Modulation Type	direct sequence spread spectrum				
Ethernet Port					
Speed	10/100 BaseT, full/half duplex, auto-negotiate				
Connector	8 pin circular (Lumberg 0321-08) - RJ45 at the power inserter				
Networked Operation					
Network topologies	Point-to-point, point-to-multipoint, Mesh/Tree, Linear Network, Roaming				
Management	Telnet, SNMP (MIB2), or Econsole reach any node over wireless				
Security	Optional 3-DES or AES encryption, 32 bit network ID / password.				
Console / Diagnostic Port					
Interface	RS-232/V.24, asynchronous 9600 to 115 kbaud				
Connector	3 pin circular (Lumberg 0321-03) - cable adapter to DB9 available				
Power					
Input Voltage	DC: Power over Ethernet (IEEE 802.3af) or +10 to +58 VDC AC: 110 to 220 VAC (with external power inserter)				
Power Consumption	Idle (link up with little or no data): 1.5 W Rx: 2.8 W Tx: 5.0 to 7.5 W (depending on tx power)				
Transient Max. Peak Power	1500W (with 10/1000 us waveform)				
Transient Max. Peak Current	35 A (with 10/1000 us waveform as defined by R.E.A.)				
Environmental					
Temperature	-40 to +70 deg C (-40 to +158 deg F)				
Humidity	Up to 95% non-condensing				
Dust & water protection	IP66 per international standard IEC 60529				
Mechanical					
Dimensions	4.72" wide x 8.66" high x 2.20" deep (120mm W x 220 H x 56 D)				
Weight	3.4 lbs. (1.5 kg).				

APPENDIX C – Channel Frequencies

900 MHz Models:

The center frequency of each channel can be determined by the following expression:

Freq(MHz) = 900 + Channel_number:

The following tables show all the channel frequencies, channel ranges for each model, and suggested assignments to get wide separation between channels.

Chan	Freq (MHz)	Chan	Freq (MHz)	Chan	Freq (MHz)
1		11	911	21	921
2		12	912	22	922
3	903	13	913	23	923
4	904	14	914	24	924
5	905	15	915	25	925
6	906	16	916	26	926
7	907	17	917	27	927
8	908	18	918	28	
9	909	19	919	29	
10	910	20	920	30	

	AR-9010E	AR-9027E
Channel ranges	3..27	5..25

Model	Number of Non-Overlapping Channels	Suggested Channel Allocation	Frequency Separation (MHz)
AR9010E	13	3, 5, 7, 9, 11, 13, 15, 17, 19, 21, 23, 25,27	2.0
	9	3, 6, 9, 12, 15, 18, 21, 24, 27	3.0
	7	3, 7, 11, 15, 19, 23, 27	4.0
	5	5, 10, 15, 20, 25	5.0
AR9027E	4	6, 12, 18, 24	6.0

2.4 GHz Models:

The center frequency of each channel can be determined by the following expression:

Freq(MHz) = 2400 + 2 x Channel_number:

The following tables show all the channel frequencies, channel ranges for each model, and suggested assignments to get wide separation between channels.:

Chan	Freq (GHz)	Chan	Freq (GHz)	Chan	Freq (GHz)	Chan	Freq (GHz)
1	2.402	11	2.422	21	2.442	31	2.462
2	2.404	12	2.424	22	2.444	32	2.464
3	2.406	13	2.426	23	2.446	33	2.466
4	2.408	14	2.428	24	2.448	34	2.468
5	2.410	15	2.430	25	2.450	35	2.470
6	2.412	16	2.432	26	2.452	36	2.472
7	2.414	17	2.434	27	2.454	37	2.474
8	2.416	18	2.436	28	2.456	38	2.476
9	2.418	19	2.438	29	2.458	39	2.478
10	2.420	20	2.440	30	2.460	40	2.480

	AR-24010E	AR-24027E	AR-24110E
Channel ranges	1..40	2..39	5..35

Model	Number of Non-Overlapping Channels	Suggested Channel Allocation	Frequency Separation (MHz)
AR24010E or AR24027E	13	3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36, 39	6.0
	10	2, 6, 10, 14, 18, 22, 26, 30, 34, 38	8.0
	8	3, 8, 13, 18, 23, 28, 33, 38	10.0
AR24110E	4	5, 15, 25, 35	20
	3	5, 20, 35	30

Adjacent channel interference:

Note that under some conditions a radio transmission in a specific channel may create interference to a nearby radio trying to receive in a neighboring channel that is labeled, in the tables above, as "non-overlapping".

When a radio transmits at high power there is a certain amount of energy that "spills over" into adjacent channels. This is an effect called "side lobe regrowth" illustrated in the spectrum image below. The image shows the spectrum created by the AR-24027E radio model transmitting at the maximum power level of 27 dBm.

The main lobe bandwidth (null to null) is 5.5 MHz. The first sidelobe (one on each side) is centered at approximately 3.8 MHz away from the main lobe. At a transmit power of 27 dBm the amplitude of this sidelobe may be around -35 dB below the main lobe. The second sidelobe is centered at about 6.3 MHz away from the main lobe and is around -40 dB below the main lobe.

The picture also shows the receiver filter of a radio tuned to a channel 6 MHz away from the transmitter. As the picture shows the first and second sidelobes fall within the receiver bandwidth. If the two radios are nearby such that the energy in these sidelobes, as seen by the receiving radio, is higher than the energy of the signal that this second radio is trying to receive, you get interference.

You can take the following steps to minimize this effect:

1. Create a channel plan that does not allocate adjacent channels for radios that operate nearby. The example above is for a channel separation of 6 MHz. This effect is reduced if the channels were 8 MHz apart and essentially disappears if 10 MHz apart.

2. Use lower transmit power levels. The sidelobe regrowth effect increases with transmit power. At a transmit power level below 18 dBm there are essentially no sidelobes.

3. Synchronize the adjacent radios. In the cluster-hub architecture radios within a cluster use TDMA and do not create the effect above. But it can happen in a multi-cluster environment in the overlapping area between two clusters. Using the multi-cluster synchronization explained in section 2.3 could overcome this issue.
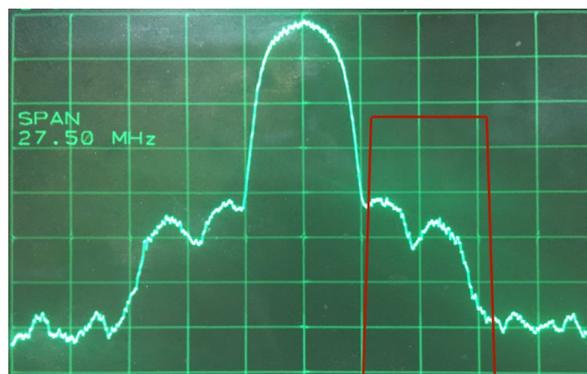
APPENDIX D – Cable Diagrams

The next two pages show the assembly drawings for the cables used to connect the Radio to a Power Inserter Unit (CAT5), and a Console cable for connection to a standard computer terminal used for Radio configuration and monitoring.

NOTES:
1. Use proper crimp tool for Item #2 connection
2. Remove cable filler gel from conductors before inserting into Item #2 and #3.
3. Insure that all eight conductors reach to end of interior channel before crimping Item #2.
4. Add label near item #2 "Afar Communications / CBL-0503-XXX" where XXX is cable length in feet.
   For cables shorter than 3 ft, the length is shown as AXX where XX is in inches.

APPLICATION		REVISION			
NEXT ASSY	USED ON	REV	DESCRIPTION	DATE	APPROVAL
		A	Initial Release	09/15/03	J.B
		B	Added short lengths	05/10/05	N.
		C	Added RJ45 alternate	05/29/12	R.B.
		D	Added RJ45 boot	06/20/12	N. R. B

ITEM #2

RADIO_ETH_TX+
RADIO_ETH_TX- 2
RADIO_ETH_RX+
VDC 4
VDC 5
RADIO_ETH_RX- 6
GND 7
GND 8

ITEM #1

WHT/ORN
ORN
WHT/GRN
WHT/BRN
WHT/BLUE
GRN
BLUE
BRN

ITEM #4

1
7
2
3
5
4
8
6

RJ 45 Plug

W/ORN   1   8   BRN

NO TAB SIDE

Solder Cups

REAR VIEW

W/GRN
W/BLU 5 2 4 GRN
W/BRN 3 1 W/ORN
8 7
BLU 6 ORN
BRN

19   SW16

Kupplung
Socket
connecteur femelle
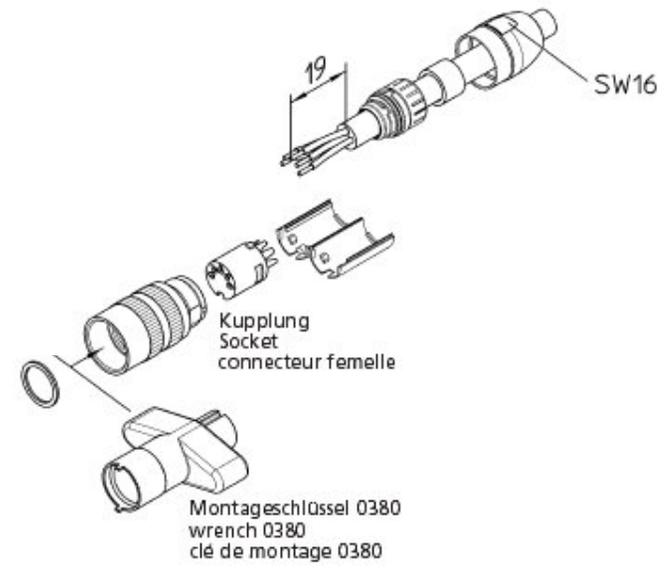
Montageschlüssel 0380
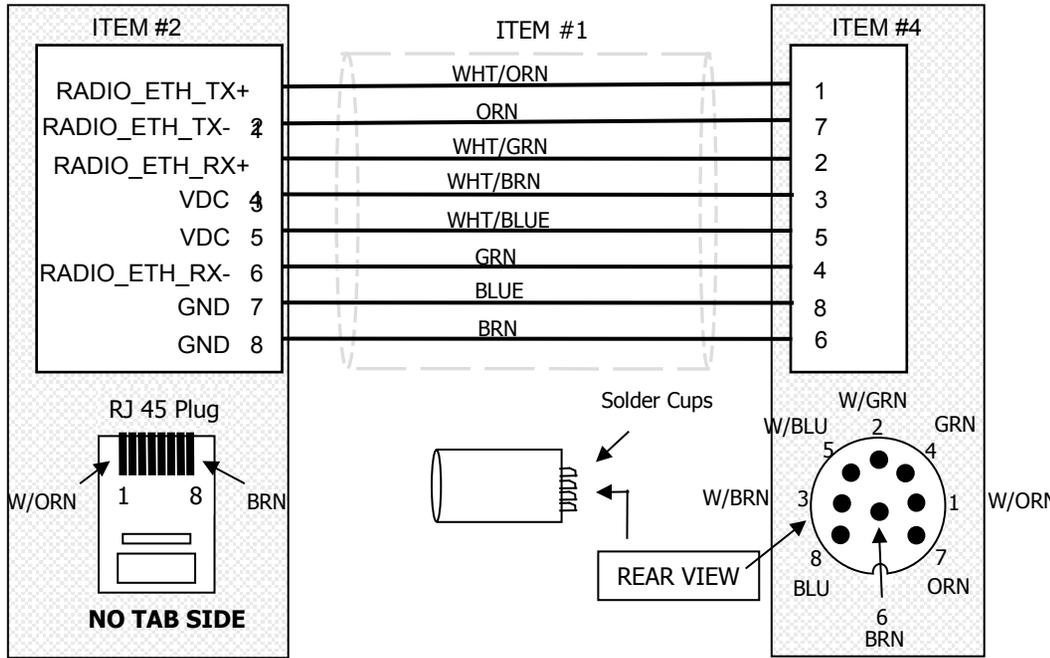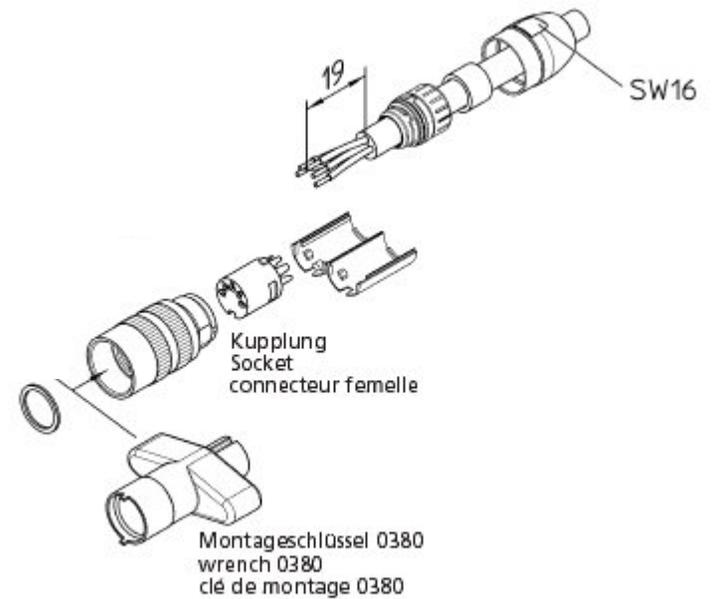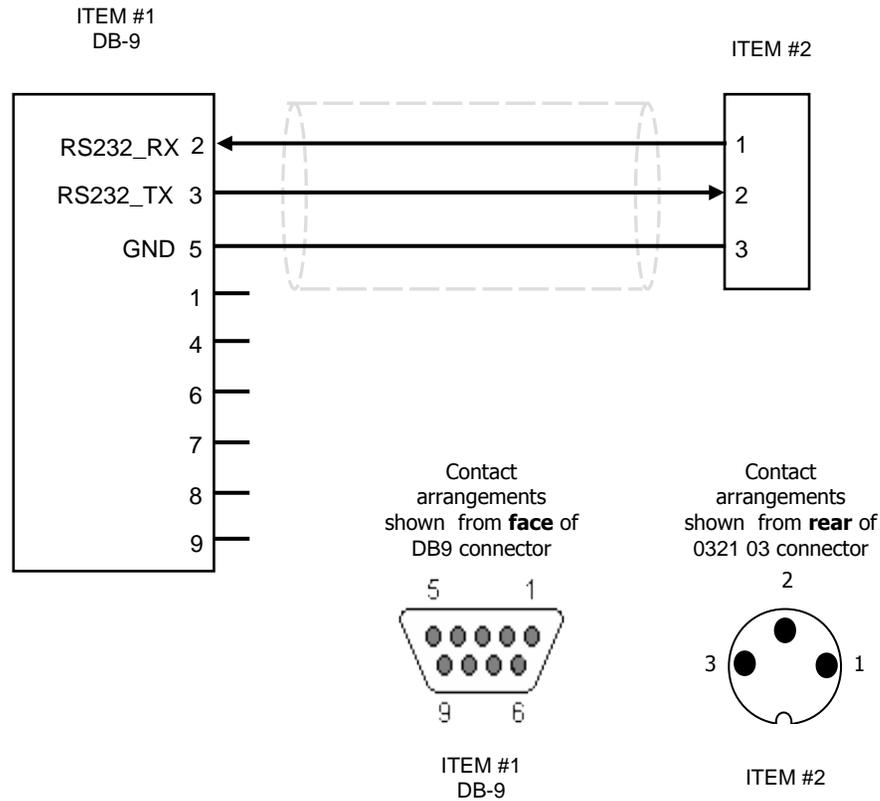wrench 0380
clé de montage 0380

Fig. A   Five pin connector is shown. Use same process for 8 pin.

Cable Length (in feet or inches) specified in part number
CBL-0503-050 for a 50 feet cable
CBL-0503-A20 for a 20 inch cable (use for cables shorter than 3 ft)

MATERIAL			
ITEM	PART NO.	MANUFACTURER	DESCRIPTION
1	4286104/10 | 5NF4	CommScope	Cable, CAT5e, Outdoor, Solid Cond.
2	AT8X8SC-2224 PT-0688L-50UL	Allen Tel Pan Pacific	Plug Connector, 8 Cond., RJ45-type
3	SR-8P8C-BLACK	PI Manufacturing Corp	Cat5 strain relief boot for RJ45
4	0321 08 or 0322 08 (fig. A)	Lumberg USA	8 Pin Field Connector, Female

DRAWN BY J. Becker	DATE 9/15/03	**AFAR Communications, Inc.**	
CHECKED BY	DATE	TITLE **CAT5 ETHERNET & POWER CABLE**	
APPROVED	DATE		
APPROVED	DATE	DRAWING NO. CBL-0503-XXX	REV D
		SCALE NONE	SHEET 1 OF 1

D-2

ITEM #1
DB-9

ITEM #2

RS232_RX 2
RS232_TX 3
GND 5
1
4
6
7
8
9

1
2
3

Contact arrangements shown from **face** of DB9 connector

Contact arrangements shown from **rear** of 0321 03 connector

5 1

9 6

2

3 1

ITEM #1
DB-9

ITEM #2

19 SW16

Kupplung
Socket
connecteur femelle

Montageschlüssel 0380
wrench 0380
clé de montage 0380

Fig. A   Five pin connector is shown. Use same process for 3 pin.

| MATERIAL			
ITEM	PART NO.	MANUFACTURER	DESCRIPTION
1	F3B20706	Belkin	Serial Direct Cable Db9, F/F 6'.**
2	0321 03 or 0322 03 (fig. A)	Lumberg USA	3 Pin Field Connector, Female

** 6' cable cut in ½ will make two cables.

DRAWN BY J. Becker	DATE 9-16-2003	**AFAR Communications, Inc.**	
CHECKED BY	DATE	TITLE **3 Pin Console Cable**	
APPROVED	DATE		
APPROVED	DATE	DRAWING NO. CBL-0403-XXX	REV A
		SCALE NONE	SHEET 1 OF 1

APPENDIX E – Quick Setup Examples

The next page show an examples on how to configure the *pulsAR* radios

PulsAR Wireless Point to Multi-Point Bridge
Quick Setup Example

Afar communications

Omni

Coax

HUB

REMOTES

AC Power

AC Power

LAN

CAT5

CAT5

LAN
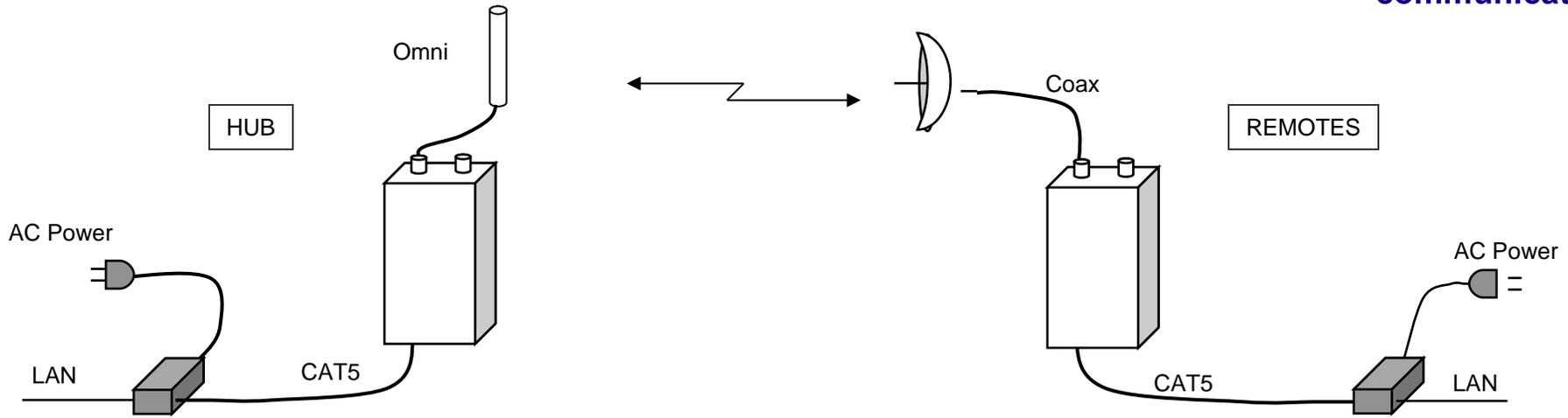
		Minimal Configuration		
	>load factory >node type=hub >save		>load factory >save	
		Changing RF Channels (optional)		
	>rf-tr ch=24 >rf-rec ch=14		>rf-rec ch=24	
		Changing Tx Power (optional)		
	>rftr power=23		rftr power=23	
		Verifying Network Operation		
	>show radios			