AR24027 – Linear Network

Operator's Manual

Rev: A

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> 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:

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> Santa Barbara, CA 93117
> U.S.A.

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- 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.

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1 PRODUCT DESCRIPTION

1.1 Radio Overview

The *AR24027* Wireless Ethernet Bridge is a license free radio that can be used to bridge Ethernet LAN's (Local Area Networks) across distances ranging from a few hundred feet to 50 miles (80 Km) and beyond. It can be deployed in point-to-point, point-to-multipoint, or in a Linear Network configuration. It can also be paired with one of the Afar NetCrossing™ Gateway models to provide a full duplex synchronous serial stream connection, in addition to the Ethernet interface, between two end points.

This manual covers the operation for the Linear Network topology. The radios must be loaded and running a separate software program dedicated to implement this topology.

The *AR24027* is a Spread Spectrum radio operating in the "Industrial Scientific and Medical" (ISM) band from 2.400GHz to 2.4835 GHz. It is designed to provide a robust link under adverse conditions, often encountered in this unlicensed band. 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 receives power over the CAT5 Ethernet cable.

2. The radio RF bandwidth is much narrower than other unlicensed devices in the 2.4 GHz band. 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 the *AR24027* the transmit and receive frequencies can be selected independently of each other.

4. The radio incorporates spectrum analysis and timing analysis tools, which allow the operator 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 radio 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. This reduces the RF throughput required by the radio.

The *AR24027* is the building block for the Afar PULSAR wireless network. In a PULSAR network all radios synchronize their trasnsmissions such that any co-located radios all transmit and receive at the same time, thereby avoiding self-generated interference. This technique allows deploying large networks with sites where upwards of 24 radios are co-located without self-interference.

The *AR24027* 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 components that are typically shipped with each *AR24027* radio.

Table 1.1 - *AR24027* Components

A	*AR24027* outdoor unit.
B	Bracket hardware for securing the *AR24027* unit to an outdoor mast.
C	Power Inserter Module including 110-240 VAC power supply
D	CD with this Operator's Manual, Econsole program, and other application notes.
E	CAT 5 cable for connection between *AR24027* radio and power inserter module ([1])
F	Auxiliary port cable for RS-232 connection ([1])
G	Auxiliary port cable with Audio jack for antenna alignment ([1])

1 Not supplied with standard radio kit. Available from AFAR as optional equipment.

1.3   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.

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.

1.4   Radio Connectors

Figure 1.1 shows the *AR24027* radio mounted on a mast. The radio is housed in a rectangular 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.

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

Table 1.2 – *AR24027* Connectors

CONNECTOR	TYPE	Function
A	N-FEMALE	2.4 GHz RF connector to antenna A. Pointing at the "Left" neighbor
B	N-FEMALE	2.4 GHz RF connector to antenna B. Pointing at the "Right" neighbor
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.

Figure 1.1. Pole Mounted Radio

An eight conductor CAT 5 cable must be connected between the *AR24027* and the Power Inserter Unit. The wiring for this cable is shown in Figure 1.2.

Table 1.3 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. AFAR has available two cables to convert from this non-standar 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 E for cable diagrams.

Table 1.3 – 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	

1.5 Power Inserter Unit

The Power Inserter Unit includes a power supply for connection to an AC outlet, two RJ45 connectors and a bi-color LED. The two RJ-45 connectors are labeled "To LAN" and "To radio". The following tables describe those connectors.

Table 1.4 – Power Inserter Unit

Connector/LED	Type	Function
To LAN	RJ-45	10/100 Base-T to be connected to the Local Area Network. Use a straight through cable to connect to a hub and a cross over cable to connect directly to a computer. See table 1.5 for pin assignments.
To radio	RJ-45	Carries the DC power and Ethernet signals to the *AR24027*. See table 1.6 for pin assignments.
LED	Amber/ Green	**Amber**: Indicates that the power inserter unit has power from the wall supply but no power is being drawn by the *AR24027*.
		Green: Indicates that the *AR24027* is drawing power.

WARNING

The Power Inserter connector 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 1.5 – "To LAN" 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	(not connected)		
5	(not connected)		
6	Ethernet Rx	Rx (-)	Ethernet to radio
7	(not connected)		
8	(not connected)		

Table 1.6 – "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

1.6 Outdoor Interconnect Cable

The interconnect cable between the Power Inserter Unit and the *AR24027* carries the following signals

1. DC voltage to supply power to the *AR24027*.
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 up to 100 meters (300 feet). Figure 1.2 shows the interconnect diagram for this cable and connector

types. Table 1.7 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 E for connector diagrams, part numbers, and assembly instructions.

RJ 45			Lumberg
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	
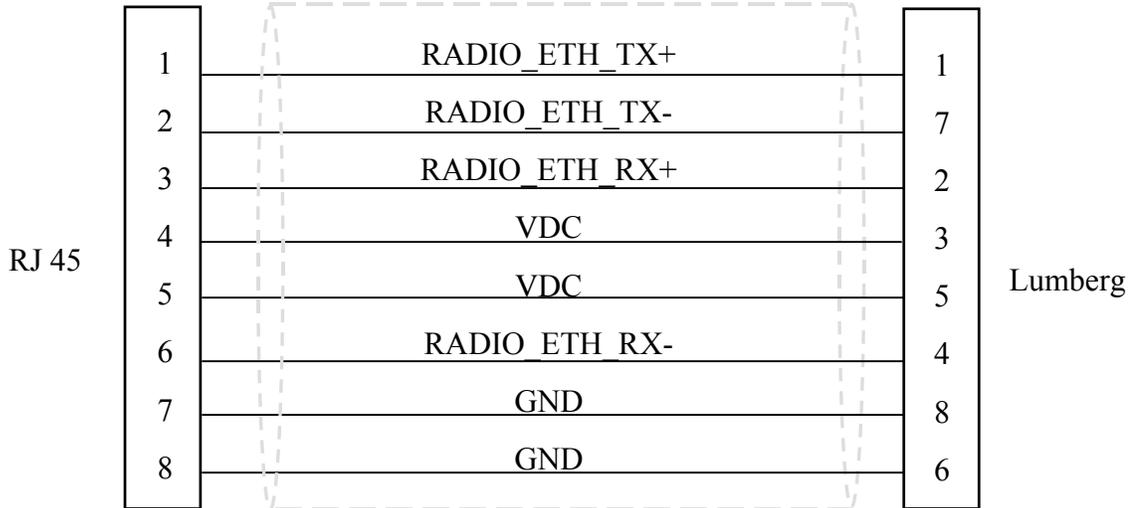
Figure 1.2 - CAT 5 Outdoor Interconnect cable diagram

Table 1.7 – 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 Overview

Figure 2.1 shows the general topology of a Wireless Linear Network. Each node in the network has at most two neighbors with which it can communicate directly. These neighbors are referred to as the **left** and **right** neighbors.   The following are some characteristics of the linear network:
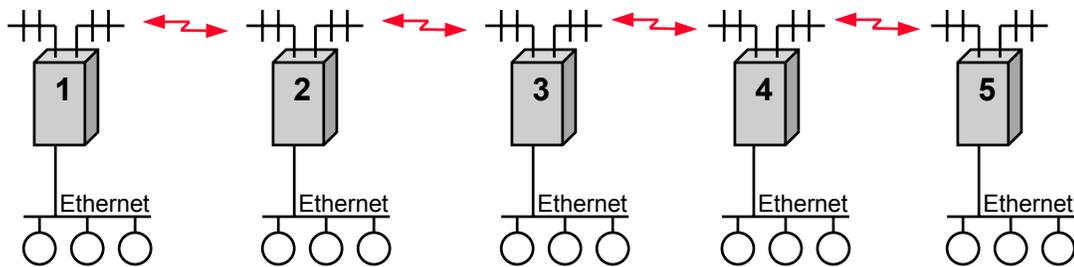
Figure 2.1. Linear Network Topology

1. Each node consists of a single radio with two RF ports. Typically a node is deployed with two directional antennas pointing at each of the node's neighbors.

2. Each node has an Ethernet port for connection to a LAN or directly to the user equipment.

3. A packet can enter the linear network at any node, through the Ethernet port. If the packet is addressed to a station at a remote LAN, the radio transmits the packet to its right or left neighbor as necessary. The packet may then go through multiple hops in one direction until it exits the linear network at its destination.

4. When a packet goes through multiple hops, the packet does not show up at the local LANs of the intermediate nodes.

5. The network supports broadcast packets, which are transmitted, left <u>and</u> right, until they show up at every local LAN.

6. The behavior described in the above paragraphs is self-learned. No user configuration is required.

7. All radios are peers, there is no master radio providing synchronization, therefore no single point failure.

8. If a node fails, the two segments of the original linear network continue to operate as two separate linear networks. Once the failed node is reactivated, the two networks automatically merge into one.

9. The radios sort all messages to be transmitted over the air into four priority levels and always transmit the higher priority messages ahead of lower priority.

10. The basic Linear Network topology can be expanded and combined with other AFAR topologies, including Point-to-Multipoint and Point-to-Point. Figure 2.1 shows an example of these combinations.

Ethernet

Ethernet
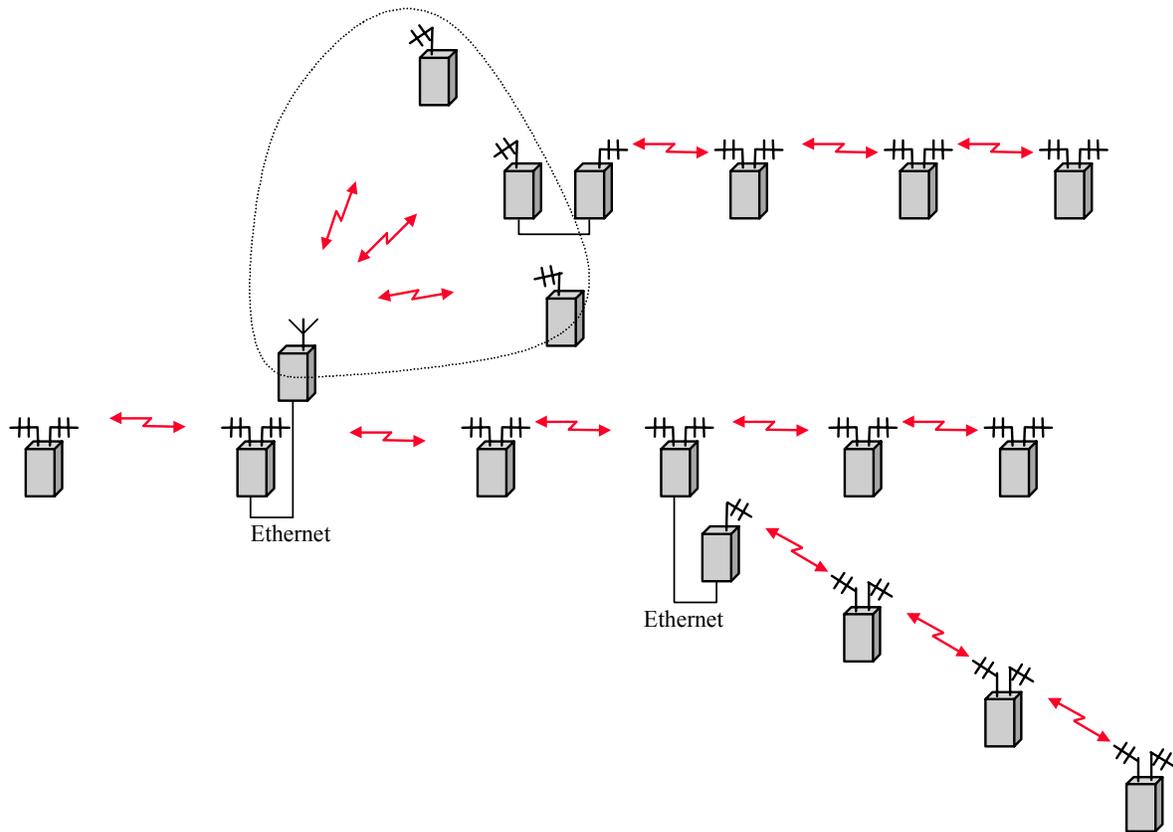
Figure 2.2: Expanded network topology example

2.2   Operation

2.2.1   Cycle Timing

The radios have two RF ports. The RF front end of the radio can be switched, under software control, to either of the two antennas. The radios are half duplex, i.e. they can either transmit

or receive. Therefore, at any given time, a radio can be doing one of four actions, as described below.

Each of the four actions occurs in fixed time slots. All radios execute the same four phase cycle, consisting of the following phases in order:

1. Transmit to the Left (TL)
2. Transmit to the Right (TR)
3. Receive from the Right (RR)
4. Receive from the Left (RL)

The total cycle time is 20 ms, with each phase lasting approximately 5 ms.

Once synchronized, adjacent radios have their respective cycles offset by exactly two slots. Figure 2.1 shows how a synchronized network operates over time.

1	2	3	4	5	6	7
TL	RR ← f1 ←	TL	RR ← f2 ←	TL	RR ← f1 ←	TL
TR → f1 →	RL	TR → f2 →	RL	TR → f1 →	RL	TR → f2 →
RR ← f1 ←	TL	RR ← f2 ←	TL	RR ← f1 ←	TL	RR ← f2 ←
RL	TR → f1 →	RL	TR → f2 →	RL	TR → f1 →	RL
TL	RR ← f1 ←	TL	RR ← f2 ←	TL	RR ← f1 ←	TL
TR → f1 →	RL	TR → f2 →	RL	TR → f1 →	RL	TR → f2 →
RR ← f1 ←	TL	RR ← f2 ←	TL	RR ← f1 ←	TL	RR ← f2 ←
RL	TR → f1 →	RL	TR → f2 →	RL	TR → f1 →	RL
TL	RR ← f1 ←	TL	RR ← f2 ←	TL	RR ← f1 ←	TL
TR → f1 →	RL	TR → f2 →	RL	TR → f1 →	RL	TR → f2 →
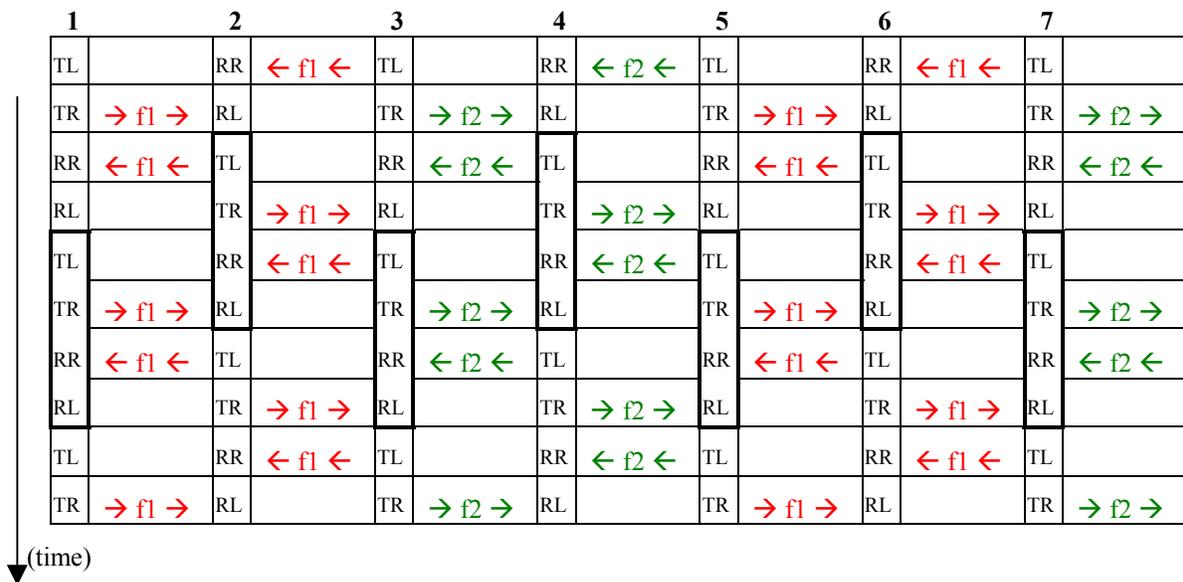
(time)

Figure 2.1. Time slotted operation of a synchronized linear network

2.2.2   RF Channel Plan

The radio configuration is field programmable with respect to the various frequencies, used to communicate with the left and right neighbors.   A complete linear network can be deployed using only two non-overlapping frequencies as shown in figure 2.1. This frequency plan assumes that the signal level at a radio five hops away will always be significantly below the signal from a neighboring radio (example: node 6 in slot 1 is exposed to the signal from node 5 but also from node 1 on the same frequency).

A different frequency plan, using more non-overlapping frequencies, can be used when the assumption above is invalid. The AR24027 has 12 non-overlapping channels. Figure 2.2 below shows a different approach using more non-overlapping channels:

Node:	1	2	3	4	5	6	7	8	9	10	11
Channel:	←5→	←6→	←15→	←16→	←25→	←26→	←35→	←36→	←5→	←6→	←15→
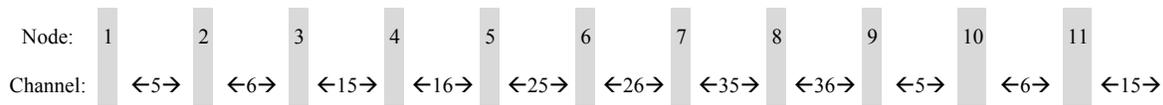
Figure 2.2 - Frequency allocation

The use of overlapping channel in adjacent links is not a problem since in the Linear Network only every other link is active at one given time. However you should avoid using the exact same channel in adjacent links. This prevents the possibility of the wrong link getting established inadvertently (for example, if you had used channel 5 between nodes 2 and 3 above, a link could get established between nodes 1 and 3 if node 2 was powered down).

In this approach the first time we repeat a channel is after 8 hops. If this was a problem you could be use channels 7,8 instead of 5,6 between nodes 9, 10 and 11.

2.2.3   Data throughput

The throughput across a single hop in the linear network is about half of what you would get in a point to point link. The reason is that each node divides its time, half to communicate with a left neighbor and the other half with the right neighbor. With the RF speed set to the maximum value of 2.75 Mbps (half duplex), the effective throughput between any two nodes is about 550 Kbps full duplex. Note that you could have communications between nodes 1 and 2 and, at the same time, between 2 and 5 (for example) without affecting each other, i.e., both could be running at ~550 Kbps simultaneously. In this example node 2 would be offering a total throughput of 2.2 Mbps (550 Kbps full duplex in each direction).

The end nodes of a linear network (furthest to the left and furthest to the right) are always looking for new neighbors to expand the linear network. In order to make sure that a new neighbor is always found, irrespective of cycle offset, the end nodes of a network "steal" one cycle every 20 to look for a new neighbor. This approach degrades the throughput capacity of the end nodes by about 5%. You can avoid this degradation by configuring a known end nodes as a **left** node and/or a **right** node (see the command **>node type=xxx**).

2.2.4   Latency

When a packet enters a node in the linear network it will take anywhere between 0 and 20 milliseconds for it to be forward in the correct direction (see figure 2.1). After the first transmission the message performs one hop every 10 ms. Therefore to cross N hops, the average and maximum delay experienced by a packet will be:

Average delay across N hops = 10 x N

Maximum delay across N hops = 10 x (N+1)

This assumes that the linear network is not congested. If the packet encounters a congested area it may be delayed further according to the packet priority.

2.3   Bridging algorithm

From a packet switching point of view, the radios operate as a three port switch, switching packets at layer 2 of the OSI model.   They implement a self-learning bridge algorithm that allows them to switch the packets appropriately with no user configuration. This is briefly described below.

The radios operate the Ethernet port in "promiscuous" mode, thereby accepting every packet traveling in the local LAN. All Ethernet packets contain a source and destination address that identifies the physical addresses of the sending and receiving device. A radio collects all the source addresses into its "ethernet address table", and tags those addresses as **local** (i.e. these devices are reachable through the Ethernet port).

The radios perform a similar algorithm when they receive a data packet over RF (left or right). In this case, the radio examines the Ethernet source address of the packet (the complete Ethernet packet is encapsulated in an RF frame). It enters that address into its address table tagged as being on the radio left or right side as appropriate.

The address table also includes a time tag of when the address entry was last updated. Once in a while the radios scan the address table and delete any entries that have not been updated for a specified timeout. This allows the network to adapt to situations where a device is moved from one LAN to another. The station timeout is configurable from as low as 5 seconds to as high as 24 hours. Large timeouts are appropriate if some devices generate packets very sporadically but need to receive them frequently.

With this mechanism, each radio in the linear network builds an address table that contains the addresses of most stations across the entire linear network, and whether they are local or can be reached through the right or left RF ports. With this table on hand, when a radio receives an Ethernet packet, on any port, it checks if the destination address is in the table, and if so, transmits the packet on the port indicated in the table (but if the packet arrived at the port that is supposed to go out on, the radio discards the packet instead).

If the destination address is not in its address table, or is the broadcast address, the radio transmits the packet on the other two ports.

With this self-learning algorithm, when the linear network is first powered up, there is a large amount of broadcast traffic since the address tables are empty. However this broadcast traffic causes all the tables to be populated and it will soon subside.

2.4   Priority Queues

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::

*   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.

- Low-priority: All other packets

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

3 INSTALLATION AND SETUP

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NOTE

Appendix F contains a quick set up diagram showing the minimum configuration and basic commands necessary to put up a simple 3 node linear network.

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

In this bench checkout you will setup three radios in a linear network configuration. In the procedure the three radios are identified as radios 1, 2 and 3, with radio 1 being the **left** radio and 3 the **right** radio. In this approach we describe the setup using the "Ethernet Console Program" to emulate the terminal across an Ethernet connection. You may also perform these configuration steps with a terminal connected to each of the console ports of the radios.   The connectivity and channel plan are the same as depicted in the Appendix F figure.

3.1   Bench Check Out (using radio Ethernet connection)

In order to use the Ethernet connection you need the "Ethernet Console Program" (Econsole) provided in the CD. See Appendix D for installation instructions for Econsole. Once Econsole is installed, perform the following steps.

1. Connect the PC Ethernet port to the "To LAN" connector of the Power Inserter Unit of radio 1. Use an Ethernet crossover cable if connecting the PC directly to the Power Inserter Unit, or use a straight cable if connecting through a hub.

2. Connect each of the three Power Inserter Units to the respective *AR24027* radios using a CAT 5 cable as defined in section 1.

3. Antenna B of radio 1 needs to have RF connectivity to Antenna A of radio 2. You may establish this connection using actual 2.4 GHz antennas. Alternatively you may connect the two antenna ports using coaxial cables **through an RF attenuator**.

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    CAUTION: You must always use an RF attenuator of 30 dB or higher when connecting two antenna ports by cable; other wise you may damage the unit RF receiver.

    </div>

4. Antenna B of radio 2 needs to have RF connectivity to Antenna A of radio 3. Again you may use a pair of 2.4 GHz antennas or use coaxial cables and an RF attenuator.

5. Connect the three Power Inserter Units to a power outlet of the appropriate voltage.

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

    > **econ**

    If only one radio is connected to the LAN, ECON will establish a connection with that radio. If more than one radio are in the same LAN, ECON provides a list of all radios found (see

Appendix D for more detailed instructions on the use of Econsole). Once a connection to the radio is established, the radio outputs the prompt:

lnw-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").

7. Set the left radio (radio 1) to its factory default configuration by typing the commands:

> **load factory**
> **rf-left rec-ch=15**
> **rf-right rec-ch=20 tr-ch=20**
> **save-configuration**
> **logout**

8. Move the Ethernet cable from the power inserter connected to radio 1 to the power inserter connected to radio 2. At the DOS window invoke once again the Econsole program. Configure radio 2 by issuing the following commands:

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

9. Move the Ethernet cable from the power inserter connected to radio 2 to the power inserter connected to radio 3. At the DOS window invoke once again the Econsole program. Configure radio 3 by issuing the following commands:

> **load factory**
> **rf-left rec-ch=25**
> **rf-right rec-ch=30 tr-ch=30**
> **save-configuration**
> **logout**

10. The three radios should now be synchronized to each other establishing a three node linear network. To examine the complete network type:

> **show radios**

Verify that the linear network listed includes all three radios and the RSSI values displayed are reasonable.

11. Once the network is established, Econsole can be used to configure the local or the remote radio. In order to switch the Econsole connection, logout of the current connection and re-invoke Econsole:

> **logout**
> **econ**

Econsole will list the three radios and give a choice to connect to any of them. Section 4 describes the command language used to further modify the radio's operating parameters.

3.2 Bench Check Out (using radio auxiliary ports)

If you want to use the radio's auxiliary port instead of the Econsole program, you need an RS-232 terminal or a terminal emulation program, like Hyperterminal, running on a PC.

Configure the terminal settings as follows:
> Baud rate: 9600
> Word length: 8 bits
> Parity: none
> Stop bits: 1

Use the special adapter console cable (available from Afar), between the three pin radio connector and the Terminal.

Connect all the radios as described in steps 2 through 5 of the previous section.

Issue the commands described in steps 7 through 10 of the previous section moving the terminal connection to the appropriate radio console port.

3.3 Field Installation

3.3.1 Configuration

The *AR24027* 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 successfully deploy a linear network you need to develop a "frequency plan" to avoid interference between adjacent links. Once you have established a frequency plan, each radio needs to be configured accordingly.

The figure below shows a suggested frequency plan as explained in section 2.

Node:	1		2		3		4		5		6		7		8		9		10		11
Channel:		←5→		←6→		←15→		←16→		←25→		←26→		←35→		←36→		←5→		←6→		←15→
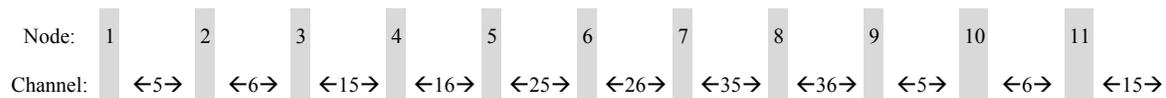
Figure 3.1 - Frequency allocation

According to the plan above, node 5 uses channel 16 for transmit and receive on the left and channel 25 for transmit and receive on the right. To configure these parameters enter the following commands:

> **> rf-left rec-chan=16**
> **> rf-right rec-cha=25 tr-chan=25**

The transmit channel for the left side does not need to be configured. This is because the linear network synchronizes from left to right and the left node will configure its right neighbor to transmit in the correct channel.

3.3.2   Antenna Installation

__NOTICE__

The antennas for the *AR24027* 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 (Federal Communications Commission, FCC, 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 *AR24027* 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 antennas with a cable run typically under 2 meters (6 feet). For the *AR24027*, AFAR Communications Inc. provides the three antenna types listed below:

Antenna Type	Gain	AFAR Model Number
Omnidirectional	9 dBi	ATO-2409
Panel	18 dBi	ATD-2418
Dish Reflector	24 dBi	ATD-2424

For the linear network we recommend the use of the 24 dBi gain antennas. Antennas at the end of each 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.

Proper grounding of the antennas is important for lightning protection as well as to prevent electrical noise interference from other sources. The antennas should be mounted to a mast or tower that is well grounded to Earth. Use threaded connectors to mate to the antenna lead connectors and check that all connectors are clean and tight.   Use weatherproof connectors in all outdoor couplings.   We recommend using "rubber mastic tape" like Scotch 2228 from 3M to further weatherproof outdoor connections.

In locations where it is warranted, install lightning protectors at the N type connectors leading to the antennas. You may also want to install a surge arrestor/lightning protection on the Ethernet cable where it connects to the equipment rack. The lightning protectors should be properly grounded. Carefully follow the installation instructions provided by the manufacturer of the lightning protection device used.

3.3.3   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 with the two neighbors. The antennas can then be aligned so that the respective RSSI is maximized.

Since in many applications the antenna is on a tower where it is not practical to have a terminal nearby, the *AR24027* 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 mode=a-antenna | b-antenna**   (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.

3.3.4   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 directive antennas greatly reduces the potential for interference. In addition, the *AR24027* includes several features, described below, to identify and overcome sources of interference.

The *AR24027* 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 input=a-antenna 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 even though the *AR24027* channels are spaced 2 MHz apart, the receiver RF bandwidth is approximately 5 MHz. Therefore the RSSI value reported for each channel represents the total energy in a 5 MHz band centered around that channel. For this reason, a narrow band transmitter will show up in the spectrum analysis report as a lobe with 5 MHz bandwidth. Conversely, you do not need to find a quiet 5 MHz 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.

Once a potential receive channel has been identified using the spectrum analysis tool, a "timing analysis" may also be used to confirm that the selected channel is indeed clear. The command:

>**time-analysis channel=xx input=a-antenna 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.

3.3.5   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 2.4 GHz band. Close to the band edges, the output power must be limited to avoid spilling over into the FCC protected band from 2.4835 GHz to 2.500 GHz. The table below takes these considerations into account and shows the maximum allowed output power for the various antennas

Maximum Output Power (dBm)				
Channel	**Frequency**		**Antenna Gain**	
	(MHz)	**9 dBi**	**18 dBi**	**24 dBi**
3 to 19		23	23	23
20	2440.0	21	23	21
21 to 33		23	23	23
34	2468.0	23	23	22
35	2470.0	23	22	21
36	2472.0	23	21	20
37	2474.0	22	19	10

3.3.6   Output Power Limits (CE)

The European Telecommunications Standards Institute (ETSI) regulations impose a limit of 20 dBm as the maximum Effective Isotropic Radiated Power (EIRP) for direct sequence spread spectrum systems operating in the 2.4 GHz band. In addition the maximum spectral power density is limited to 10 dBm per MHz maximum EIRP. Of these two limits the power density is the most restrictive for this radio. The installer must reduce the output power of the *AR24027* so that the EIRP of the radio does not exceed 10 dBm. The antenna gain, cable and connector losses must be taken into account when computing the maximum output power.

3.3.7   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 1 mW/cm^2 , 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.

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

Antenna Gain (dBi):	9	18	24
Max. Output Power	23	23	23
MPE safe distance (cm)	11*	28*	63*

*NOTE: For fixed location transmitters, the minimum separation distance is 2 m, even if calculations indicate a lower MPE distance.

3.4   Upgrading the Firmware.

3.4.1   Description

The operational firmware for the *AR24027* 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:

lnwNN_NN.bz   (binary zipped file for downloads through the Ethernet port)
lnwNN_NN.dwn (ascii file for download through the serial port, or via Telnet)

where NN_NN 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 "econ" 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 all radios in the network 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 sessions 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 several radios of a working network. The upgrade is performed from a single PC connected via Ethernet to one of the nodes anywhere in the linear network. Note that new firmware does not need to be compatible with the firmware currently running. You can still download incompatible firmware and restart the link from a single location.

1. If you have not done so, install the utility program "econ" in the PC. This utility program is distributed with the radios and can also be downloaded from the website. Please refer to appendix D for instructions on how to install this utility.

2. Make sure the file with the new firmware (file lnwNN_NN.bz) is in the PC.

3. Start the econsole utility by typing "econ" from a DOS window. Econ will send a "discovery" message and display all the radios that can be reached. Verify that all radios in the network are listed. Then select one of the radios in the network that you wish to upgrade.

4. Issue the command:

    >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 lnwNN_NN.bz 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).

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:

    >**download** *path/***lnwNN_NN.bz**

    where *path/* is the directory in the PC where the lnwNN_NN.bz file is stored (*path/* is not required if the file is in the same directory as the ECON program). As the download proceeds econ displays a line showing the current percentage complete.

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

    >**set-default-program lnwNN_NN**

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

8. Issue the command:

   >**single-node-reboot-timeout =60**

   in order to speed up the network recovery if the new firmware is incompatible with the old one.

9. Depress the "**F4**" key to log-off the session with the current radio. "Econ" displays the list of all radios from the initial discovery phase. Select another radio in the network and repeat steps 4 through 8.

10. Once all radios in the network have been loaded with the new program, you need to reboot each radio in turn. If the new software is compatible with the old one you can log onto each radio in turn and issue the command::

    >**reboot**

    to cause the radio to restart using the new firmware.

11. If the new firmware is incompatible with the old one, you must reboot the radios in a specific order so that you always have access to the radios you need to reboot. To determine the order first log onto the local radio and issue the command:

    >**show radios**

    which lists all radios in the linear network in order, and identifies the local radio position

12. Prepare a list of the radio names in the following order:

    Start with the furthest radio to the right of the local radio, (last one listed in the "show radios" report) and down towards your local radio. **Do not include the local radio**.

    Now continue with the furthest radio to the left of the local radio (first one listed in the "show radios" report) sequentially towards the local radio. Add your local radio as the last one to be rebooted.

13. Use the "**F4**" key to logout of each radio in turn and display the list of all radios as discovered by econ (note that this list is not in the same order as the show radios list). Logon to each radio in the order of the list prepared in step 12 and issue the command:

    >**reboot**

14. Wait at least ten seconds from the moment you entered the reboot command on the local radio, then press <CR>. Econsole automatically attempts to reconnect to the local radio. Once a new session with that radio is reopened issue the command:

    > **version**

    and check that the local radio is indeed executing the new version. Then issue the command:

    >**show radios**

    to verify that the complete network is up and running.

15. Depress the "**F4**" key to log-off the session with the local radio. Once again select each radio in turn and issue the command:

>**version**

to verify that each radio is running the new firmware verion.

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 ".dwn" extension, e.g., lnw01_05.dwn.

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 lnwNN_NN.dwn 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=lnwNN_NN method=inline**

    where NN_NN 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 ".dwn" 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 filename=lnwNN_NN**

where NN_NN 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 *AR24027* 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 ".dwn" extension, e.g., lnw01_05.dwn.

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 57600 baud will be used. Set the console speed of the radio to 57600 baud by issuing the command:

    >**console-speed-bps 57600**

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 lnwNN_NN.dwn 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=lnwNN_NN method=inline

   where NN_NN 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 ".dwn" 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 filename=lnwNN_NN

    where NN_NN 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 *AR24027* has 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 COMMANDS

4.1   Configuration techniques

There are three ways to configure the radio. One uses the auxiliary port at the bottom of the unit and consists of an asynchronous RS-232 link used for issuing configuration commands and monitoring the local radio status and performance. This port is always set to operate with the following parameters:

> Baud rate: 9600
> Word length: 8 bits
> Parity: none
> Stop bits: 1

This console port allows configuring and monitoring only the local radio, i.e. you can not monitor and configure any of the remote radios reachable through RF.

A second configuration method uses the Ethernet connection to the radio to perform the configuration. This approach has the advantage that any radio reachable across the Ethernet, or the RF link, can be configured from a single PC. Additionally the Ethernet connection is more readily available indoors than the console port.

In order to use the Ethernet connection to configure the radios the "Ethernet Console Program" (Econsole) needs to be installed at a PC. This PC must be connected to the LAN where one or more *AR24027* are connected. From this PC it is then possible to configure not only the radios directly connected to the LAN, but also any other radios reachable through one or more RF hops. Refer to Appendix D for instructions on the installation of Econsole.

The third configuration method is using Telnet from a remote location. Telnet is explained in more detail in section 5.

After power up the radio performs several diagnostic and calibration tests. At the end of these tests it outputs the command prompt. The default prompt is:

lnw-nnnnn #>

where nnnnn are the last five digits of the radio serial number. 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 *AR24027* 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 *AR24027* 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*

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 input=a-antenna 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, hexadecimal, or octal notation. To enter a number in hexadecimal notation precede it with a 0x or 0X. To enter a number in octal notation precede it with a 0 (zero). All other numeric values are interpreted as decimal. Example:

  > **rf-left rec-ch=0x1a**   (hexadecimal)

  > **rf-left rec-ch=014**   (octal)

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 *AR24027* 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.

Examples:

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

WARNING

The *AR24027* is shipped with no password. If the "change-password" command is issued make sure you do not forget the password. Once locked, without a password, the radio must be returned to the factory to be 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**

> **> discon**

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.

ethernet

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

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 10 Mbps but negotiates the half or full duplex. The **auto** setting negotiates both the speed and duplex to the fastest configuration supported by the other devices on the Ethernet.

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.

Examples:

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

node

type= middle or *left* or *right*

Configures the node according to its position in the linear network. You can always have all nodes with a type set to **middle**. However, when a node of type middle is at an end position its throughput capacity is degraded by approximately 5%. Setting the end node type to the appropriate value cancels this degradation. Note that a node of type **left** can never acquire a new node to its left and a node of type **right** can never acquire a new node to its right.

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.

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-left-setup

receive-channel=3..37
power-dbm=0..23
speed-mbps= *0.25* or *0.50* or *1.37* or *2.75*

This command configures the receive channel as well as the transmit power and transmit speed for the left link (connected through antenna A).

Note that for the radio to establish a link to its left neighbor, the receive channel selected by this command must match the right transmit channel selected at the left neighbor.

Example:

> **> rfleft rec-ch=15**

rf-right-setup

receive-channel=3..37
transmit-channel=3..37
power-dbm=0..23
speed-mbps= *0.25* or *0.50* or *1.37* or *2.75*

This command configures the receive and transmit channel as well as the transmit power and transmit speed for the right link (connected through antenna B)

Note that for the radio to establish a link to its right neighbor, the transmit channel selected by this command must match the left receive channel of the neighbor to its right.

Example:

> **> rfright rec-ch=15**

single-node-reboot

timeout-sec=30..3600

After power up, a radio attempts to get connected to neighbors on either side. If a radio fails to get a link up (or drops both links), it will perform a complete reset after the timeout specified in this command.

This feature is useful if a command is issued to a remote radio changing its parameters in such a way that breaks the links to both peers. In that case the remote radio will wait for the "single-node-reboot" and then perform a reset. As a result, the radio reverts to the saved configuration, allowing it to get reattached to its neighbors.

Examples:

> **> snr 60**

.

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>

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.

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..1400

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=0 or 1

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**

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 antenna alignment aid set to a or b antennas the radio outputs, through the auxiliary port, an audio signal with a pitch proportional to the Receive Signal Strength (RSS) level of packets received through that 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 set to "a" or "b" 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 ("a", "b" or "off") 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-link

clear=0 or 1

This command continuously displays link statistics including link status, RF parameters, and RSSI. The command displays two lines, one for each of the two links.

The "clear=1" parameter clears the cumulative counts in the report.

Examples:

>**monitor-link clear=1**

show-table

table=status or *ethernet* or *econsole* or *radios* or *ip-stack*
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, statistics of the links with the two neighbors, Ethernet port actual speed and status. The "format" parameter is not applicable for this table.

ethernet-stations table

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

>**show ethernet**

```
Ethernet Stations:
                                          --Discard--      --Forward--
  #       MAC address    IP address    Radio  from      to     from      to
  0 ff-ff-ff-ff-ff-ff                  Bdcst     0       0        0      183
  1 00-d0-39-00-2d-cb                     me     0       0      209      165
  2 00-a0-cc-66-8e-a6  207.154.90.171  left    136      54   139575      172
  3 00-d0-39-00-2d-c3                  right     0       0        0        0
```

>**show ethernet times**

```
Ethernet Stations:
  #       MAC address    IP address    Radio MC  Time added        Idle
```

```
0 ff-ff-ff-ff-ff-ff                 Bdcst    29-Nov 16:17:08
1 00-d0-39-00-2d-cb                   me      29-Nov 16:17:08   0.01
2 00-a0-cc-66-8e-a6 207.154.90.171  left     29-Nov 16:17:15   0.00
3 00-d0-39-00-2d-c3                 right     29-Nov 16:23:41   9.18
```

Both formats list all the ethernet stations attached to any of the radios. The tables list the MAC (Ethernet) address of the station, and, if known, the IP address.

The first entry in the table tracks broadcast traffic while the second entry is always the address of the radio itself. The "Radio" column shows the radio port where that station can be reached.

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. In bridge mode the radios are in "promiscuous" mode and look at all the ethernet packets in the Local Area Network. The radios "discard" the packets that are known to be local, but "forward" all other packets to the remote radio. 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.

radios

The unit broadcasts a "linear network probe" message to both the right and left neighbors. Each node sends a reply message to the originator containing information about itself and its place in the network. The originator then displays a complete list of the linear network numbering the radios from 1 to N, with 1 being the left most radio and N the right most. The entry for the originator node is marked with an asterisk. The table includes the node names, RF channels being used in each link, the distance between nodes, and RSSI levels.

spectrum-analysis

input=a-antenna or *b-antenna*
display=graph or *table*
dwell-time-ms=1..1000

This command switches the receiver to the specified antenna (defaults to A) and then performs a scan of **all** the channels from 2.400 to 2.500 MHz, dwelling on each channel for the specified amount of time (defaults to 20 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 even though the *AR24027* channels are spaced 2 MHz apart, the receiver RF bandwidth is approximately 5 MHz. Therefore the RSSI value reported for each channel represents the total energy in a 5 MHz band centered around that channel. For this reason, a narrow band transmitter will show up in the spectrum analysis report as a lobe with 5 MHz bandwidth. Conversely, you do not need to find a quiet 5 MHz 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.

Examples:

>**spectrum-analysis input=b-antenna**

>**spa dwell=500**

time-analysis

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

This command switches the receiver to the specified antenna (defaults to A) and then measures the RSSI for a **single** 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").

Example:

>**time-analysis input=b-antenna**

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

4.7 File Utilities

The *AR24027* 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 *AR24027* 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/lnw01_02 lnw01_02**

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 lnw01_03**

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
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 **.bz**). 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 ".bz" extension is required in the command. The download "method" must be "binary" (which is the default).

Example:

> **>download C:\load\lnw01_12.bz**

  download the file lnw01_12.bz from the PC directory C:\load into the unit file flash/lnw01_12

If the download is executed from a terminal connected to the Auxiliary port, the file is in ASCII format and has the extension .dwn. 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=lnw01_12 method=inline**

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

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 lnw01_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 lnw01_04**

4.8   Event Logging Commands

The *AR24027* 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..200
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 *AR24027* 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 NETWORK MANAGEMENT

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 *AR24027* that are useful for this purpose.

5.1 Telnet

5.1.1   General

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   Starting a Telnet Session

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.

<u>5.1.3   Telnet Security</u>

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

<u>5.2.1   Command Line Interface Versus SNMP</u>

Configuration settings on the *AR24027* 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 *AR24027* 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 *AR24027*, 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   *AR24027* Management Information Base (MIB)

The *AR24027* 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.

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6 ANTENNAS, SITE SELECTION & PATH ANALYSIS

6.1   Link Budget Calculations

AFAR supplies a Link Budget Calculator (Figure 6.1 below) that allows you to quickly perform some of the free space path analysis explained later in this section. You can use the calculator for the following computations:

- Determine the maximum range for a link.

- Find out what transmit power you should choose to obtain a desired fade margin.

- Find the expected Received Signal Strength and Fade Margin in a particular installation.

Figure 6.1. RF Link Budget Calculator

This calculator is in the CD provided with the radio and at our website.

6.2   Selecting Antenna Type

Because *AR24027* radios communicate with each other by means of radio waves, all aspects of antenna installation affect their performance significantly, namely:

- antenna type used

- clear line-of-sight path between antennas

- antenna orientation

- antenna placement

- antenna-to-antenna distance between radios

- distance between the radio and its antenna (antenna cable length)

Therefore antenna installation is a vital part of system installation. Improper installation may greatly reduce system performance, possibly rendering the system inoperable.

This section discusses these issues and provides guidelines for selecting antenna type, selecting antenna location, and achieving an optimally functioning installation.

6.3   Selecting Antenna Type

There are a vast number of antenna types designed for various general and special purposes, but despite the huge variety, all designs essentially address two concerns, directionality and gain. These selection criteria are discussed in the following paragraphs, along with a third criterion, polarization.

For the *AR24027*, the three antenna types listed below will fulfill most installation requirements.

Antenna Type	Gain	AFAR Model Number
Omnidirectional	9 dBi	ATO-2409-000
Panel	18 dBi	ATD-2418-000
Semi-Parabolic	24 dBi	ATD-2424-000

6.3.1   Directionality

An antenna may be designed to receive and transmit in all directions.   Such antennas are omnidirectional. The sensitivity and power of an omnidirectional antenna are unfocused; that is, they are spread through a wide volume of space, so the advantage of being able to communicate in all directions is traded off for limited sensitivity and power.

If it is determined that all signals of interest are coming from a definable direction, the omnidirectional antenna can be replaced by a directional or sectoral antenna, which increases sensitivity and power by focusing the beam in the desired direction.

In practice, even omnidirectional antennas take advantage of directionality by focusing their sensitivity and power in the horizontal plane. Rather than waste performance by sending signals into space or into the ground, the omnidirectional antenna redirects its power and sensitivity from these directions, increasing performance in the horizontal plane.

In point-to-point applications, where the direction of communication is known and fixed, a highly focused directional antenna can be used to provide maximum sensitivity and power. In addition, because of its decreased sensitivity in all directions but the desired one, the directional antenna improves performance by rejecting signals not coming from the desired direction. This provides an effective increase in signal-to-noise performance.

A sector antenna has a wider "spread" than a directional (generally between 60 to 120 degrees) which makes it a cross between an omnidirectional and a directional. This is useful in a point to multipoint configuration where multiple sites are grouped in the same general area.   The installer can then make use of the higher sensitivity and power but also take advantage of the wider beam pattern and improved front to back ratio.

6.3.2   Gain

"Gain" specifies the receive and transmit performance of any antenna compared to a theoretical "isotropic" antenna or "spherical radiator".   The objective of a directional antenna design is to achieve gain, improving sensitivity and effective radiating power to increase range or data rate.

Gain is measured and stated in decibels, abbreviated dB. The decibel is a unit used to indicate the relative difference in power between two signals. For example, a signal 3 dB greater than another signal has twice as much power. The decibel is a logarithmic unit so each doubling of decibels represents a fourfold increase in power. Since 3 dB represents a doubling of power, 6 dB represents a fourfold power increase, 12 dB represents a 16-fold increase, etc. For antenna performance, the unit used is dBi, "i" standing for "isotropic,".

One type of directional antenna available from AFAR Communications Inc. is called a "semi parabolic". This antenna has a gain of 24 dBi, representing power and sensitivity levels 256 times greater than those of a isotropic antenna.

For omnidirectional coverage from fixed locations, AFAR Communications Inc. provides collinear antennas.   The collinear design achieves gain by increased focus in comparison with the dipole design. The standard collinear antenna used with the *AR24027* provides 9 dBi gain, representing an eight-fold power and sensitivity increase.

6.3.3   Polarization

Another important concept for antenna performance is polarization. An antenna radiates radio waves that vibrate in a specific plane, normally horizontal or vertical. Polarization refers to the restriction of wave vibration to a single plane.

NOTE

> Do not confuse polarization with directionality. The plane of wave vibration has nothing to do with the direction of wave propagation. For example, an antenna that focuses its energy in the horizontal plane may be vertically or horizontally polarized.

Designs such as the semi parabolic offer a choice of polarization. Mounting a semi parabolic antenna with the radiating element horizontal provides horizontal polarization, while mounting the antenna with the radiating elements vertical provides vertical polarization.

In setting up the *AR24027* system, either vertical or horizontal polarization can be used, as long as polarization is the same at both ends of each link. For any given pair of line-of-sight antennas, it is essential that they both have the same polarization. Differences in polarization among antennas – called "cross-polarization" – can reduce signal considerably.

6.4   Site Selection

At the high operating frequencies of the *AR24027* system, radio waves travel in a nearly straight line-of-sight path. This is in contrast to the lower-frequency radio waves used for AM broadcasting. These waves bounce between the ionosphere and the earth's surface to travel long distances and operate over and around obstructions. Higher-frequency radio waves do not behave in this manner and are greatly weakened by substantial obstructions or the absence of a direct path. Simply put, all antennas communicating with each other must be able to physically "see" each other.

For this reason, a proper antenna site must meet the following criteria:

1. For optimum performance at maximum range, there must be a clear line-of-sight path among all antennas that communicate directly with each other. At shorter ranges, some degree of obstruction may be tolerated, but performance in the presence of obstruction is difficult to predict.

2. Elevating one or more of the antennas in the system increases maximum line-of-sight range, called the radio horizon. If antennas are located at a greater range than the ground-level radio horizon, a means must be available for elevating the antennas.

3. All antennas must be properly oriented, and a directional antenna must be carefully aimed at its target antenna to ensure communication at maximum range.

4. All antenna cables attenuate (reduce) signal strength in proportion to their length. Since various cable types offer different attenuation levels, maximum length depends on cable type. Since the *AR24027* is designed for outdoor installation, it can be installed in close proximity to the antenna, reducing or eliminating cable losses.

Each of these criteria is discussed at greater length in the following paragraphs.

6.4.1   Line-of-Sight Path

Because high-frequency radio waves are attenuated by obstructions, a clear line-of-sight path between antennas is required for optimum performance at maximum range. For shorter ranges, a degree of obstruction may be acceptable. For example, at less than maximum ranges the radio has some ability to "penetrate" trees and other foliage. On the other hand, geographical features (hills) and large buildings are likely to interfere with communications, and antennas must be elevated to "see" each other above such objects.

Because of the uncertainties of radio communication, it is difficult to predict the results in conditions where obstructions exist. The only valid advice is to try the proposed configuration and be prepared to move or elevate the antennas.

6.4.2   Radio Horizon (Maximum Line-of-Sight Range)

In visual terms, the horizon is the point in the distance where an object drops out of sight because it is blocked by the earth's curvature. If the observer or object is elevated, the visual horizon is extended, that is, the object can be seen at a greater distance before it drops out of view.

The same concept applies to radio signals: The radio horizon is the point in the distance where the path between two antennas is blocked by the curvature of the earth. Like the visual horizon, the radio horizon can be extended by elevating the antennas to extend communication range.

The radio horizon can also be extended or shortened by certain phenomena such as refraction due to atmospheric density and temperature inversions. Fog and rain, which reduce signal strength, can also shorten the radio horizon although in the ISM band, this loss is negligible.

A reasonable approximation of the radio horizon based on antenna height can be obtained from the graph in Figure 6.2 . (Note that this graph does not take atmospheric effects into account.) To use the graph, set a straight edge so that it crosses the height of one of the antennas in the column on the left and the height of the other antenna in the column on the right. The radio horizon in miles/km is shown where the straight edge crosses the center column.

If the radio horizon is well within maximum communication range of the system, this graph provides a reasonable guide for antenna height. However, as maximum range of the system is approached, results are less reliable because of atmospheric effects and other unpredictable phenomena. In such cases, the more thorough point-to-point path analysis described in the next section should provide more reliable results.
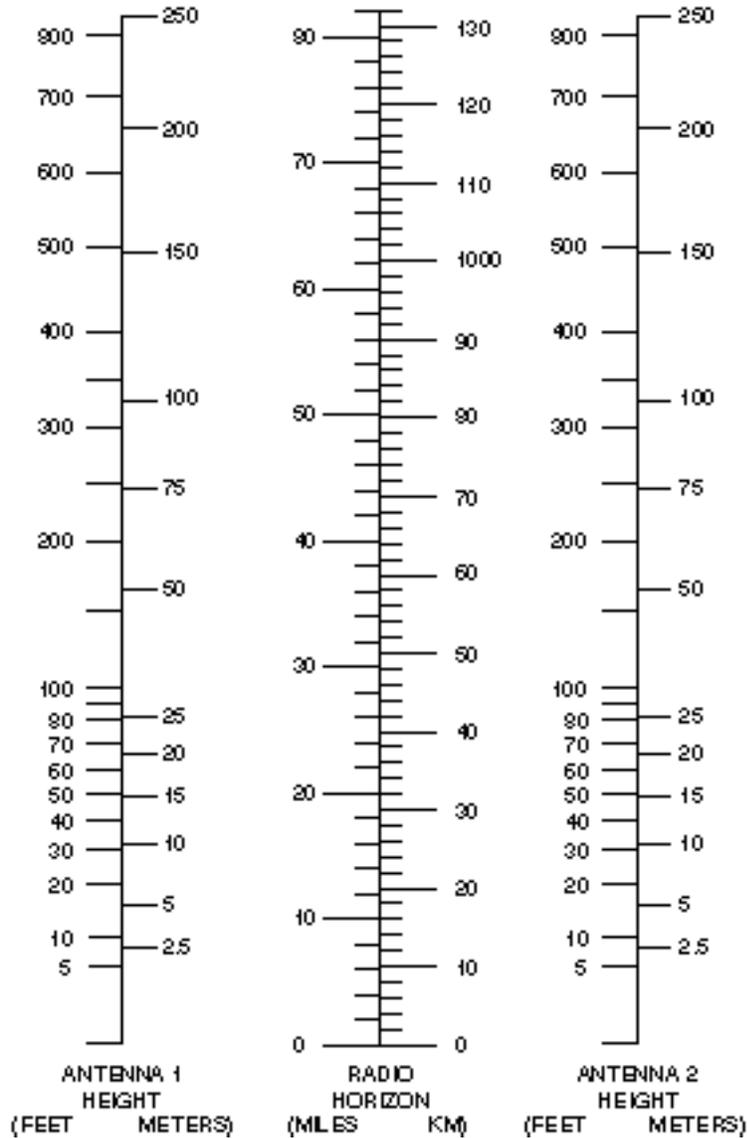
Figure 6.2 - Antenna Height and Radio Horizon Graph

6.4.3   Antenna Orientation

Antennas at each end of a communications link must be mounted similarly in terms of polarity, and directional antennas must be carefully oriented towards each other. 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 system antennas for horizontal polarization.

Orientation of directional antennas is critical because their sensitivity is greatly reduced outside a fairly narrow angle. Performance of the system can be seriously degraded by mis-aligned directional antennas. The *AR24027* has a built in feature that allows the operator to use an audio signal to assist in aligning the antenna. Refer to chapter 5 on the use of this built-in antenna alignment feature.

6.4.4   Cable Loss (Attenuation)

The *AR24027* is housed in a watertight enclosure so that it may be mounted in very close proximity to the antenna. Using short cables to connect the radio to the antenna reduces signal losses. Table 3.2 shows loss per 100 feet (30 meters) at 2.4 GHz for typical antenna cable types.

Table 3-2. Loss at 2.4 GHz for Standard Coaxial Cable Types

Cable Type	Loss per 100 ft. (30 m)
RG-8 A/U	14.4 dB
Belden 9913	8.0 dB
LMR 195	19 dB
LMR 400	6.7 dB

To determine total cable loss for your installation, perform the following calculation:

For US units, multiply length in feet by the loss figure and divide by 100.

For metric units, multiply length in meters by the loss figure and divide by 30.

For example, for a 75-foot length of Belden 9913, the loss is:

$$\frac{75 \times 8.0}{100} = 6.0 \text{ dB}$$

6.4.5   Connector Loss

Loss is introduced with each pair of cable connectors. Attenuation losses of some standard cable types are shown in the following table:

Connector type	Loss per connector
N-Type	0.25 dB
SMA-Type	0.25 dB

The loss of each pair of connectors on all cables must be included to determine the total signal loss (attenuation) between the radio and the antenna.

6.5   Point-to-Point RF Path Analysis

A full point to point analysis should include:

- Background noise evaluation of all locations where radios are to be installed

- Determination of the minimum antenna height required to obtain "line-of-sight".

- Calculation of the expected Receive Signal Strength (RSS) level to be received at each of the locations.

The background noise measurement is critical as it gives the operator a preview of the potential performance variations and the feasibility of utilizing a particular radio at a location. For example, if the background noise is found to be at the same level as the radio sensitivity (when set to maximum speed), a tradeoff analysis can be conducted before installation to determine if lowering the data rate will allow the radio sufficient link margin to operate. The *AR24027* includes a built-in spectrum analysis tool that can be used to perform this background scan.

A line-of-sight is required to insure the best performance from the radio. The calculations below will allow the operator to build towers and other mounting areas to the correct height before the antennas are installed.

The calculation of the RSS level is useful for two purposes. The first is to determine the link margin at the site. This information, when coupled with the background noise measurement, will tell the operator if a link can be established and give a reasonable "a priori" estimate of the performance of the system. In addition, the calculated RSS level allows the operator to do a quick check on the integrity of the system installation by verifying that the actual RSS level (reported by the radio) is close to the calculated value.

6.5.1   Antenna Height Analysis

Although the graph of Figure 6.2 provides a useful guide to antenna height requirements, a more accurate determination of those requirements can be obtained by means of the analysis described in the following steps. Note that computer programs, available from many vendors, can perform portions of this procedure.

Requirements for this procedure are:

- A topographical map of the installation site.

- Graph paper, ten divisions per inch or equivalent metric scale

- Straight edge

- Calculator

Procedure:

1. On the topographic map, plot the precise location of each antenna site.

2. Draw a line between the sites; this line is the radio path.

3. On the graph paper, establish a vertical axis for elevation and a horizontal axis for distance. It is usually easiest to make the vertical axis in feet or meters and the horizontal axis in miles or kilometers.

4. Following the radio path line on the map, identify all obstructions. Most topographical maps identify geographic information, such as hills and lakes, only. However, vegetation, buildings or other structures that will interfere with radio transmissions must also be included.

5. Plot each obstruction on the graph, marking its elevation and distance from the sites. For dense vegetation such as forests, add 40 to 60 feet (12 to 18 m) to the ground elevation.

6. Add the Earth's curvature to the height of each obstruction. For each obstruction calculate this increment by using the following formula:

$$d = \frac{d1 \times d2 \times C}{K}$$

Where:

(for US units:)

d	=	additional height increment in feet
d1	=	distance of the obstruction from the first site in miles
d2	=	distance of the obstruction from the second site in miles
C	=	.667 for US units
K	=	refractive index (use a value of 1.33).

(or for metric units:)

d	=	additional height increment in meters
d1	=	distance of the obstruction from the first site in km
d2	=	distance of the obstruction from the second site in km
C	=	.079 for metric units
K	=	refractive index (use a value of 1.33).

Add the "d" value to the height of each obstruction plotted on the graph.

7. Add the Fresnel Zone clearance to the height of each obstruction (the required increment is 60% of the first Fresnel zone radius). For each obstruction calculate the increment using the formula:

$$d = C\sqrt{\frac{d1 \times d2}{F \times D}}$$

Where:

(for US units:)

d	=	60% of the first Fresnel zone radius in feet
d1	=	distance of the obstruction from the first site in miles
d2	=	distance of the obstruction from the second site in miles
C	=	1368 for US units
F	=	2400 (frequency in MHz)
D	=	total path length in miles (d1 + d2).

(or for metric units:)

d	=	60% of the first Fresnel zone radius in meters
d1	=	distance of the obstruction from the first site in km
d2	=	distance of the obstruction from the second site in km
C	=	259 for metric units

F   =   2400 (frequency in MHz)
D   =   total path length in km (d1 + d2).

Add the "d" value to the height of each obstruction plotted on the graph.

8. Determine ideal antenna height by drawing a line on the graph between the sites and across the top of the obstruction heights. Note the elevation at each antenna site.

6.5.2   Receive Signal Strength Calculation

This section shows how to calculate the RSS level expected at the radio and to determine the theoretical link margin. The AFAR "RF Link Budget Calculator", available in the CD or at the website, that performs all of these computations.

1. Determine free-space path loss, using either the following formula or the graph of Figure 6.3.

$$-L = C + 20\log(D) + 20\log(F)$$

Where:

(for US units)
    -L =   loss in dB
    C =   36.6 for US units
    D =   path length in miles
    F =   2400 (frequency in MHz)

(or for metric units)
    -L   =   loss in dB
    C   =   32.5 for metric units
    D   =   path length in km
    F   =   2400 (frequency in MHz)

For example, for a distance of 10 miles

$$-L = 36.6 + 20\log(10) + 20\log(2400)$$

$$-L = 124 dB$$
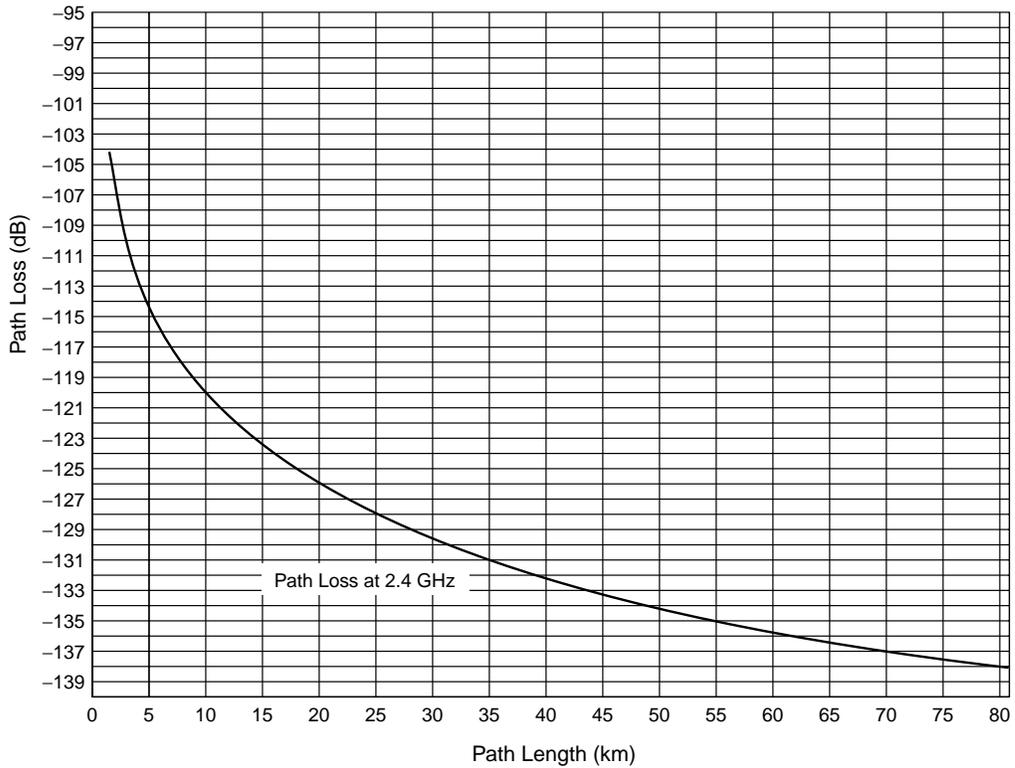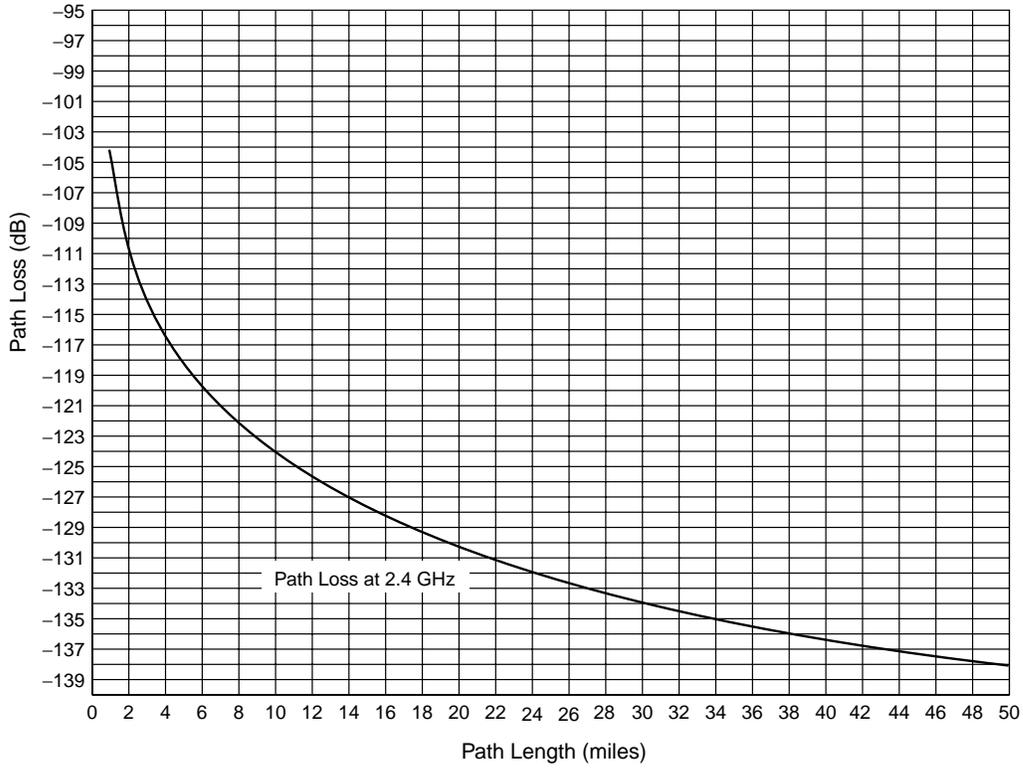
Figure 6.3 - Free-Space Path Loss at 2.4 GHz

2. Calculate effective radiated power (ERP) at the transmit antenna using the formula:

$$ERP = TxPower - CableLoss + AntennaGain$$

Since the *AR24027* is housed in an outdoor enclosure, there is usually little or negligeable cable loss if the antenna is connected directly to the radio connector. However, if an additional cable is used between the radio and the antenna, the cable loss (attenuation) must be included.

Transmit output power	=	+ 23 dBm
Cable and connector loss	=	- 2 dB
Transmit antenna gain	=	+ 18 dB
Effective Radiated Power	=	+ 39 dBm

NOTE: Table 3.2 lists attenuation values for various cables.

3. Calculate the RSS level at the receive radio using the formula:

$$\textbf{RSS = ERP - Lp + Gr - Cl}$$

Where:

ERP	=	Effective Radiated Powerfrom the transmit antenna
Lp	=	Path loss
Gr	=	Gain of the receive antenna
Cl	=	Cable and connector losses between antenna and receive radio

For the above system, at a distance of 10 miles, Effective Radiated Power of 39 dBm, receive antenna gain of 24 dB, and cable loss of 2 dB, the equation would be:

$$\textbf{RSS = 39 dBm - 124 dB + 24 dB – 2dB}$$
$$\textbf{= -63 dBm}$$

4. Calculate link margin by subtracting radio sensitivity from the calculated RSS level.

Calculated RSS level at receiver	=	-63 dBm
Sensitivity of *AR24027* at 2.7 Mbps	=	-85 dBm
link margin	=	+22 dB

This figure, link margin, is the amount of signal received by the radio that is above the minimum required for the radio to meet its performance characteristics. This value is important since it gives the operator an indication of how much signal fade the system can tolerate. Signal fading may be caused by multiple radio paths (reflections) atmospheric conditions such as rain, temperature inversions, fog, etc., and may last anywhere from a few moments to several hours and cause as much as 20 to 30 dB of signal strength loss. Although it is possible to operate a system with a link margin as low as 5 dB, as a general rule of thumb it is recommended that all systems have a link margin of better than 20 dB.

6.6   Antenna Grounding

WARNING

VERY IMPORTANT INFORMATION

As an elevated metal object with a wire connection below, an antenna is an excellent lightning attractor, and an effective ground must be provided to deflect lightning strikes to ground. An additional advantage of effective system grounding is the minimizing of electrical noise and interference, which can significantly degrade system performance.

Grounding involves providing a good, very low resistance connection from the antenna and radio to earth ground to provide a better path for lightning and electrical noise than that through the equipment. The following points should be taken into account in setting up system grounding:

- The antenna should be mounted on a mast or tower that is well grounded to earth.

- All antenna lead connectors should be correctly installed to provide a good, solid connection to the cable shield.

- Threaded couplings mating antenna lead connectors should be clean and tight; bayonet type connectors should not be used.

- Weatherproof connectors must be used for outdoor connections to prevent corrosion, which will interfere with grounding.

- All power and antenna grounds should be made common at a single point such as an equipment rack, cabinet enclosure chassis, or antenna tower. This single-point ground should have a solid ground connection to earth.

- If the unit is installed indoors, a surge arrestor or lightning protector should be installed at the point where the antenna cable enters the building or cabinet. The lightning protector should be properly grounded at the single-point chassis ground. Carefully follow the installation instructions provided by the manufacturer of the protection device. Appropriate lightning protectors are available from AFAR Communications Inc.

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
ethernet	speed	auto-10, 10hdx, 10fdx 100hdx, 100fdx, auto	auto-10
	timeout-sec	5..1800	30
	multi-cast-timeout-sec	5..3600	600
node	type	middle, left, right	middle
	name	(23 character string)	lnw-nnnnn
	network-id	0..65535	0
	location	(25 character string)	
	contact	(25 character string)	
rf-left-setup	receive-channel	3..37	20
	speed-mbps	0.25, 0.50, 1.37, 2.75	2.75
	power-dbm	0..23	18
rf-right-setup	receive-channel	3..37	25
	transmit-channel	3..37	25
	speed-mbps	0.25, 0.50, 1.37, 2.75	2.75
	power-dbm	0..23	18
single-node-reboot	timeout-sec	30..3600	900

Internet Protocol (IP) Management Commands

Command	Parameters	Values
ip-configuration	address	ip address
	netmask	ip address
	gateway	ip address
ping	destination	ip address
	count	0..500 (def **4**)
	size-bytes	32..1400
snmp	manager	ip address
	community	ASCII string (9 max)
	access	g, gs, gt, gst
	authentication-traps	0, 1
	delete	1..4

Installation and Link Monitoring Commands

Command	Parameters	Values	Factory Configuration
antenna-alignment-aid	mode	off a-antenna, b-antenna	off
monitor-link	clear	**0**, 1	
show-tables	table	**status** ethernet econsole radios ip-stack	
	format	**count** times	
spectrum-analysis	input	**a-antenna** b-antenna	
	display	**graph** table	
	dwell-time-ms	1…1000 (def: **20**)	
time-analysis	channel	0..50	
	input	**a-antenna** b-antenna	
	display	**graph** table	
	dwell-time-ms	1, 2, 5, 10, **20**, 50, 100, 200, 500	

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	
RF Frequency Band	2.406 GHz to 2.474 GHz (center frequencies)
RF Signal Bandwidth (-20 dBc)	4.6 MHz
RF Channels	35 (12 non-overlapping)

Transmitter Output Power
  FCC
  CE
	
	0 to 23 dBm
	0 to 20 dBm

Modulation Type	direct sequence spread spectrum
RF Data Rates (one way)	0.25, 0.50, 1.375, 2.75 Mbps
Receiver Sensitivity (10^{-6} BER)	-97 dBm (@ 0.250 Mbps) -94 dBm (@ 0.500 Mbps) -93 dBm (@ 1.375 Mbps) -90 dBm (@ 2.750 Mbps)
Data Interfaces	
Auxiliary Port	RS-232
Ethernet Port	10/100 BaseT (auto-negotiate)
Power Requirements	

Input Voltage (Outdoor Unit)
  Standard:
  High voltage model:
	
	+8 to +28 Volts DC
	+12 to +32 Volts DC

Input Voltage (AC)	110 VAC or 220 VAC
Power Consumption	less than 5 Watts
Environment	
Temperature	-40 to +70 Degrees C
Max. Humidity	90% non-condensing
Mechanical:	
Dimensions	4.72" wide x 8.66" high x 2.20" deep (120mm W x 220 H x 56 D)
Weight	2.4 lbs. (1.1 Kg).

APPENDIX C – Channel Frequency Assignment

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

Freq(MHz) = 2400 + 2 x Channel_number

The table below shows the frequencies for all channels that fall in the ISM band.

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

Number of Non-Overlapping Channels	Suggested Channel Allocation	Frequency Separation (MHz)
12	3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36	6.0

APPENDIX D – Ethernet Console Program

Short description

The ethernet console program was developed in order to accommodate the remote configuration of a radio, i.e. the configuration in cases where the physical access to the radio is not feasible, or it is cumbersome. The software consists of two parts: the client and the server. The client runs on the administrator's PC, while the server runs on the radio.

The communication is done via a TCP-like protocol. There is an acknowledgment for every packet that is sent, as well as a retransmission mechanism when a packet gets lost.
Each radio allows multiple sessions, i.e. more than one client can be connected concurrently to the same server (radio). Nevertheless, for performance reasons, it is not recommended to have more concurrent sessions than they are really needed, and definitely not more than the maximum number which currently is 4.

System requirements

- Win95, Win98, Windows ME, WinNT, Win2000, WinXP
- NetBIOS installed
- WinPCap installed

Note: With regard to Windows NT platform, the code has been tested with versions 4.0, or newer. There is also a Linux beta version

Installation for Windows

In order to install the WinPCap library, if not already installed, just click on the WinPCap.exe. Support and updates for this library can be found at http://netgroup-serv.polito.it/winpcap/. It is strongly suggested to uninstall older versions of the library and reboot the machine before installing the new one. NetBIOS is a software component that comes by default with all Windows system, so you don't have to install it. To start the Econsole, simply open a MS-DOS window and type *econ*. For available command line arguments, please read the "*input arguments*" section.

Included files

- *win_readme.doc* The file that you are reading
- *econ.exe* The EConsole client
- *WinPCap* The Windows installer for the WinPCap library
- *input_script.txt* A sample input script file, that contains a list of radio commands.

Input arguments

You can provide the following arguments in the command line, even though none of them is required.

Input file

There are two sources for the input commands: the keyboard, or a text file. The second option is useful when you are running the same set of commands periodically, so you want to avoid retyping them every time you want to execute them. If there is an input file in the command line, then the keyboard will be deactivated and only the function keys will be available. If the specified file cannot be found, the application will be terminated.

example:
C: > econ -i input.txt

Sample input file:

help
 # this is a comment - note that the character # must appear as the fist character
time
date
 # the following is a local command specifying a delay in seconds
. delay 10
time
. delay 1.5
version
logout

As you probably noticed from the above file, all the lines are interpreted as radio command, unless:
a) They start with the character '#' which implies a comment
b) They start with the character '.' which implies a local command. Currently there is only one local command, namely the *delay < time in secs>*

Important note: All the input scripts should end with the *logout* command. Since all the commands are terminated with the new line character, there must be one command per line and after the final *logout* command you must have an extra empty line.

Output file

When you want to capture the output of a session into a text file, you can pass the filename as an argument. If the file does not exist it will be created, otherwise it will be overwritten.

example:
>econ -o output.txt

Radio MAC address

If you are interested in a specific radio, you can pass its MAC address and let the client ignore any response from other radios. That's very handy when you are always getting connected to the same radio and you want to avoid the manual selection of a preferred one. Very useful also in case you are using scripts for fully automated procedures.

example:
>econ -r 00:78:24:22:BA:4F

Radio Serial Number

The same functionality as above (see Radio MAC address) can be achieved by providing the radio serial number, instead of the radio physical address. Note that you should <u>not</u> include the initial UC characters of the serial number (i.e. type *11078* instead of *UC11078*)

example:
>econ -r 11787

Local Physical Address
Even though econsole identifies the PC local physical address automatically, there are some cases in which the user wants to specify the local address on his/her own. These cases usually arise when there are multiple NIC cards with the same names under WinNT operating system. In such case, the econ might pick up the wrong MAC address, and therefore the user should supply manually the physical address as a command line argument.

example:
>econ -m 00:78:24:22:BA:4F

Inverse Screen Colors
You can change the default settings (white texture on black background) by providing the -b option, which will change the settings to black characters on white background.

example:
>**econ -b**

Change the console window size
Currently you can specify two values, either 25 or 50. These values indicate the number of lines of the MS-DOS window.

example:
>**econ -l 50**

Help
Function keys, including F1, are activated after you get connected to a radio. If you want to get help from the command line, you can use the -h argument.

example:
>**econ -h**

Syntax:
econ *<argument list>*
argument list = *argument list | argument | {}*
argument = *-o outputfile | -i inputfile | -r MAC address*

Examples
Let's say you want to read a list of commands from the text file called in.txt, and capture the output to a text file called out.txt. You are also interested only in a specific radio with MAC address equal to 00:78:24:22:BA:4F. In that case, you will start the EConsole with the following arguments (the arguments order is irrelevent):

>econ -i in.txt -o out.txt -r 00:78:24:22:BA:4F   *or*

If you are reading from the keyboard, and you are simply interested in capturing the output of the session, use the following syntax:

>econ -o out.txt

Since no input file was specified, it is assumed that the keyboard will be used for input, and ALL radios will participate in the discovery process.

Function Keys
Currently there are 6 different function keys.
F1 - Online help - gives a short description of the other function keys and the input   arguments
F2 - Active/deactivate diagnostic messages. Initially diagnostic messages are not shown, therefore if you want to see them you should press F2. Diagnostic messages include warnings, and retransmission info in order to get an idea of the connection's speed/integrity. Error messages are always shown.
F3 - Terminates the current session and closes the application.
F4 - Close the session with the current radio and display the results of the initial discovery phase to allow the user to connect to a new radio.
F5 - Reverse/Restore screen settings. Initially the screen displays white letters on black background, but you can reverse it to black letters on a white background.
F6 - Increases the console window buffer. This introduces a side bar which enables the user to scroll up and down. Available in Windows NT Only.

Troubleshooting & Updates

Common problems
1. Failed to open adapter
This usually happens when you haven't installed properly the WinPCap library, or you have and older version of it. Please visit http://netgroup-serv.polito.it/winpcap/ to get the latest version. You should also make sure that your Ethernet adapters are working properly.

2. Cannot find radio(s) even though they are running properly
Make sure that:
- The ethernet cables are OK
- You are getting connected to the right network segment (i.e. try all ethernet adapters)
- You are using the right MAC address. The system tries to identify the adapter physical address through some NetBIOS calls in the Win9X case, or some NDIS queries in the WinNT/Win2000 case. If NetBIOS is not installed, the econ will probably use the wrong local host MAC address. Also if there are more than one Ethernet adapter installed with the same name, this might cause problem in the WinNT case.
Resolution: Use the command line argument to specify the correct physical local address. You can see all the local physical address by executing the *ipconfig -all* command. Example:
>econ -m 00:78:24:22:BA:4F

3. Find a radio but not getting connected
Check if the maximum number of sessions has been reached. The maximum number of sessions on the server side is limited to four, therefore you should NOT connect to the same radio multiple times if not absolutely necessary. When the number of sessions reaches the limit the radio will ignore any new discovery messages.

Another reason might be a unreliable RF link causing a high packet loss. Since during the discovery phase there isn't any retransmission mechanism, it is quite possible that you managed to "see" the radio, but you weren't able to connect to it, because the connection request packet was lost. In such case, try to connect again.

4. High drop rate - screen freezes momentarily - connection times out
   There are two possible causes.
   1. The link between the client (PC) and the server (radio) is very weak. If the packet drop rate is more than 20%, then the connection is problematic.
   2. There are multiple sessions opened on the same server. With many concurrent sessions the server response may be noticeably slower. Always close the session gracefully by executing the *logout* radio command, and not by closing the MS-DOS console. If the *logout* command is not issued the session at the server will remain open for an additional 15 minutes. Use the *list long* command to find out the number of open sessions.

5. If I leave the client inactive for half an hour, and try to type a new command, I get an unable to transfer packet message or I get a "session timeout - application will be closed" message.

An open session times out after 15 minutes of inactivity on the server side, and 30 minutes on the client side.

Report a bug & Updates
Please visit htttp://www.afar-inc.com/ for more info.

Acknowledgments

The WinPCap library was obtained from "Politecnico di Torino" and the code is distributed in binary form as part of the Econsole. The following copyright notice applies to that library.
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APPENDIX E – 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.
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

SW16

19

Kupplung
Socket
connecteur femelle

Montageschlüssel 0380
wrench 0380
clé de montage 0380

ITEM

ITEM		
1	WHT/OR	
7	OR	
2	WHT/GR	
3	WHT/BR	
5	WHT/BLU	
4	GR	
8	BLU	
6	BR	

ITEM

RADIO_ETH_TX+	1	WHT/OR
RADIO_ETH_TX-	2	OR
RADIO_ETH_RX+	3	WHT/GR
VDC	4	WHT/BR
VDC	5	WHT/BLU
RADIO_ETH_RX-	6	GR
GND	7	BLU
GND	8	BR

RJ 45

W/OR   1

BR

NO TAB

W/OR

W/GR   GR   4

W/BL   2

5   3

1   7   OR

6   BR

8   BL

W/BR

Solder

REAR

Cable Length, in feet, specified in part
number:

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

	MATERIAL		
ITEM	PART NO.	MANUFACTURER	DESCRIPTION
1	5EXH04P24-BK-R-CMS-PV	CommScope	Cable, CAT5, Outdoor, Solid Cond.
2	AT8X8SC-2224	Allen Tel	Plug Connector, 8 Cond., RJ45-type
3	0321 08 or 0322 08 (fig. A)	Lumberg USA	8 Pin Field Connector, Female

REVISION

RE	DESCRIPTIO	DAT	APPROVA
A	Initial Release	09/16/03	J.B

APPLICATIO

NEXT	USED

SW16

19

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.

AFAR Communications,

DRAWN	DAT
J. Becker	9-16-2003

CHECKED BY	DAT

TITL   **3 Pin Console Cable**

APPROVE	DAT

DRAWING	CBL-0403-	RE	A

APPROVE	DAT

SCAL	NON	SHE	T	1

ITEM #2

1
2
3

ITEM #1
DB-9

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

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

1
2
3

ITEM #2

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

5   1
9   6

ITEM #1
DB-9

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.