NOT MEASUREMENT SENSITIVE

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30 NOVEMBER 1994

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4 APRIL 1994

MILITARY STANDARD

INTERFACE AND PERFORMANCE STANDARD FOR AUTOMATED CONTROL APPLIQUE FOR HF RADIO

AMSC N/A

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DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

FOREWORD

1. This military standard is approved for use by all Departments and Agencies of the Department of Defense (DoD).

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: HQ, U.S. Army Information Systems Engineering Command, ATTN: ASQB-OST, Fort Huachuca, Arizona 85613-5300, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

3. In accordance with DoD Instruction 4630.8, it is DoD policy that all forces for joint and combined operations be supported through compatible, interoperable, and integrated Command, Control, Communications, and Intelligence (C3I) systems. Furthermore, all C3I systems developed for use by U.S. forces are considered to be for joint use. The Director, Defense Information Systems Agency (DISA), serves as the DoD single point of contact for developing information technology standards to achieve interoperability and compatibility. All C3I systems and equipment shall conform to technical and procedural standards for compatibility and interoperability, as developed or recommended by the DISA.

4. Military Standards in the 187 series (MIL-STD-187-XXX) address telecommunications design parameters based on evolving technologies and concepts that may be subject to change. These planning standards differ from military standards in the 188 series (MIL-STD-188-XXX) which address telecommunications design parameters based on mature technologies. Nothing in a MIL-STD-187 series document is mandatory unless invoked in a contract, and then only to the extent of the contractual agreement.

5. Planning standards are developed considering present and future plans for the Defense Information System, commercial systems (both national and international), and North Atlantic Treaty Organization (NATO) and other allied military systems. These planning standards may be based on, or make reference to, draft or mature American National Standards Institute (ANSI) standards, International Telecommunications Union - Telecommunications (ITU-T) recommendations, International Organization for Standardization (ISO) standards, NATO standardization agreements (STANAG), and other standards, wherever applicable. MIL-STD-187-XXX standards provide uniform guidance for the design of the evolving and future Defense Information System. Providing this guidance as early as possible will minimize ineffective designs and costly interoperability

problems at later stages of implementation. It will also help to ensure utilization of appropriate advances in technology.

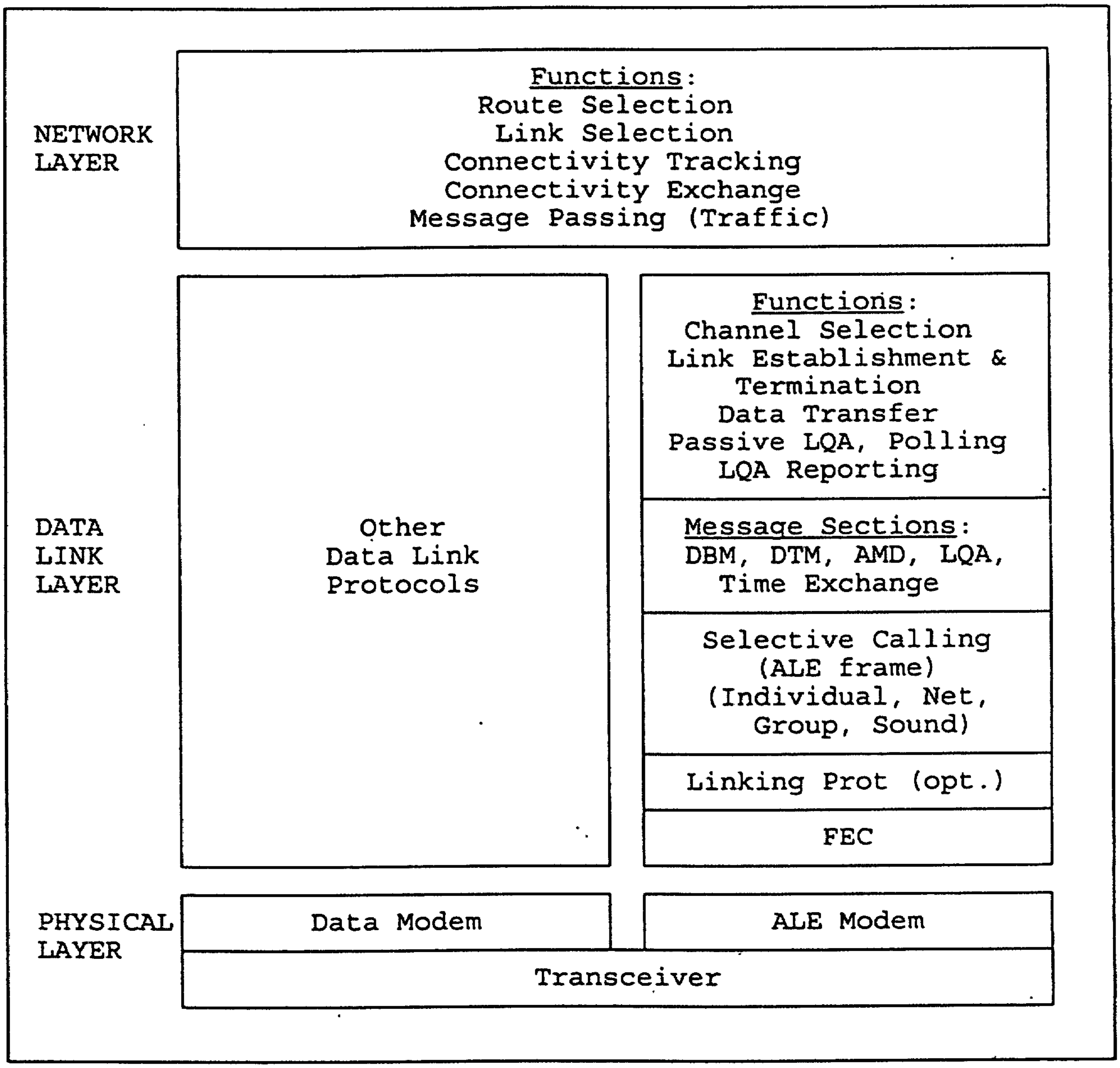
6. The treatment of automatic link establishment (ALE) in MIL-STD-188-141 provides the technical foundation upon which this document rests. The second generation ALE system was one of the adaptive high frequency (HF) radio features developed through a MITRE effort in 1986. The remainder of the original concept is being documented in MIL-STD-187-721. Therefore, a brief summary of the basic principles of this ALE system is provided.

7. The principal functions included in an automated HF station are shown schematically on the following figure. This diagram is structured along the lines of the ISO Open Systems Interconnection Reference Model, with functions at each layer supporting higher layers and using lower layers.

8. MIL-STD-188-141 specifies a basic HF radio, along with a set of robust physical and data link layer functions for ALE. The ALE modem employs 8-ary frequency shift keying (FSK) with 8 millisecond (ms) tones; the 3-bit symbols are sent at a rate of 125 per second, giving a raw data rate of 375 bits per second (bps). Forward error correction (FEC) coding is applied to the 24-bit ALE words used at the data link layer; a (24,12) Golay code is applied to each (12-bit) half of the 24-bit ALE word, producing two 24-bit results. These two 24-bit Golay words are then interleaved bit by bit, and a stuff bit is appended to produce a 49-bit word to be transmitted. Finally, each 49-bit word is sent three times, which allows the receiver to correct some errors using 2 of 3 majority voting.

9. At the receiver, received bits from the modem are (conceptually) shifted into a 99-bit register. Majority voting among the outputs of this shift register yields a 48-bit "majority word" (stuff bits are discarded), which is de-interleaved to produce two 24-bit Golay words. These are delivered to the Golay decoder, which attempts to recover a 24-bit ALE word.

10. Because no bits in the ALE word are spent on synchronization, the acquisition of word sync in this system employs a series of tests on the prospective word after each received symbol (tri-bit) is shifted in. First, the number of unanimous votes in the majority vote decoder must exceed a threshold. Next, the Golay decoder must successfully decode both halves of the 48-bit word. Finally, the resulting 24-bit ALE word must be acceptable to the ALE protocol module. Once word sync has been achieved, it is automatically tracked for the remainder of the transmission using these same tests.



Functional hierarchy of an automated HF station.

11. The MIL-STD-188-141 data link layer comprises several sublayers. The lowest sublayer is concerned with error detection and correction (FEC sublayer). Above this is an optional protection sublayer (linking protection), which protects layers above it from unwanted interference. The ALE protocol is divided into three sublayers on the figure above: the lowest manages the exchange of ALE frames among stations that are specified using a standardized addressing structure; the next deals with orderwire and other message sections embedded within ALE frames; and the

highest contains the data link layer functions apparent to users, such as channel selection, link establishment, and orderwire communications.

12. The contents of this document provide the technical parameters for the functions and features of advanced adaptive HF radio, and provide logical and cohesive guidelines for both industry and the Government. Many of these advanced techniques will support third generation ALE.

13. The technical parameters of this standard have not been verified by testing or implementation. Careful engineering, desk top modeling, and simulation are the source of these parameters. The preparing activity and the custodians are confident that the technology is definitively developed and is technically sound. Users of this standard are requested to inform the preparing activity and the Lead Standarization Activity (see address below) of planned implementations, the status of those implementations, and any problems encountered in applying this standard.

Preparing Activity

U.S. Army Information Systems
Engineering Command
ATTN: ASQB-OST
Fort Huachuca, AZ 85613-5300

Lead Standardization Activity

Joint Interoperability and
Engineering Organization
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1. SCOPE

1.1 Scope. The purpose of this document is to describe the technical parameters for adaptive high frequency (HF) radio that are more advanced than those described in MIL-STD-188-141. This document is structured segmentally, with each segment having been added as it was developed. Together, these segments will guide the planning of military adaptive HF radio network technology into the 21st century. To fully understand and utilize this document, it is necessary to refer to portions of MIL-STD-188-141 for the basic automatic link establishment (ALE) criteria.

1.2 Applicability. This standard is approved for use within the Department of Defense (DoD) for the design and development of new (adaptive) HF radio equipment. MIL-STD-187-721 contains theoretical designs and solutions that have been supported by desk top analysis and modeling, but in most cases this technology has not been imbedded into hardware/software or undergone proof of concept testing.

1.3 Application guidance. MIL-STD-187-721 is a planning standard organized in segments to allow the various functions and features of adaptive radio to be documented separately to encourage technical development. MIL-STD-188-141 contains only technical documentation that is supported by empirical data, whereas this standard documents the advanced techniques, providing a greater level of technology, but not yet supported by test data. Either a DoD user or an industry manufacturer may develop hardware or software implementations of technical parameters described in a MIL-STD-187-XXX document. A manufacturer may wish to implement the technical parameters described in this document in order to be first in a market offering, thereby gaining market and advertising advantage. A DoD user organization also may have a requirement for technical features described in this document and may include MIL-STD-187-721 in an acquisition contract, thereby causing the development of the equipment or software as a part of the contractor's effort. Whether a manufacturer implements a MIL-STD-187-721 function using "venture capital" or a Government agency "sponsors" the development through inclusion in a contract, the result is the same: testable hardware/software and empirical data. This empirical data allows the MIL-STD-187-721 segment (wholly or in part) to migrate into a MIL-STD-188 series document. This process provides a logical and orderly progression while assuring a level playing field for Government and industry alike. Additional application guidance for DoD acquisitions is contained in paragraphs 6.1.2 and 6.1.3.

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2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation.

STANDARDS

FEDERAL

FED-STD-1037	- Telecommunications: Glossary of Telecommunications Terms.

MILITARY

MIL-STD-188-110	- Interoperability and Performance Standards for Data Modems.
MIL-STD-188-141	- Interoperability and Performance Standards for Medium and High Frequency Radio Equipment.
MIL-STD-1777	- Internet Protocol.
MIL-STD-2045-14502-01	- Internet Transport Profile for DoD Communications, Part 1, Transport and Internet Services.

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, ATTN: NPODS, 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

USAISEC Technical Reports

ASQB-OSI-S-TR-92-04	- A 24-Bit Encryption for Linking Protection (Johnson Algorithm).

TR 94089	- Management Information Base for Automated High Frequency Radio, Networking.
TR 94142	- HF Data Link Protocol.

(Requests for this document shall be referred to: Commander, U.S. Army Information Systems Engineering Command, ATTN: ASQB-OST, Fort Huachuca, Arizona 85613-5300.)

2.2 Non-Government publications.

STANDARDS

ISO/IEC 3309:1991	- Information Technology-Telecommunications and Information Exchange Between Systems-High Level Data Link Control (HDLC) Procedures-Frame Structure.
ISO/IEC 8824	- Information Technology-Open Systems Interconnection-Specification of Abstract Syntax Notation One (ASN.1).
ISO/IEC 8825	- Information Technology-Open Systems Interconnection-Specification of Basic Encoding Rules for Abstract Notation One (ASN.1).

(Application for copies should be addressed to the International Organization for Standardization, Geneva, Switzerland.)

IEEE STANDARDS

IEEE 802.2	- Logical Link Control (LLC) and Medium Access Control (MAC).
IEEE 802.3	- Carrier Sense Multiple Access with Collision Detection (CSMA/CD).

(Application for copies should be addressed to the IEEE, Inc., 345 East 47 Street, New York, NY 10017.)

INTERNET DOCUMENTS

RFC-768	- User Datagram Protocol.

RFC-1321	- The MD5 Message-Digest Algorithm.
RFC-1441	- Introduction to Version 2 of the Internet-standard Network Management Framework.
RFC-1442	- Structure of Management Information for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1443	- Textual Conventions for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1444	- Conformance Statements for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1445	- Administrative Model for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1446	- Security Protocols for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1447	- Party MIB for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1448	- Protocol Operations for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1449	- Transport Mappings for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1450	- Management Information Base for Version 2 of the Simple Network Management Protocol (SNMPv2).
RFC-1451	- Manager-to-Manager Management Information Base.
RFC-1452	- Coexistence Between Version 1 and Version 2 of the Internet-Standard Network Management Framework.

RFC-1540 - Internet Official Protocol Standard.

RFC-1662 - PPP in HDLC-Like Framing.

(May be obtained by anonymous ftp from nis.nsf.net or nic.ddn.mil.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Terms. Definitions of terms used in this document are in accordance with (IAW) the current edition of FED-STD-1037. In addition, the following definitions are applicable for the purposes of this standard.

a. Any-media - A network capable of routing traffic over a variety of physical media, and of dynamically adapting to the acquisition and loss of entire subnetworks.

b. Application level 0 (AL-0) - In adaptive radio, the unprotected application level of linking protection.

c. Application level 1 (AL-1) - In adaptive radio, the unclassified least protected application level of linking protection.

d. Application level 2 (AL-2) - In adaptive radio, the unclassified, enhanced application level of linking protection.

e. Application level 3 (AL-3) - In adaptive radio, the unclassified but sensitive application level of linking protection.

f. Application level 4 (AL-4) - In adaptive radio, the classified application level of linking protection.

g. Linking protection (LP) - In adaptive radio, a technique that protects the linking functions from unintentional or malicious interference by scrambling the ALE signaling exchanged among protected stations for cryptographic authentication of HF ALE signaling.

h. Multi-media - A network capable of routing traffic over more than one physical medium.

i. Protection interval (PI) - In linking protection, transmissions are encrypted using time-varying randomization data. The period between changes in the time of day portion of this randomization data is termed a protection interval.

j. Trap - An unsolicited message from a logical element to a management station that announces the occurrence of an exceptional event.

3.2 Abbreviations and acronyms. The abbreviations and acronyms used in this document are provided below. Those listed in the current edition of FED-STD-1037 have been included for the convenience of the reader.

a. ACK - acknowledgement.

b. ADC - available data capacity.

c. AI - articulation index.

d. AL-0 - unprotected application level.

e. AL-1 - unclassified application level.

f. AL-2 - unclassified enhanced application level.

g. AL-3 - unclassified but sensitive application level.

h. AL-4 - classified application level.

i. ALE - automatic link establishment.

j. ALQA - advanced link quality analysis.

k. AMD - automatic message display.

l. AME - automatic message exchange.

m. ANSI - American National Standards Institute.

n. ARQ - automatic repeat-request.

o. ASCII - American Standard Code for Information Interchange.

p. ASN.1 - abstract notation one.

q. AVQ - achievable voice quality.

r. BBS - bulletin board system.

s. BCD - binary-coded-decimal.

t. BER - bit error ratio.

u. bps - bits per second.

v. C3I - Command, Control, Communications, and Intelligence

w. CLNP - connectionless network protocol.

x. CMD - ALE preamble word COMMAND.

y. CONEX - connectivity exchange.

z. CQM - channel quality measure.

aa. CRC - cyclic redundancy check.

ab. CSMA/CD - carrier sense multiple access with collision detection.

ac. DATA - ALE preamble word DATA.

ad. dB - decibel.

ae. dBm - decibel referenced to one milliwatt.

af. DBM - data block message.

ag. DCS - Defense Communication System.

ah. DISA - Defense Information Systems Agency.

ai. DO - design objective.

aj. DoD - Department of Defense.

ak. DODISS - Department of Defense Index of Specifications and Standards.

al. DTM - data text message.

am. EFI - error-free interval.

an. FEC - forward error correction.

ao. FSK - frequency shift keying.

ap. HDLC - high-level data link control.

aq. HF - high frequency.

ar. HFDLP - HF data link protocol.

as. HFNC - HF networking controller.

at. HFTP - HF transport protocol.

au. HNMP - HF network management protocol.

av. HRMP - HF relay management protocol.

aw. HSSP - HF station status protocol.

ax. Hz - Hertz.

ay. IAW - in accordance with.

az. ICD - interface control document.

ba. ICMP - internet control message protocol.

bb. ID - identification.

bc. IEC - International Electrotechnical Commission.

bd. IEEE - Institute of Electrical and Electronics Engineers.

be. iff - if and only if.

bf. IP - internet protocol.

bg. ISO - International Organization for Standardization.

bh. ITU-T - International Telecommunications Union - Telecommunications.

bi. kHz - kilohertz.

bj. LC - link controller.

bk. LCIP - link controller interface ptotocol.

bl. LCP - link control protocol.

bm. LEA - limited exclusion area.

bn. LLC - logical link control.

bo. LP - linking protection.

bp. LPCM - linking protection control module.

bq. LPL - linking protection level.

br. LPM - link performance measure.

bs. LPT - linking protection time.

bt. LQA - link quality analysis.

bu. lsb - least significant bit.

bv. MAC - medium access control.

bw. MHz - megahertz.

bx. MIB - management information base.

by. MP - multi-path.

bz. MRU - maximum received unit.

ca. ms - millisecond.

cb. msb - most significant bit.

cc. NAK - negative acknowledgement.

cd. NCS - net control station.

ce. NPODS - Naval Print on Demand System.

cf. NRM - normal response mode.

cg. NSA - National Security Agency.

ch. NSAP - Network service access point.

ci. OSI - open systems interconnection.

cj. P/F poll/final.

ck. PBER - pseudo bit error ratio.

cl. PDU - protocol data unit.

cm. PI - protection interval.

cn. PIN - personal identification number.

co. PPP - point-to-point protocol.

cp. PQM - path quality matrix.

cq. QOS - quality of service.

cr. RF - radio frequency.

cs. REP - ALE preamble word REPEAT.

ct. RFC - request for comments.

cu. RQ - relay quality.

cv. RT - routing table.

cw. S&F - store and forward.

cx. SD - spectral distortion.

cy. SDLP - station data link protocol.

cz. SINAD - signal-plus-noise-plus-distortion to noise-plus-distortion ratio.

da. SNMP - simple network management protocol.

db. SNRM - set normal response mode.

dc. TCP - transmission control protocol.

dd. TOD - time of day.

de. TR - technical report.

df. UA - unnumbered acknowledge.

dg. UDP - user datagram protocol.

dh. UTC - universal time, coordinated.

di. USAISEC - U.S. Army Information Systems Engineering Command.

dj. VAP - ALE protocols.

dk. VF - voice frequency.

3.3 Timing symbols.

a. T_{lc} - leading call phase.

b. T_{lww} - last word wait time.

c. T_{rs} - redundant sound phase.

d. T_{rw} - redundant word time.

e. T_{sc} - scanning call phase.

3.4 ALQA mathematical expressions.

a. E_i - effective sensation level of energy in a speech sub-band (AI).

b. F_i - weighting factor relating human sensitivity to energy in a speech sub-band to measured energy in that sub-band (AI).

c. L_f - length of messages in queue when message transfer finishes (ADC).

d. L_m - length of message body (ADC).

e. L_s - length of messages in queue when message transfer begins (ADC).

f. R - effective message data rate (ADC).

g. T_b - beginning time of message transfer (ADC).

h. T_f - time when message transfer finishes (ADC).

i. U - station utilization (ADC).

j. W_i - non-linearly scaled sub-band energy (AI).

4. GENERAL REQUIREMENTS

4.1 Data link sublayers. The MIL-STD-188-141 data link layer contains three sublayers: a lower sublayer concerned with error correction and detection (forward error correction [FEC] sublayer), an upper sublayer containing the ALE protocol (ALE sublayer); and an optional protection sublayer in between, as shown on figure 1. Within the FEC sublayer are redundancy and majority voting, interleaving, and Golay coding applied to the 24-bit ALE words which constitute the service-data-unit, in terms of the International Organization for Standardization (ISO) model. The ALE sublayer specifies protocols for link establishment, data communication, and rudimentary link quality analysis (LQA) based on the capability of exchanging ALE words. Linking protection (LP) is placed in the intermediate "protection" sublayer so that it may make full use of the error correcting power of the FEC sublayer while intercepting unauthorized attempts to communicate with the local ALE protocol entity to establish links or otherwise disrupt operations.

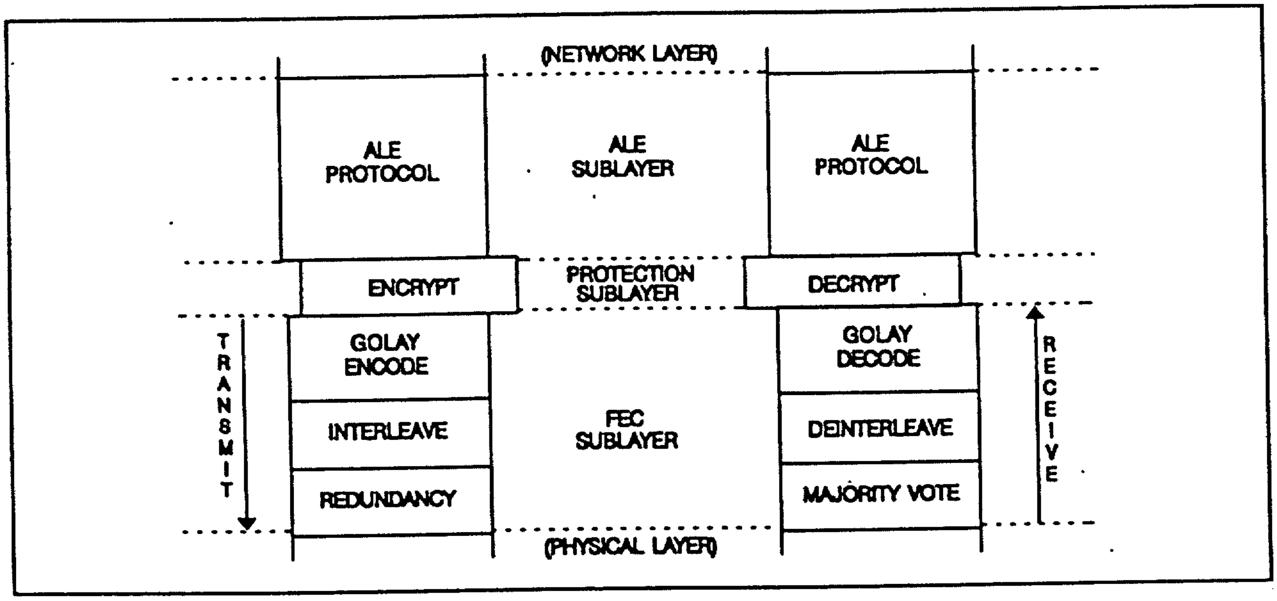

FIGURE 1. Conceptual model of data link layer protocols in MIL-STD-188-141.

4.2 Linking protection. See MIL-STD-188-141.

4.2.1 Linking protection application levels. The following application levels of LP are defined in this section, with the classified application (AL-4) providing the highest degree of protection. The classified and unclassified but sensitive application levels (AL-4 and AL-3 respectively) require distinct hardware scramblers, while the unclassified enhanced application level and the unclassified application level (AL-2 and AL-1 respectively) scramblers may be implemented in software or firmware. All protected radios shall be capable of operation at AL-1. A method shall be provided to disable automatic linking at linking protection application levels less secure than the application level in use by the station being called. For example, a station that is operating at AL-3 shall be able to disable the receiver from listening for linking attempts at AL-0 (unprotected) through AL-2. (Design objective [DO]: Alert the operator but do not link automatically when a valid call is received from a transmitter with a lower linking protection application level.) This mechanism shall not preclude the operator from manually initiating ALE using a disabled application level. This manual override is required for interoperability.

4.2.1.1 <u>AL-0 (unprotected application level)</u>. See MIL-STD-188-141.

4.2.1.2 <u>AL-1 (unclassified application level)</u>. See MIL-STD-188-141.

4.2.1.3 <u>AL-2 (unclassified enhanced application level)</u>. See MIL-STD-188-141.

4.2.1.4 <u>AL-3 (unclassified but sensitive application level)</u>. The AL-3 scrambler (for U.S. Government use only) shall employ the algorithm and the interface control document (ICD) developed by National Security Agency (NSA). Systems employing AL-3 LP must meet NSA security requirements. The protection interval is a maximum of 2 seconds.

4.2.1.5 <u>AL-4 (classified application level)</u>. The AL-4 scrambler (for U.S. Government use only) shall employ the algorithm and the ICD developed by NSA. An AL-4 scrambler may be used to protect classified orderwire traffic. Systems employing classified application level LP must meet NSA security requirements. The AL-4 protection interval is a maximum of 1 second.

4.2.2 <u>Protocol transparency</u>. See MIL-STD-188-141.

4.2.3 <u>Transmit processing</u>. See MIL-STD-188-141.

4.2.4 <u>Receive processing</u>. See MIL-STD-188-141.

4.3 <u>Time of day (TOD) synchronization</u>. See MIL-STD-188-141.

4.4 Link quality functions. Link quality functions, including passive LQA, polling, and LQA reporting, support a data base of recent propagation measurements of the channels available to a station for establishing links with other stations. This data base of bilateral link quality data, stored in the LQA matrix described in MIL-STD-188-141, is used to rank channels to determine the order in which to attempt link establishment and to select channels for voice and data traffic. LQA data is obtained from measurements of received traffic and sounds, and from data explicitly sent in the polling and LQA report protocols.

4.4.1 Passive LQA.

a. Evaluation of channel quality by measuring the characteristics of received signals is termed passive LQA because the local radio does not transmit a request for this data. Such passive LQA can obtain useful data from normal ALE traffic (while linked) as well as from sounds.

b. A key characteristic of passive LQA is that the data it produces is unilateral; only the link quality from the distant transmitter to the local receiver is obtained.

NOTE: Certain military applications prevent use of active LQA techniques.

4.4.2 Polling.

a. Bilateral LQA data may be obtained by using one of the active LQA techniques such as polling or LQA reporting.

b. The polling protocols are used to acquire current bilateral link quality data by handshaking with one or more other stations, directly measuring the transmissions received, and exchanging these measurements with the other station(s). Polling is used to actively acquire current bilateral LQA data for stations and channels for which recent LQA data may be unavailable in the LQA matrix.

c. LQA is mandatory in MIL-STD-188-141; existing radios can execute any polling protocol that does not depart from the standard ALE protocols. The protocols specified in section 5 support polling for existing radios. Advanced polling protocols that provide greater efficiency of channel use are also specified.

NOTE: Use of polling can produce severe channel congestion when conducted by more than a few stations (see 6.1.2.1).

4.4.3 LQA reporting. The LQA reporting protocol is used to exchange previously measured LQA data, rather than to measure the quality of the current channel. This data may be from either active or passive sources. By exchanging unilateral measurements from passive LQA, stations can quickly accumulate bilateral data for many channels and stations.

NOTE: LQA reporting may introduce excessive overhead burden. LQA should only be used when a validated requirement exists (see 6.1.2.2).

4.5 Advanced link quality analysis (ALQA) function. In ALQA, the link quality measures are divided into two types: channel quality measures and link performance measures. Channel quality measures evaluate the performance of individual channels between pairs of stations, while link performance measures combine measures of channel performance and traffic load to derive a single quantitative measure of link performance for use by network controller routing algorithms. ALQA techniques (except for error-free interval estimation) differ from the basic LQA techniques in the following respects:

a. Measurements shall be histogrammed in accordance with 4.5.3 rather than averaged.

b. The quality of a channel shall be reported as the fraction of measurements that exceeded a threshold in accordance with 5.5.3, rather than an average of the measurements.

NOTE: ALQA is used to obtain more detailed link quality evaluation than is available from the standard LQA technique but requires significantly increased overhead transmissions for data collection. Additionally, ALQA results may not correlate well with the channel performance of modems other than the ALE modem. ALQA should only be used when a validated requirement exists (see 6.1.2.3).

4.5.1 Channel quality measures. All implementations of ALQA shall support signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD) and pseudo bit error ratio (PBER) as described in 5.5.1.1. Articulation index, spectral distortion, and error-free interval are optional; implementations shall comply with the applicable sections of 5.5.1. The following channel quality measures are standardized for ALQA:

a. SINAD measurements shall be derived from the ALE modem on a baud-by-baud time scale (see 5.5.1.1).

b. Articulation index estimates shall also be derived from the ALE modem using a non-uniform weighting of signal-to-noise ratios from each ALE tone (see 5.5.1.2).

c. PBER shall be derived from the majority vote decoder as described in MIL-STD-188-141. However, for ALQA use, the PBER values shall be histogrammed on a word-by-word basis, rather than contributing to a running average for the transmission (see 5.5.1.1).

d. Spectral distortion due to fading and multipath effects causes degradation in the bit error ratio (BER) performance of the ALE modem, as compared to its performance over Gaussian noise channels. The severity of spectral distortion shall be gauged by comparing instantaneous samples of BER and SINAD (measured on received ALE words) to the theoretical Gaussian channel performance in accordance with 5.5.1.3.

e. The mean error-free interval shall be evaluated indirectly. ALE word errors detected by the Golay decoder and the ALE protocol shall be accumulated to estimate word-error and word-error-burst probabilities; these probabilities shall then be used to estimate error-free interval in accordance with 5.5.1.4.

4.5.2 Link performance measures. The link performance measures for ALQA are standardized as follows:

a. Achievable voice quality samples shall combine SINAD measurements (DO: articulation index measurements) with channel occupancy to produce a histogram of the voice quality of the best channel available during each scan of the channels by the ALE controller, in accordance with 5.5.2.1.

b. Data link performance shall be gauged using available data capacity in accordance with 5.5.2.2. Available data capacity samples measure the effective data rate available to each station, including the effects of retransmissions due to channel errors, and contention for transmission facilities from other traffic.

NOTE: Achievable voice quality and available data capacity are optional; implementations shall comply with the applicable sections of 5.5.2.

4.5.3 ALQA histogramming. Measurements of SINAD, PBER, articulation index, spectral distortion, achievable voice quality, and available data capacity shall be accumulated for ALQA use as described below.

4.5.3.1 Exceedance distributions. An "exceedance distribution" $Q_x(x)$ is related to the cumulative probability distribution function $P_x(x)$:

$$Q_x(X) = Pr[X > X] = 1 - P_x(X).$$

Exceedance distributions for the channel quality measures and link performance measures listed in 4.5.3 shall be estimated by first histogramming samples of these measures, and then averaging the histograms over the integrating periods specified in 4.5.3.2. A history of these histograms shall be retained for use when no current data is available.

4.5.3.2 Integrating periods.

a. Four distinct time epochs shall be used for accumulating the histogram data. Within each epoch k, N_k histograms shall be accumulated and averaged, each containing measurements over a period of t_k. Epoch 1 represents the short term for the HF channel. Because the values defined in the channel quality measure descriptions above are intended to provide short-term granularity on the HF channel on the order of 1 minute, t_1 = 60 seconds. Since 15 minutes represents a time interval over which the statistics of the nominal HF channel may be considered approximately stationary, N_1 = 15. This first epoch represents the most up-to-date channel quality measure available.

b. The second, third, and fourth time epochs shall consist of: 5 minute intervals up to 1 hour old (second epoch), hourly intervals from the current hour to 24 hours (third epoch), and cumulative results since start-up (fourth epoch). Epoch 2 employs t_2 = 300 seconds and N_2 = 12 so that five t_1-length samples from epoch 1 are summarized in each t_2-length sample ($t_2 = 5t_1$) in epoch 2. Similarly, epoch 3 consists of 24 1-hour samples: t_3 = 3600 seconds and N_3 = 24. Finally, epoch 4 contains counters which accumulate all samples.

4.5.3.3 Histogram generation.

a. For each channel quality measure or link performance measure X, where X is one of the channel quality measures or link performance measures listed in 4.5.3, sets of bins $h_x(i;\ j,\ k)$ shall be used to store exceedance histograms of the samples x of that measure as described below, for every channel to every reachable station. In the notation $h_x(i;\ j,\ k)$, the index k refers to an epoch $(1 \leq k \leq 4)$, the index j refers to a particular exceedance histogram (set of bins) within that epoch $(1 \leq j \leq N_k)$, and the index i refers to a particular bin within that histogram (see figure 2). In addition, for each epoch, a set of counters shall be used to accumulate current measurements to form the next set of histograms; these counters are labeled as j = 0 in the figure.

b. For the purpose of histogramming, the range of values for each measure shall be quantized into a number of subranges with lower thresholds, in accordance with table XVIII, plus an additional (lowest) subrange with a threshold less than any valid sample. As each sample arrives, it shall be compared to the lower endpoint of each subrange. Each counter shall be incremented if the sample *exceeds* the lower endpoint of the subrange corresponding to that counter. Because the lower endpoint of the lowest subrange is always less than the smallest possible value, bin 1 in each exceedance histogram will contain a count of the total number of samples represented in that histogram. Because the same thresholds are used for each of the four epochs, only one quantizer is needed. Each epoch independently accumulates the samples as they arrive.

c. For each epoch, when an integrating period t_k has elapsed, the histograms shall be shifted one position to the right; the counter contents shall become $h_x(\ ;\ 1,\ k)$, and the oldest histogram $h_x(\ ;\ N_k,\ k)$ shall be discarded. Epoch 4 is a special case; epoch 4 counters shall simply accumulate all samples, with no averaging over individual integrating periods.

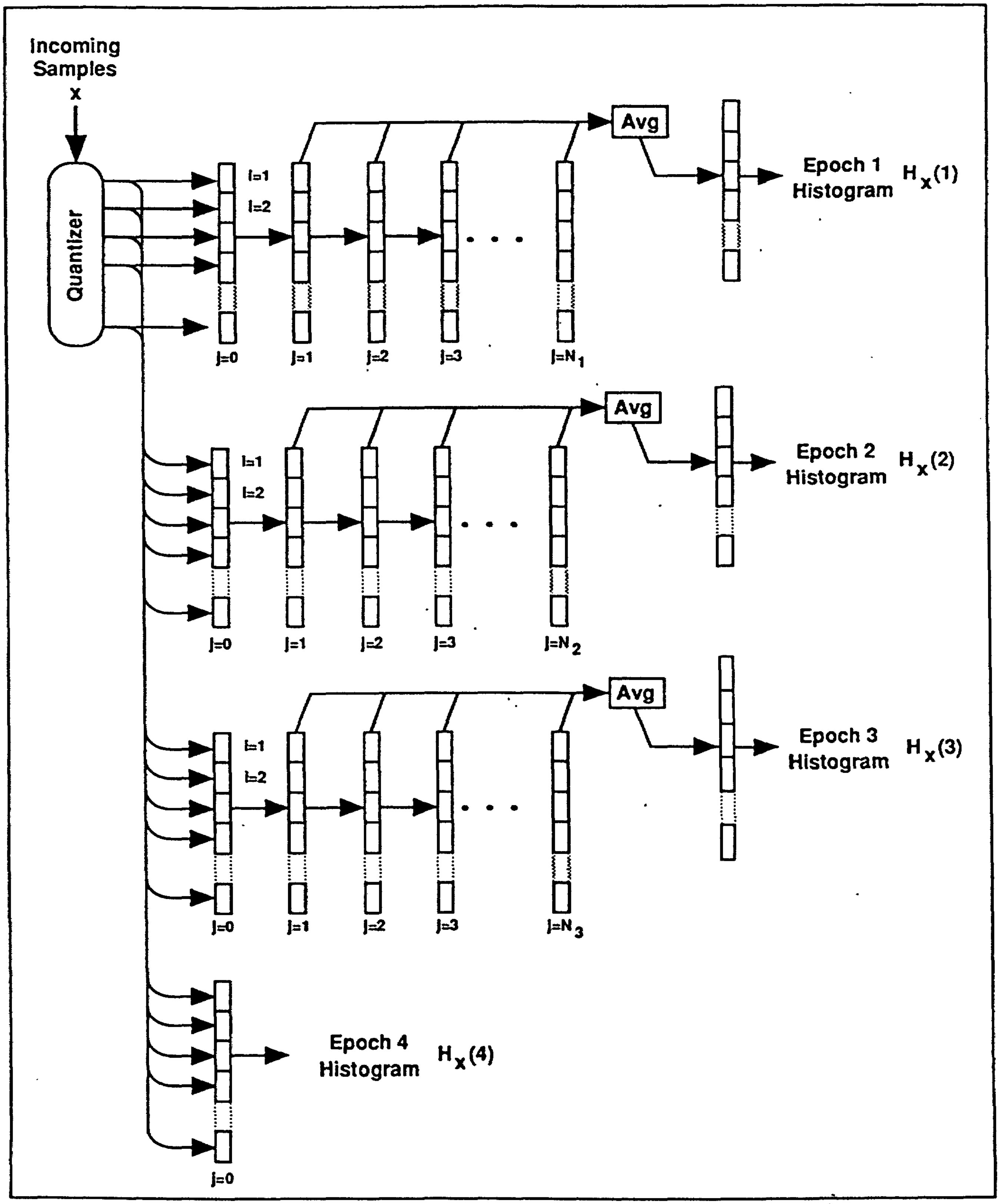

FIGURE 2. Histogram generation.

d. For epochs 1 through 3, the running average histograms $H_X(k)$ shall be computed from the most recent N_k histograms $h_X(i;\ j,\ k)$ as follows (each bin in H_X is denoted $H_X[i;\ k]$):

$$H_x(i;k) = \frac{1}{N_k} \sum_{j=1}^{N_k} \frac{h_x(i;j,k)}{h_x(1;j,k)}.$$

$$\text{where } h_x(1;j,k) \neq 0$$

4.5.4 Link quality prediction programs. Link quality predictions from programs such as IONCAP may be used, when available to the ALE controller, to supplement channel quality measures.

4.6 Networking functions.

a. MIL-STD-188-141 establishes the technology baseline needed for establishing and maintaining links among HF radio stations. Networking technology augments this direct-connection capability with the ability to find and use indirect routes.

b. The functions performed at the network layer may be grouped into two broad categories: routing functions and data management functions. Routing functions select paths through the network for voice and data traffic, using stored information (provided by operators, local data link controllers, and remote networking controllers) about the quality of available links to other stations. Data management functions acquire and communicate that (and other) information.

c. Link-level error statistics directly characterize the quality of single-link paths and are used to compute end-to-end path quality for multiple-link paths through relays. These results are stored in a path quality matrix (PQM), which is organized to provide the path quality to any reachable destination via each directly-reachable relay station. From this path quality data, a routing table (RT) is formed. This table lists the best path to each reachable station for various types of communication (e.g., voice and data).

4.6.1 Indirect calling and relaying. When a station cannot directly link with a desired destination, other stations may be employed to assist in getting the message through. The simplest option is to have the local link controller or the HF Network Controller (HFNC) establish a link with a station other than the desired destination so that the station operators can manually communicate (using either voice or data orderwire) after the fashion of a torn-tape relay. When the equipment at the intermediate station is able to automatically establish an indirect path to the destination, this is termed relaying. A variety of relaying techniques are possible, some of which are shown on figure 3. These techniques are differentiated by where the cross-connection occurs in the protocol stack. Each alternative is briefly discussed in table I.

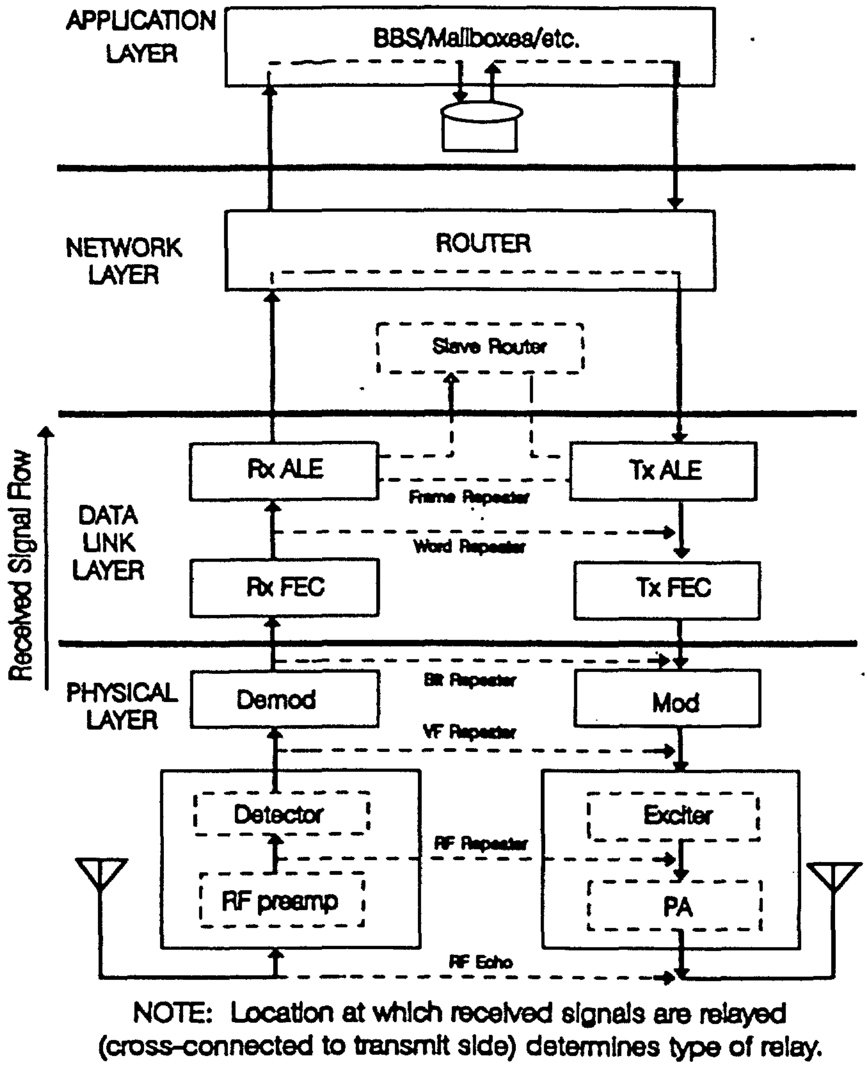

FIGURE 3. Relaying alternatives.

TABLE I. Relaying alternative notes.

TYPE	DESCRIPTION
RF echo	No radios required. Examples: float a large aluminized balloon or use a billboard reflector.
RF repeater	Formed by connecting an RF amplifier between two antennas. Uses different RF frequencies by heterodyning or translating the received frequencies.
VF repeater	Formed by connecting two radios back-to-back through the audio ports. This and all following relays can easily use different RF frequencies.
Bit repeater	Formed by connecting data ports of modems. Regenerates audio and bit timing.
Word repeater	Occurs just above FEC sublayer (and below LP). Corrects errors in data words but does not examine those words or otherwise manipulate their contents. Introduces one word time delay.
Frame repeater	Occurs within data link protocol sublayer. Like word repeater, but buffers an entire frame before retransmitting it; introduces delay of frame time plus time to detect the end of the frame. This and all following relays require only one radio, but can use more if available.
Slave router	Occurs just above data link layer. Effectively connects data links in tandem as directed by indirect addresses in data link frames. Makes no routing decisions; merely implements the routing scheme specified in frames that it receives (hence the name).
Router	Network layer function. Determines where to send each received frame using local routing information; this routing information may be entirely static or it may include real-time data (in an adaptive router). Uses network layer message header; normally has access only to message section of data link layer (e.g., ALE) frame. May buffer data when no path currently exists to destination.
Mailbox	Application layer function. Stores messages for later retrieval by specified recipient.
BBS	Application layer function. Stores messages for later retrieval by anyone with access to that bulletin board.

4.6.2 Networking controller. A networking controller performs the network-layer functions relating to traffic routing and relaying. In the simplest case, the network layer functions reside within a radio and have access only to the links achievable by that radio. A more advanced radio may include both ALE and HF data modems, along with a networking controller that is capable of establishing links using the ALE modem and protocols and is capable of switching to the data modem for data communication (see figure 4). Such a networking controller could use either of the modems (via its respective data link layer entity) to carry traffic for the local user or to relay others' traffic within the network. A still more sophisticated networking controller could manage several radios in a major communications hub, routing traffic through the radio that has the best path to the destination. Such a networking controller could be generalized to act as a multi-media gateway, routing traffic over media such as wire, fiber, microwave, and satellite links as well as HF links.

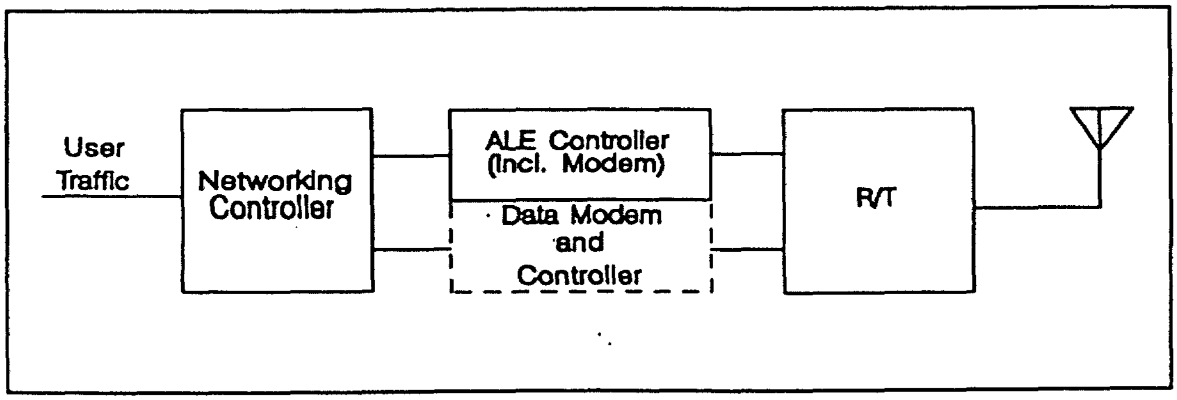

FIGURE 4. Functional block diagram of an automated HF station.

The principal functions performed within the networking controller are route selection and link selection, automatic message exchange (AME) and message store and forward (S&F), and connectivity tracking. Note that the connectivity tracking function employs the connectivity exchange protocol described in 5.7.4 and the connectivity monitoring protocol described in 5.7.6.6.3. The interactions among the various functions and data structures within the networking controller are shown on figure 5.

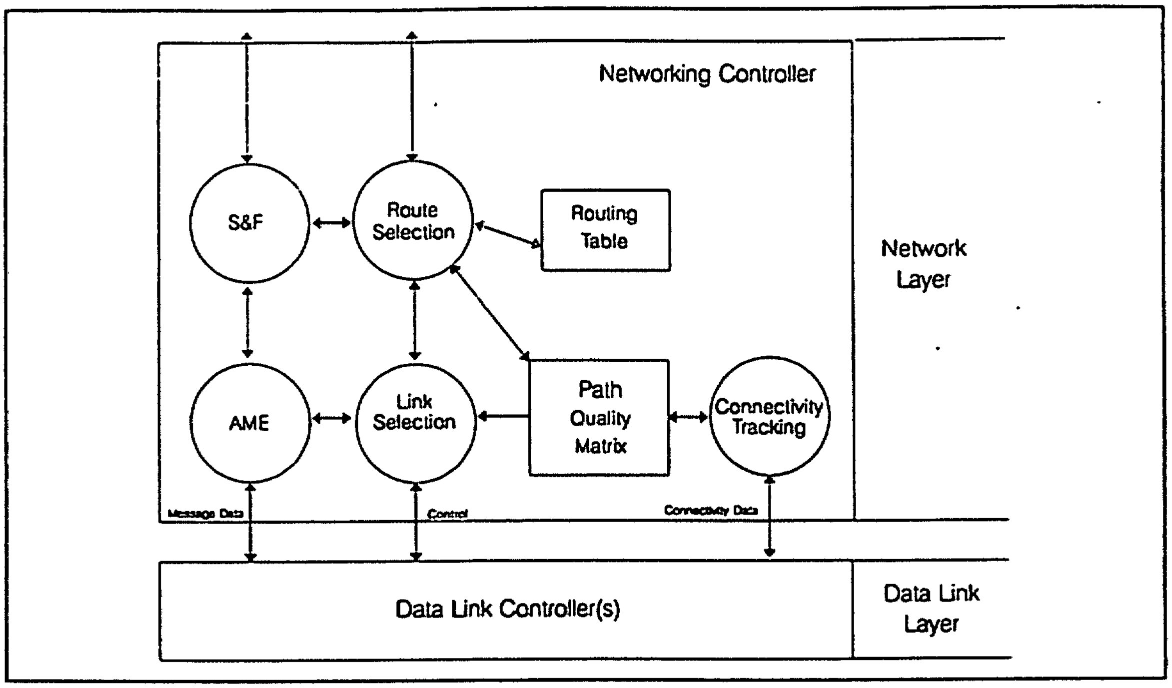

FIGURE 5. Networking controller.

4.6.2.1 Data structures. Depending upon the level of functional capability of a networking controller (see 4.6.2.7), it shall implement one or both of the following data structures.

4.6.2.1.1 Routing table. The networking controller shall maintain a routing table that stores the preferred route from that station to other reachable stations (DO: also alternate routes); specifically, for each reachable station the routing table shall indicate how traffic destined for that station should be routed. Separate entries shall be maintained for voice and for data traffic. The routing table entries shall be individually programmable as static (entered manually by the operator or downloaded verbatim from other stations) or adaptive (computed automatically by the networking controller using the path quality matrix). See 5.7.1.2 for detailed requirements for the routing table.

4.6.2.1.2 Path quality matrix. The central data structure supporting adaptive routing is the path quality matrix. This matrix shall be organized to separately record voice and data path quality to any reachable destination via each directly-reachable relay station. These path quality estimates shall be based upon link quality measurements reported by the link controllers in accordance with 5.7.1.1.

4.6.2.2 Route selection. The route selection function routes voice and data traffic through networks using direct or indirect paths as required. While accomplishing this, it uses and maintains the routing table discussed in 4.6.2.1.1. The route selection function supports both indirect calling and various types of relaying, including analog repeaters, frame repeaters, and message store and forward.

4.6.2.3 Message store and forward. The message store and forward function provides message delivery service for users or transport-layer processes (the term transport message is used in all cases). This function may buffer in-transit messages for varying periods of time depending upon the storage facilities available within the network controller.

The store and forward process at each networking controller employs the route selection function to determine routes through the network for messages, and employs the automatic message exchange process to actually deliver messages over HF links. When full store and forward functionality is not required, a null store and forward function provides the interface to automatic message exchange (see 5.7.5.3).

4.6.2.4 Automatic message exchange (AME). Automatic message exchange refers to the network layer function that accepts network messages from the store and forward function for delivery to a specified directly reachable station (relay or final destination), and automatically delivers each message when a link is available to that station. When a link cannot be established to the requested station, the automatic message exchange function may either reject the network message, allowing the store and forward function to attempt delivery by alternate means, or it may store the message for future delivery when the desired link is established (so-called "discovery mode").

4.6.2.5 Link selection. The link selection function of the network controller shall interact with local data link controllers to request the establishment and status of links. It shall use data from the path quality matrix to select among available data link controllers for data transfer to the distant station. The link selection function makes no routing decisions per se.

4.6.2.6 Connectivity exchange. Information about routes to stations that are not directly reachable, and which have not routed traffic through the local station recently, can sometimes be obtained from the connectivity data stored by a directly reachable station. This data may be shared either upon request or by periodic broadcast. When stations report their path quality matrix contents to other stations, this is termed connectivity exchange (CONEX). When, on the other hand, a station asks for replies from stations with connectivity to a specified destination this is termed query routing (e.g., "Who can reach Joe?"). Protocols for both functions are specified in section 5.

4.6.2.7 Standard levels of capability. The standard levels of functional capability listed in table II are defined for HFNCs. Note that each level includes the capabilities of all lower-numbered levels.

TABLE II. Levels of HF networking controller functional capability.

Functional Level	Capabilities
Level 1 Minimal HFNC (No routing table) (No path quality matrix)	Controls ALE radio (including indirect calling) Remote data fill support Automatic message exchange Null store and forward Internet protocol (optional) Controls HF data modem (optional)
Level 2 Basic HFNC (No path quality matrix)	(All capabilities of Level 1 HFNC) -plus- Route selection using static routing table Message store and forward Routing table data fill Routing queries Repeater control (optional) Connectivity monitoring Controls multiple radios and modems (optional)
Level 3 Adaptive HFNC	(All capabilities of Level 2 HFNC) -plus- Path quality matrix Connectivity exchange (CONEX) Adaptive routing
Level 4 Multi-media gateway	(All capabilities of Level 3 HFNC) -plus- Routing via alternate media Internet protocol (mandatory) Internet gateway

4.7 Interface to link controllers. The following functions form a minimal interface between a networking controller and the link controllers that it uses. Because of the wide range of implementations possible, the specifics of this interface are not yet fully standardized.

4.7.1 Link control. The networking controller must be able to request the establishment and termination of links, specifying desired destinations using the appropriate link-level addresses. However, artifacts of particular link controllers (e.g., padding ALE addresses on the right with '@' characters) shall not be required of networking controllers. Link controllers should report the success or failure of link establishment and the identities of linked stations (e.g., stations responding to an ALE net call).

4.7.2 Link quality reporting. The networking controller requires reports from the link controllers regarding the quality of links to other stations available from each link controller. These reports will specify the data necessary for path quality matrix entries (e.g., BER and SINAD), but should not contain data such as channel numbers that are relevant only to the link controller.

4.7.3 Network messages. Messages to be sent from one networking controller to another over a link shall be delivered to a link controller in two parts: a network message (which is handled transparently by the link controller); and control information which specifies to the link controller the data-link layer addressee of the message as well as other requirements for the transmission. The link controller is presumed to assume custody of each message that it accepts for transmission. Received messages delivered by link controllers to an HFNC should be accompanied by the link layer address of the sender of the message.

4.8 Network management.

4.8.1 Network management functions. Automated network management functions support the efficient control of automated HF networks. The tools for network management specified in section 5 include protocols for the following functions:

a. Monitoring and reporting network status (e.g., topology, capabilities, congestion, and faults).

b. Downloading ALE controller data.

c. Updating network routing tables.

d. Identifying software versions and updating the software in ALE and networking controllers.

e. Re-keying linking protection scramblers.

f. Remotely controlling station operations.

g. Adjusting transmitter power of linked stations.

h. Hand-off from ALE modems to other modems.

i. Transition among security modes.

4.8.2 Network management application program capabilities. The network management application program (often running on networking controller hardware) integrates the monitoring, reporting, and control capabilities of attached networking and link controllers to allow the network manager to view and adjust the operation of a network. These capabilities include the LQA, ALQA, Version, and Capabilities functions of the ALE controller, and the CONEX function of the networking controller. Network management programs employ the data communication capabilities of networking and link controllers to exchange network management messages.

4.8.3 Simple Network Management Protocol (SNMP). All HF radio equipment should implement the SNMP, as specified in Request for Comments 1441-1452 (RFC-1441) with the HF-specific enhancement specified in 5.9.2. This combination of SNMP with HF radio enhancements is hereafter denoted HF network management protocol (HNMP). Equipment not implementing HNMP may be managed through the use of proxy agents, which translate between HNMP commands and equipment-specific commands.

NOTE: An HFNC is the platform for proxy agents because of its connections to most other equipment at a station.

Every HFNC that implements HNMP shall also implement the HF AME protocol if carrying traffic over HF. (DO: HFNCs should also implement the Internet Protocol (IP) of MIL-STD-2045-14502-01 (also see MIL-STD-1777) and the User Datagram Protocol (UDP) of RFC-768).

4.9 Multi-media networks.

a. From a user's perspective, a communication system should seamlessly integrate any available media to provide end-to-end service. In addition to this general requirement for static multi-media interoperability, many Government systems (especially military and law enforcement agency systems) require robust networks that can sustain communications in the face of widespread loss of assets, and that can be rapidly extended into new locales using any available facilities. It is this dynamic element that distinguishes so called "any media" networks from the more common multi-media networks.

b. Because of the dynamic characteristics of ionospheric propagation, HF radio node controllers (HFNC) are designed specifically to cope with fluctuating connectivity. This makes the HFNC especially suitable for service as a router in any-media networks.

c. HF radio may be integrated with other media in two complementary ways:

(1) A network of HFNCs may contain not only HF links, but also wireline, microwave, tropo- or meteor-scatter, and satellite links. Such HF networks use HF links for mobile or remote stations and for contingencies, with other media used as dictated by tactics and economics.

(2) A network of HFNCs may serve as a subnetwork in a larger internet (such as the Internet). Such an "HF" subnetwork may of course employ any of the media listed above. The HF component of such internets provides an inexpensive means to extend the network to remote or mobile users. Examples include Defense Communication System (DCS) entry and providing access to the commercial telephone system from remote regions of the world (e.g., northern Canada).

When multi-media or any-media networking is required, the other media shall be interconnected to HF assets via HFNCs. For fully automatic internetworking, the HFNC level of functional capability must be level 2 or above (see 4.6.2.7, Standard levels of capability). A level 4 HFNC is required for internet gateways in case b above.

4.10 New ALE or orderwire functions. The new ALE or orderwire functions defined in this standard are listed in table III, including cross-references to the paragraphs that define the use of these functions.

Table III. New ALE or orderwire CMD words.

First Character	Second Character (if applicable)	Function	Reference
` 1100000		ALQA	5.5.3.1
c 1100011		Channels	5.4.3.3
f 1100110		Frequency	5.6.3
m 1101101	a 1100001	Analog Port Selection	5.6.4.3
	c 1100011	Crypto Negotiation	5.6.4.2
	d 1100100	Data Port Selection	5.6.4.4
	n 1101110	Modem Negotiation	5.6.4.1
	q 1110001	Digital Squelch	5.6.4.6
	z 1111010	Digital LINCOMPEX Zeroize	5.6.4.5
n 1101110		Noise Report	5.4.2.2
p 1110000		Power Control	5.6.5
r 1110010		LQA Report	5.4.4
t 1110100	a 1100001	Adjust Slot Width	5.6.6.1
	b 1100010	Station Busy	5.6.6.2
	c 1100011	Channel Busy	5.6.6.3
	d 1100100	Set Dwell Time	5.6.6.4
	h 1101000	Halt and Wait	5.6.6.5
	l 11011001	Contact Later	5.6.6.6
	m 1101101	Meet Me	5.6.6.7
	n 1101110	Poll Operator (Default NAK)	5.6.6.8
	o 1101111	Request Operator ACK	5.6.6.9
	p 1110000	Schedule Periodic Function	5.6.6.10
	q 1110001	Quiet Contact	5.6.6.11
	r 1110010	Respond and Wait	5.6.6.12
	s 1110011	Set Sounding Interval	5.6.6.13
	t 1110100	Tune and Wait	5.6.6.14

Table III. New ALE or orderwire CMD words - continued.

First Character		Second Character (if applicable)		Function	Reference
		w	1110111	Set Slot Width	5.6.6.15
		x	1111000	Do Not Respond	5.6.6.18
		y	1111001	Year and Date	5.6.6.16
		z	1111010	Zulu Time	5.6.6.17
v	1110110	c	1100011	Capabilities	5.6.2
		s	1110011	Version	5.6.1
~	1111110			Time Exchange	5.2.1.1

4.11 HF data link protocol. The data link protocol described in appendix A was designed specifically to provide reliable data transfer over HF channels using the serial-tone modem specified in MIL-STD-188-110.

5. DETAILED REQUIREMENTS

5.1 Linking protection. See MIL-STD-188-141.

5.1.1 Linking protection control module. See MIL-STD-188-141.

5.1.2 Procedure.

a. The procedure to be employed in protecting transmissions consisting entirely of 24-bit ALE words is presented in 5.1.2.1 and 5.1.2.2, followed by the procedure for the data block portion of data block mode transmissions.

b. When a radio is neither transmitting nor receiving, the PI number shall be incremented as follows:

(1) When using AL-2 LP, the Fine Time field shall be incremented at the end of each PI by the length of the PI, modulo 60.

(2) When the Fine Time field rolls over to 0, the Coarse Time field shall be incremented, modulo 1440.

(3) At midnight, the Coarse Time and Fine Time fields shall be set to 0, and the Date fields shall be updated.

c. When using AL-1 LP, the Fine Time field shall contain all 1's, and the Coarse Time field shall be incremented at the end of each minute, modulo 1440. At midnight, the Coarse Time field shall be set to 0, and the Date fields shall be updated.

5.1.2.1 Transmitting station.

a. Each word to be transmitted shall be encrypted by the scrambler using the current seed information. In the course of a transmission, the protocol described below may cause a discrepancy between the TOD fields in the seed and the real-time. Such a discrepancy is a normal consequence of the LP procedure, and shall persist until the conclusion of each transmission, whereupon the TOD fields of the seed shall be corrected.

b. The Word Number field w shall be used as follows:

(1) During the scan calling phase (T_{SC}) of a call, the calling station shall alternate transmission of

words encrypted using w = 0 and w = 1. The first word of T_{sc} shall use the value of w that results in w = 1 for the last word in T_{sc}. The TOD used during T_{sc} shall change as required to keep pace with real-time, except that TOD shall only change when w = 0; words encrypted with w = 1 shall use the same TOD as the preceding word.

(2) At the beginning of the leading call phase (T_{lc}) of a call (which is the beginning of a single-channel call), the first word shall be encrypted using w = 0 and the correct TOD for the time of transmission of that word.

(3) All succeeding words of the call shall use succeeding word numbers up to and including w = w_{max}. For the word following a word encrypted with w = w_{max}, the TOD shall be incremented and w shall be reset to 0. The w_{max} = 2 for a 1 second PI, w_{max} = 5 for a 2 second PI, and w_{max} = 153 for a 60 second PI.

(4) Responses and all succeeding transmissions shall start with w = 0 and the current (corrected) TOD, with these fields incremented as described in step (3) above for each succeeding word.

c. Figure 6a illustrates the permissible TOD|w combinations for a transmitting station using a 2 second PI (w_{max} = 5), and the permissible sequences of these combinations. On the figure, T represents the stored TOD.

d. Sounds are protected in the same fashion, with T_{rs} (redundant sound phase) in the place of T_{lc}. A single-channel sound is analogous to a single-channel call, and begins the procedure at step (2) above. A multi-channel sound is analogous to a scanning call, and begins at step (1) above.

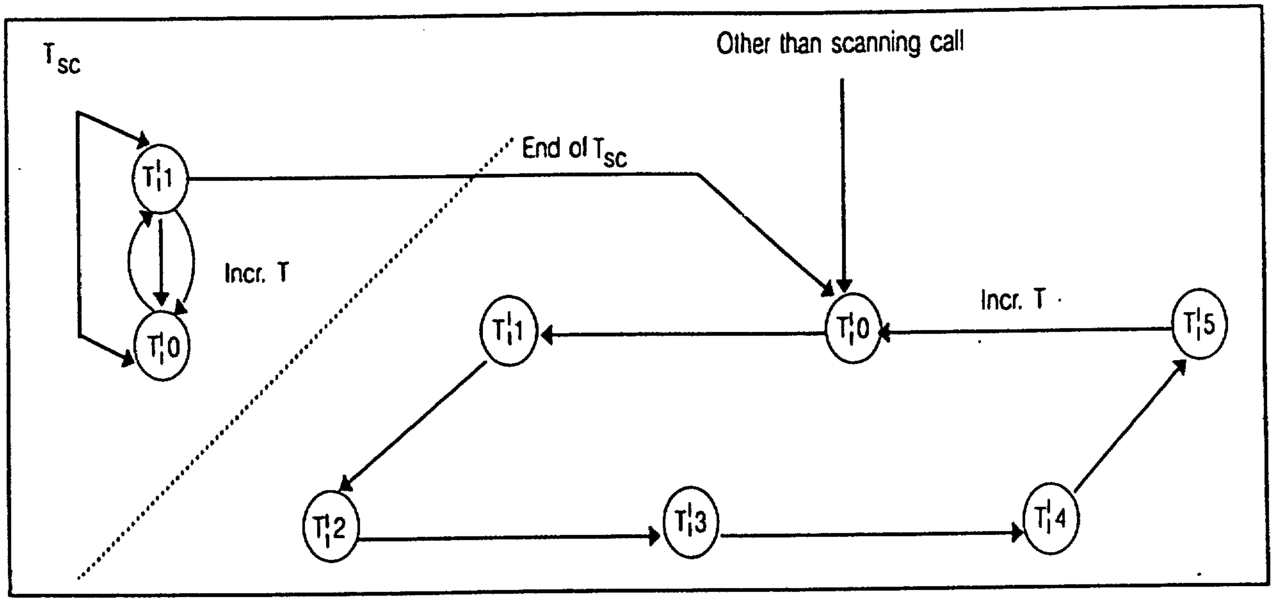

FIGURE 6a. Transmitting station state diagram (2 second PI).

5.1.2.2 Receiving station.

a. Because of the possibility of acceptable decodes under multiple TOD/word number combinations, receivers shall attempt to decode received words under all allowed combinations (the current and adjacent PIs [future and past], and both **w** = 0 and **w** = 1) when attempting to achieve word synchronization with a calling station (six combinations). Stations prepared to accept time requests (see 5.2.3.2) shall also attempt to decode received words using coarse TOD (Fine Time = all 1's, correct Coarse time only) with both **w** = 0 and **w** = 1 (eight combinations total). ALL VALID COMBINATIONS SHALL BE CHECKED while seeking word sync; after achieving word sync, the number of valid combinations is greatly reduced by the LP protocol.

b. Figure 6b illustrates the permissible TOD|**w** sequences for a receiving station using a 2 second PI after word sync is achieved. Note that, unlike the transmitter, the receiving station state machine may be non-deterministic. For example, when in T_{sc} and in state T|1, a received word may yield valid preambles and ASCII when decrypted using all of the valid combinations: T|0, (T+1)|0, and T|2 (the latter implying that T_{lc} started two words previously), and will therefore be in three states at once until the ambiguity is resolved by evaluating the decrypted words for compliance with the LP and ALE protocols.

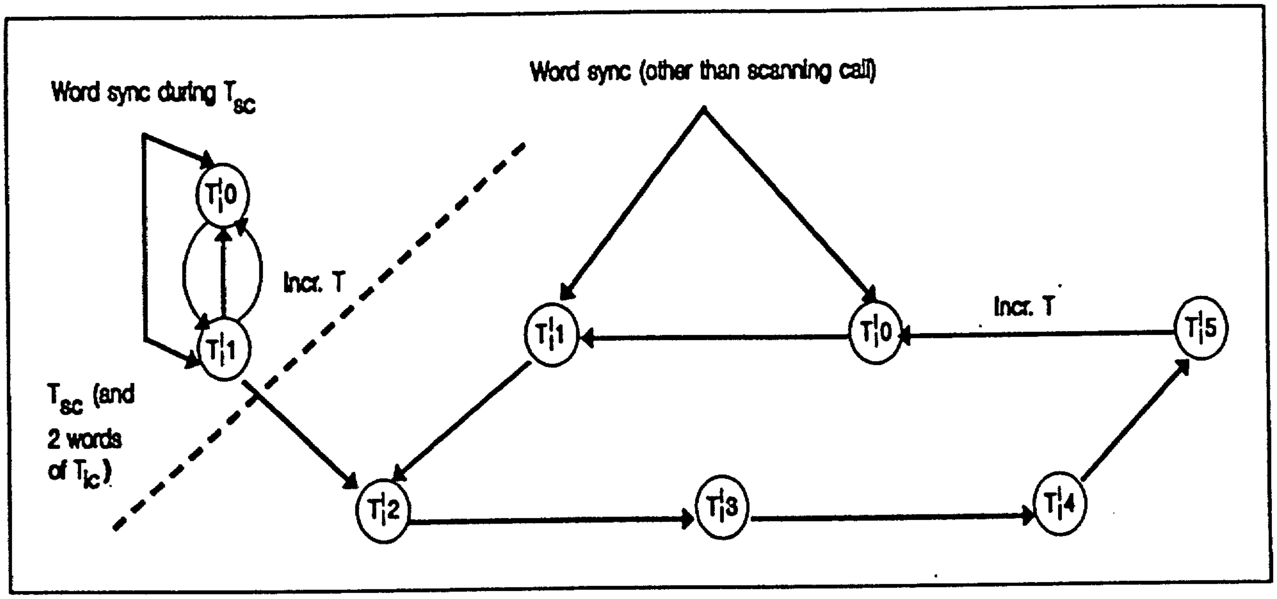

FIGURE 6b. Receiving station state diagram (2 second PI).

c. Stations using a protection interval of 2 seconds or less shall not accept more than one transmission encrypted using a given TOD, and need not check combinations using that TOD. For example, if a call is decrypted using TOD = X, no TOD before X + 1 is valid for the acknowledgment.

5.1.2.3 Data block message mode.

a. A DBM data block contains an integral number of 12-bit words, the last of which comprises the least significant 12 bits of a cyclic redundancy check (CRC). These 12-bit words shall be encrypted in pairs, with the first 12-bit word presented to the linking protection control module (LPCM) by the ALE protocol module as the more significant of the two. When a data block contains an odd number of 12-bit words (i.e., basic DBM data block and extended DBM data blocks with odd N), the final 12-bit word shall not be encrypted, but shall be passed directly to the FEC sublayer.

b. The Word Number field w of the seed shall be incremented only after three pairs of 12-bit words have been encrypted (rather than after every 24-bit word as in normal operation), except that the word number w shall be incremented exactly once after the last pair of 12-bit words in a DBM data block is encrypted, whether or not it was the third pair to use that word number. As usual, TOD shall be incremented whenever w rolls over to 0.

5.2 Time exchange protocols. See MIL-STD-188-141.

5.3 Channel and frequency designators.

a. When two or more stations need to explicitly refer to channels or frequencies other than the one(s) in use for a link, the following encodings shall be used. A frequency is designated using binary-coded-decimal (BCD). The standard frequency designator is a 5-digit string (20 bits), in which the first digit is the 10 megahertz (MHz) digit, followed by 1 MHz, 100 kilohertz (kHz), 10 kHz, and 1 kHz digits. A frequency designator is normally used to indicate an absolute frequency. When a bit in the command associated with a frequency designator indicates that a frequency offset is specified instead, the command will also contain a bit to select either a positive or a negative frequency offset.

b. A channel differs from a frequency in that a channel is a logical entity that implies not only a frequency (or two frequencies for a full-duplex channel), but also various operating mode characteristics, as defined in the section on Channel Memory in MIL-STD-188-141. As in the case of frequency designators, channels may be specified either absolutely or relatively. In either case, a 7-bit binary integer is used which is interpreted as an unsigned integer in the range 0 through 127. Bits in the associated command indicate whether the channel designator represents an absolute channel number, a positive offset, or a negative offset.

5.4 Link quality functions.

5.4.1 LQA matrix. The central data structure for the link quality functions is the LQA matrix (see MIL-STD-188-141, the figure on connectivity and LQA memory). This is an array of link quality records, each containing bidirectional measurements for (at least) BER, SINAD, and multi-path (MP), and each tagged with the ages of the measurements. The matrix is conceptually organized as a two-dimensional array, indexed by channel number and by directly reachable station (i.e., matrix contains an entry for the potential quality of a link to each station that can be called directly on every channel defined for reaching that station).

5.4.2 Sounding. Sounding is the periodic broadcast of a station's address, so that other stations can evaluate the quality of the frequency carrying the sound for future link establishment to the sounding station.

5.4.2.1 Sounding intervals. The required rate of sounding is determined by how busy the intended recipients are, and the maximum acceptable probability that the most recent sounds received from some stations are older than some maximum acceptable age. For example, if B is the probability that a receiver is busy when a sound is sent, A is the maximum acceptable age (in hours), and P is the maximum acceptable probability that an entry is older than that age, then R sounds will be sent per hour, where:

$$R=\frac{\log P}{A\log B}.$$

A and P are chosen by the network manager to satisfy network performance goals. B is measured from actual network operation. Specifically, B is the fraction of time during a measurement period that the observed radio is not able to receive sounds; this usually means the fraction of time that the radio is not scanning. Note that B includes both traffic and overhead (e.g., sounding and polling) busy time. For example, if polling is not used to fill in gaps in sounding data, the system may be willing to accept only a 10 percent probability that each entry in the LQA matrix is over 1 hour old. Then R is a function of B as shown in table IV.

TABLE IV. Example sounding interval calculation.

B (Prob. Station Busy)	R (Minimum Sounds/Hr/Chan)	Maximum Sounding Interval
1%	0.5	2 hr.
10%	1	1 hr.
32%	2	30 min.
46%	3	20 min.
56%	4	15 min.
68%	6	10 min.

5.4.2.2 Local noise report.

a. The call acceptance and call rejection sounding protocols defined in MIL-STD-188-141 result in only unilateral link quality assessment at the receiving station. The local noise report is an alternative broadcast technique that permits receiving stations to approximate the bilateral link quality for the channel used by the station sending the local noise report. An example application of this optional technique is for networks in which most stations are silent but which need to have a high probability of linking on their first attempt with a sounding station.

b. A station receiving a sound can measure the unilateral link quality for the channel to it from the sounding station. If a local noise report is included in a transmission, the recipient can compare the noise level at the transmitter to its own local noise level, and estimate the bilateral link quality. The local noise report is contained in a single command (CMD) word as shown on figure 7, and reports the mean and maximum noise power measured on the channel (by the sending station) during the last 60 minutes.

3	7	7	7
CMD	Noise Report (ASCII 'n')	Max	Mean
110	1101110		

FIGURE 7. Local noise report.

c. Units for the Max and Mean fields are decibels (dB) relative to 0.1 microvolt in a 3 kHz channel. If the local noise measurement to be reported is 0 dB or less, a 0 is sent. For measured noise ratios of 0 dB to +126 dB, the ratio in dB is rounded to an integer and sent. For noise ratios greater than +126 dB, 126 is sent. The code 127 (all 1's) is sent when no report is available for a field.

d. By comparing the noise levels reported by a distant station on several channels, the station receiving the noise reports can select a channel for linking attempts based upon knowledge of both the propagation characteristics and the interference situation at the distant station.

5.4.3 Polling protocols. The polling protocols are used to measure and exchange current bilateral link quality data.

5.4.3.1 Individual poll: two stations, one channel. A two-station poll may be performed using a 3-way handshake with an LQA request in the call, an LQA report with a request in the response, and an LQA report in the acknowledgment (which may also terminate the link).

5.4.3.2 Multiple station - single channel polling. Slotted response structures (net and group calls) in star topologies yield bilateral results at the hub (which receives hub-to-spoke reports in the slotted responses and measures spoke-to-hub LQA during those responses), but only unilateral (hub-to-spoke) LQA measurements at the out stations. For the hub to report the LQA values measured on the responses, the existing protocols require individual handshakes with each out station. With slight extensions to the existing protocols, however, efficient bilateral LQA measurements for all stations' links to the hub can be obtained. (Some unilateral spoke-to-spoke measurements may also be made by stations able to do so.) These protocols should only be used when a network uses net or group calls in normal operation.

NOTE: Net poll and group poll protocols hold stations on channel for extended periods while awaiting slotted responses. Unless a network uses slotted-response calls regularly and has been programmed accordingly, use of this type of polling will severely degrade linking performance. These protocols should only be used when a network uses net or group calls in normal operation. See 6.1.2.1.

5.4.3.2.1 Hub net poll.

a. The hub net poll protocol evaluates bilateral connectivity between the originator of the call and each of the responding net members. At the completion of the protocol, only the calling station (the "hub") knows all of the bilateral measurements; each responding net member may know only the hub-to-spoke link quality that it measured from the call and the acknowledgment (see figure 8).

b. Although the hub is called net control station (NCS) in the example, this call may be originated by any station. The hub calls the net with an LQA request embedded in the call. Each net member that hears the call responds in its assigned slot, reporting the LQA data that it acquired from the call. The hub completes the three-way handshake with an acknowledgment that contains no LQA report, and returns the net to scan with a THIS WAS termination.

c. If any responding station requests LQA from the hub in its response, the hub shall insert an LQA report in its acknowledgment, but the LQA report shall contain all fields set to all 1's ("no report") to avoid confusing other stations.

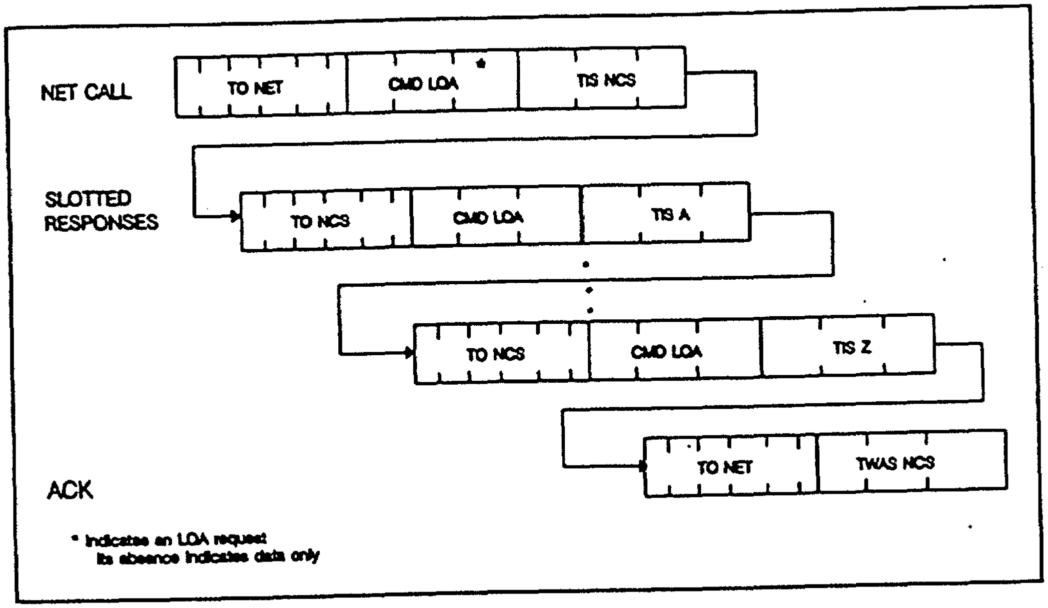

FIGURE 8. Hub net poll (T_{SC} not shown).

5.4.3.2.2 Full net poll.

a. The full net poll protocol evaluates and reports bilateral connectivity between the originator of the call and each of the responding net members (see figure 9). The hub calls the net, with an LQA request embedded in the call. Each net member that hears the call responds in its assigned slot, reporting the LQA data that it acquired from the call and requesting that the hub return an analysis of the station's response in the acknowledgment. The hub completes the three-way handshake with an acknowledgment that returns LQA data to the net members in *slot order* and returns the net to scan with a THIS WAS termination. For compatibility with stations not equipped to receive this data, the message section in the acknowledgment shall start with a "no report" LQA CMD, followed by LQA reports embedded in DATA words. The first DATA word shall contain the LQA report for the station in slot 1, and so on. Note that positions in the acknowledgment corresponding to nonresponding net members (including the hub) shall be filled with "no report" words.

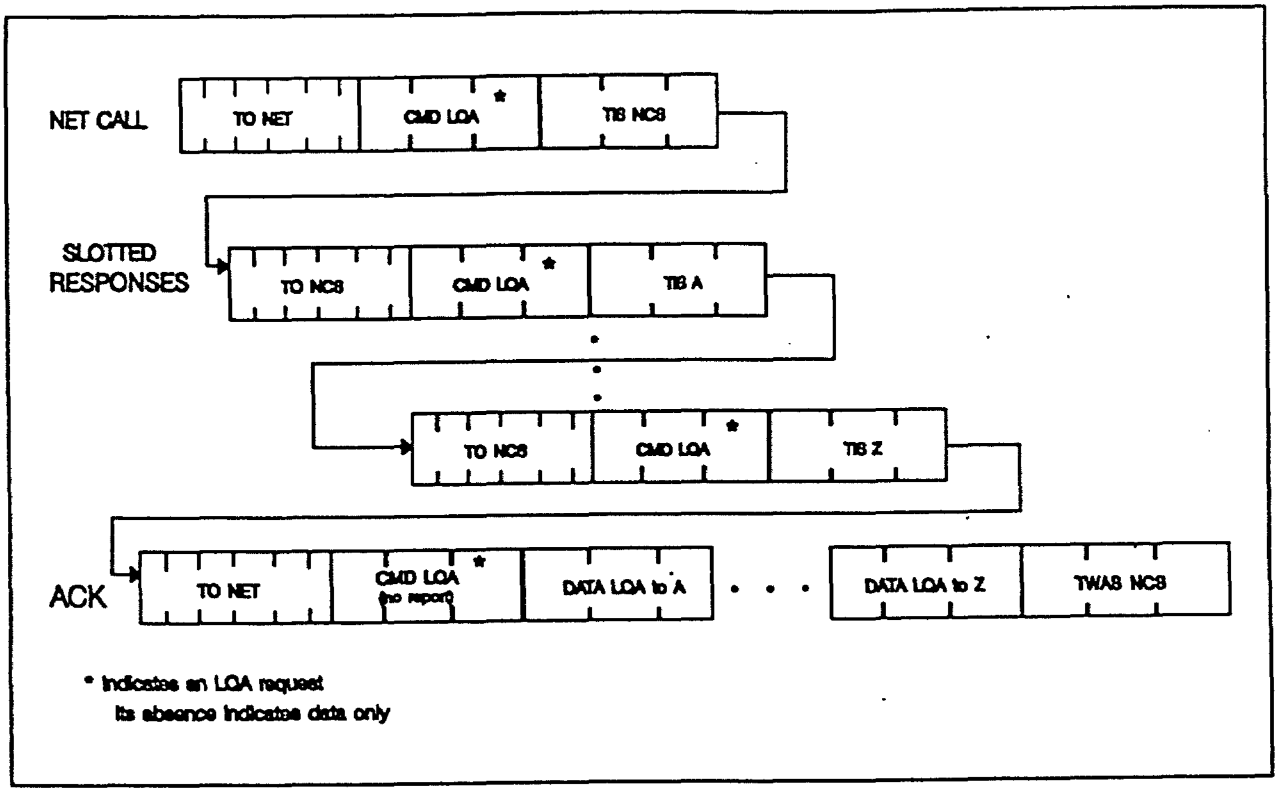

FIGURE 9. Full net poll (T_{SC} not shown).

b. The time required to execute this protocol on one channel (including the scanning call time for [T_{SC}]) is about 40 seconds for a 10 station net with a 10 channel T_{SC}, or 275 seconds for 100 stations.

5.4.3.2.3 Hub group poll. The hub group poll is structurally similar to the hub net poll, except that the net call is replaced by a group call. The acknowledgment may address all of the stations addressed in the call; alternatively, those stations whose response is not heard by the hub may be omitted in the acknowledgment.

5.4.3.2.4 Full group poll. The full group poll is structurally similar to the full net poll, except that the net call is replaced by a group call. The acknowledgment may address all of the stations addressed in the call; alternatively, those stations whose response is not heard by the hub may be omitted in the acknowledgment. The order of LQA reports in the acknowledgment (following the "no report" LQA CMD) is determined by the order of addresses in the acknowledgment. Non-responding stations may be omitted from both the leading call and message section of the acknowledgment.

5.4.3.3 Two station - multiple channel polling.

a. A technique commonly called "poll before linking" evaluates several channels immediately before linking to select the current best channel. This may be performed using an individual poll on each channel, but a significant amount of time is wasted in unnecessary scanning calls. For example, evaluating 10 channels takes about 150 seconds, with over half of this time consumed by calling cycles of scanning calls. All but the first scanning call may be eliminated if the stations involved agree upon a list of channels to be evaluated, and then step through this list synchronously.

b. When stations with identical scan sets want to evaluate all channels in their common scan set, the following protocol is used:

(1) The caller embeds **CMD** <LQA request> **CMD** <channel scan request> in the call. (A channel scan request carries as a parameter the sender's tune time, as shown on figure 10).

(2) The responder shall respond to the LQA request (requirement of MIL-STD-188-141). If the response contains **CMD** <channel scan request>, the requested channel scan has been accepted, and both stations are obligated to complete it. Otherwise, an individual poll is completed on the current channel, and the protocol terminates.

(3) When the response contains a channel scan request (along with an LQA report with the request bit set), an individual poll is completed on the initial channel. The acknowledgment from the caller will contain an LQA report with the request bit negated.

(4) Both stations proceed to the next channel, listen for activity, and tune. After the longer of the two tune times in the channel scan request has elapsed, the caller initiates a non-scanning individual poll: a leading call, an LQA request, and the caller's frame termination. The response will contain an LQA report with the request bit set, and the acknowledgment from the caller will contain an LQA report with the request bit negated.

3	7	2	3	2	7
CMD	Channels (ASCII 'c')	Type	Tune	Mode	Control
110	1100011	00			

FIGURE 10. Channel scan request CMD format.

c. The synchronous polling shall proceed through the channels from the initial channel to the next lower frequency, and so on, wrapping around from the lowest frequency to the highest, and continuing through all of the channels. Busy channels are not evaluated. Since both stations tune before the call, no tune time is needed between the call and the response. This permits additional speed-up in evaluating the channels. The stations always proceed to the next channel synchronously, whether or not they successfully measure the current channel (e.g., busy or non-propagating channels). The time step per channel is the longer tune time plus 18 T_{rw} (redundant word time) (assuming three-character addresses).

d. The Type field of the channel scan request CMD word is set to 00 to distinguish it from other types of channel commands.

e. The Tune Time field is encoded as listed in table V. It indicates the time that must be allowed for tuning before each non-scanning call.

TABLE V. Tune time encoding.

Tune Field	Tune Time
000	100 ms
001	200 ms
010	500 ms
011	1 s
100	2 s
101	5 s
110	10 s
111	30 s

f. The Mode field of the channel scan request CMD word is encoded as listed in table VI. The purpose of this field is to indicate whether data words follow the channel scan request CMD word, and whether they contain channel designators or frequency designators.

TABLE VI. Mode field encoding.

Mode Field	Meaning
00	Use current scan list channels
01	Channel list follows
10	Frequency list follows
11	List accepted without modifications

g. In mode 01 or mode 10, the Control field is set to 1000000 when the channel or frequency designators (respectively) are positive offsets relative to the initial channel, or to 1100000 for negative offsets. In all other cases, the Control field is set to 0000000.

h. When the set of channels to be evaluated must be negotiated before the channel scan, channel designators are sent following the Channel Scan Request CMD word in DATA words. Up to three channel designators are sent in each DATA word. The order of channels scanned is determined by the order the channels are listed.

(1) The first channel scanned after the initial channel is designated in the most significant character position of the first DATA word.

(2) The scan proceeds in order through the remaining channels designated in the first data word followed by channels designated in subsequent data words.

(3) Unused character positions in the final DATA word shall be filled with 0's.

i. When the caller provides an explicit list of channels following its channel scan request, the responder may either accept this list without modifications by returning a channel scan request with a mode of 11, or it may add channels to the list by returning a channel scan request with a mode of 01 followed by the list of channels to be added.

j. When the correspondence of channel numbers to frequencies is different for the stations wishing to poll before linking, the set of frequencies to be evaluated shall be negotiated before the channel scan. In this case, frequency designators are sent following the channel scan request CMD word in DATA words. One frequency designator is sent in each DATA word in positions W_5 through W_{24}. W_4 is set to 0. The order of frequencies scanned is determined by the order the frequencies are listed.

(1) The first frequency scanned after the initial channel is designated in the first DATA word.

(2) The scan proceeds in order through the frequencies designated in subsequent data words.

k. When the caller provides an explicit list of frequencies following its channel scan request, the responder may either accept this list without modifications by returning a channel scan request with a mode of 11, or it may add frequencies to the list by returning a channel scan request with a Mode 10 followed by the list of frequencies to be added.

5.4.4 LQA report protocol.

a. The unilateral LQA data derived from measurements on traffic and sounds received on several channels can be exchanged among the stations sending and measuring those transmissions to provide each with bilateral LQA data for those channels. Thus, the LQA report protocol "closes the loop" with passive LQA. The LQA report protocol is used by station A to report to station B the LQA data collected by A from transmissions from B to A.

b. LQA reports are embedded in ALE frames as follows: the first word in an LQA report message is an LQA report CMD word, formatted as shown on figure 11. This is followed by LQA reports for the number of channels specified in the Chan field in the LQA report CMD. These are carried either in a data text message (DTM) or in a data block message (DBM), as specified by control bit KR5 (see table VII). In either case, the message carrying the reports shall immediately follow the LQA report command word.

3	7	2	5	2	5
CMD	LQA Report (ASCII 'r')	Type	Control	*	Chan
110	1110010	00		00	
* Reserved block (set to 00)					

FIGURE 11. LQA report CMD format.

TABLE VII. Control bit assignments (LQA report CMD word).

Control Bit	Meaning
KR5 (most significant bit)	0 if reports in DTM message 1 if reports in DBM message
KR4, 3, 2	000 data only (no channel or frequency designators) 001 data and channel designator (negative offset) 010 data and channel designator (absolute) 011 data and channel designator (positive offset) 100 data and frequency designator (negative offset) 101 data and frequency designator (absolute) 110 data and frequency designator (positive offset) 111 (reserved)
KR1 (least significant bit)	(reserved)

c. The individual reports have one of three formats, as specified by control bits KR4, KR3, and KR2; data only (16 bits per report); channel and data (23 bits); or frequency and data (36 bits) (see figure 12). In all cases, the data portion of the report has the same format: age of the data (3 bits), multipath (3 bits), SINAD (5 bits), and BER (5 bits), with encodings as specified in paragraph e below. When a channel or frequency designator is included in each report, it immediately precedes its corresponding data field, and is formatted as described in 5.3.

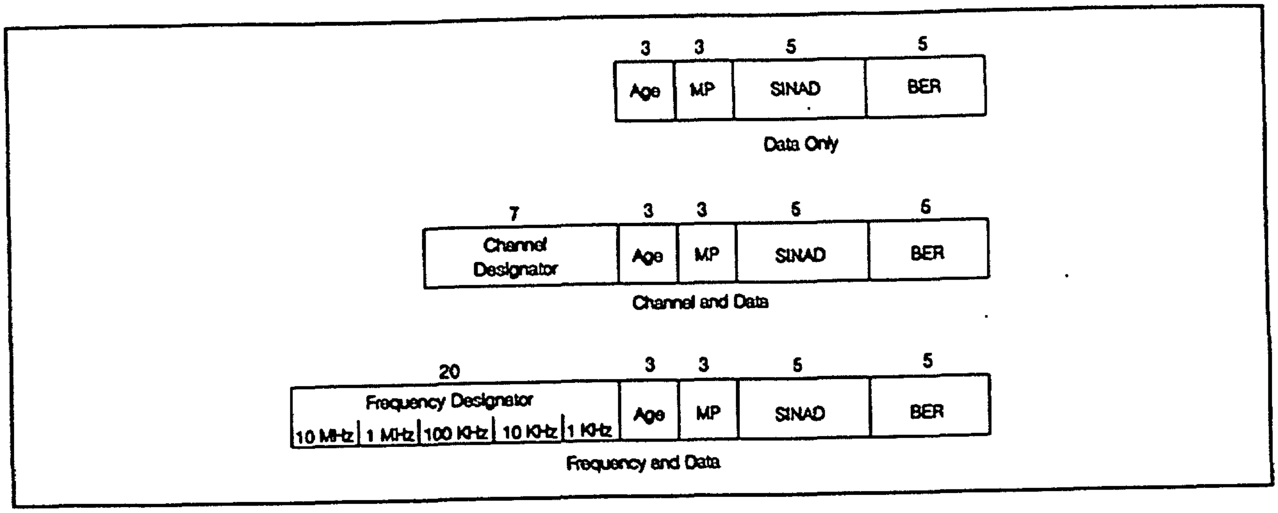

FIGURE 12. LQA report formats.

d. When a DTM is used to carry LQA reports, the reports are packed bit-by-bit into the 21-bit data fields without aligning each report with the start of a new word. When the reports do not fill the final ALE word, the remaining bits after the last report are filled with 0's. The DBM data block is likewise filled with packed reports, with the Length field set to indicate the length of reports.

e. The BER field in LQA reports is encoded as in LQA CMD words (MIL-STD-188-141, section entitled Basic Bit Error Ratio Values). SINAD is encoded as an integer in dB: 0-30, with the code 31 (11111) reserved to indicate no SINAD report. Multipath is similarly encoded as an integer in ms: 0-6, with the code 7 (111) reserved to indicate no multipath report. The age of each report is encoded as shown in table VIII.

TABLE VIII. Age field encoding.

Age Field	Age of Reported Data
000	0-15 min
001	15-30 min
010	30-60 min
011	1-2 hr
100	2-4 hr
101	4-23 hr
110	23-25 hr
111	>25 or unknown

f. LQA reports may be sent either upon request or by pre-arranged schedule. A station may request an LQA report by sending an LQA report request, which shall be formatted as shown on figure 13. The bits of the control field are used to request the format of LQA reports, and shall be assigned in accordance with table VII. The Age field specifies the maximum age acceptable for the reports and shall be encoded in accordance with table VIII. If the Age field is set to 110, all channels with LQA measurements shall be reported; if the Age field is set to 111, all channels common to the two stations shall be reported, including those for which no data is available.

3	7	2	5	4	3
CMD	LQA Report (ASCII 'r')	Type	Control	*	Age
110	1110010	10		0000	
* Reserved block (set to 0000)					

FIGURE 13. LQA report request CMD format.

5.5 Advanced link quality analysis. Stations supporting ALQA shall maintain an ALQA matrix analogous to the LQA matrix (see the section on Connectivity and LQA Memory in MIL-STD-188-141) that stores histograms as described in 4.5.3 for the stations listed in the section on Other Address Memory in MIL-STD-188-141. For each station, the ALQA matrix shall contain one set of histograms for each implemented channel quality measure for each channel scanned, and one set of histograms for each implemented link performance measure.

5.5.1 Channel quality measures. Channel quality measurements for ALQA shall be in accordance with the applicable paragraph below.

5.5.1.1 SINAD and PBER. SINAD and PBER shall be measured as described in MIL-STD-188-141 for each ALE word received beginning when word synchronization is achieved. For ALQA use, the word-by-word samples shall not be averaged (as in MIL-STD-188-141), but shall be histogrammed as described in 4.5.3.

5.5.1.2 Articulation index.

a. Articulation index shall be computed using a weighted sum of the signal-to-noise ratios within the frequency bands centered on the 8 ALE modem tones in accordance with table IX. (The weights F_i shown in table IX reflect the varying sensitivity of human hearing to different frequencies.) The effective sensation levels E_i in each sub-band ($1 \leq i \leq 8$) shall be accumulated during each ALE triple-redundant word reception (49 symbol periods). For each sub-band i, S_i is the mean spectral density of the ALE modem input signal in the i-th frequency band (in decibel referenced to one milliwatt (dBm)/hertz (Hz)) averaged over those symbol periods for which the demodulator chose symbol i, while N_{Oi} is the mean spectral density in the i-th frequency band (in dBm/Hz) averaged over those symbol periods for which symbol i was not chosen (an estimate of the noise and interference in sub-band i). The E_i (in dB) shall be determined from these measurements using the formula $E_i = S_i - N_{Oi}$.

TABLE IX. ALE tone weighting factors.

Tone(i)	Nominal Freq.	Freq. Sub-Band	Weight (F_i)
1	750	625 - 875	0.161
2	1000	875 - 1125	0.147
3	1250	1125 - 1375	0.142
4	1500	1375 - 1625	0.131
5	1750	1625 - 1875	0.131
6	2000	1875 - 2125	0.113
7	2250	2125 - 2375	0.095
8	2500	2375 - 2625	0.080

b. Scaled measurements W_i (ranging from 0 to 1) shall be determined from the effective sensation level E_i of each speech sub-band as follows:

(1) For $E_i < 1$ dB, $W_i = 0$.

(2) For 1 dB $\leq E_i \leq$ 12 dB, get W_i from table X.

(3) For 12 dB $< E_i \leq$ 36 dB, $W_i = (E_i - 6)/30$.

(4) For $E_i > 36$ dB, $W_i = 1$.

The articulation index sample for each received ALE word shall be computed from measurements W_i within each frequency band as follows. The weighting factors F_i shall be taken from the last column of table IX above:

$$AI = \sum_{i=1}^{8} F_i W_i .$$

Articulation index samples shall be histogrammed as specified in 4.5.3.

NOTE: The articulation index measurements are performed only over the 625 to 2625 Hz frequency range, but the articulation index value obtained is extrapolated to the entire voice range so that the range of articulation index values is 0 to 100 percent.

TABLE X. E_i to W_i conversion ($1 \text{ dB} \le E_i \le 12 \text{ dB}$).

E_i (dB)	W_i	E_i (dB)	W_i
1.0 - 2.2	0.01	8.4 - 8.7	0.11
2.3 - 3.1	0.02	8.8 - 9.1	0.12
3.2 - 3.9	0.03	9.2 - 9.5	0.13
4.0 - 4.6	0.04	9.6 - 9.9	0.14
4.7 - 5.3	0.05	10.0 - 10.3	0.15
5.4 - 6.0	0.06	10.4 - 10.7	0.16
6.1 - 6.6	0.07	10.8 - 11.1	0.17
6.7 - 7.2	0.08	11.2 - 11.5	0.18
7.3 - 7.8	0.09	11.6 - 11.8	0.19
7.9 - 8.3	0.10	11.9 - 12.0	0.20

5.5.1.3 Spectral distortion.

a. Spectral distortion shall be measured by comparing pairs of SINAD and PBER measurements of received ALE words to the theoretical modem performance curve (the dashed line labeled 'G' on figure 14). Each (e.g., SINAD and PBER) measurement pair falls within one of the regions on figure

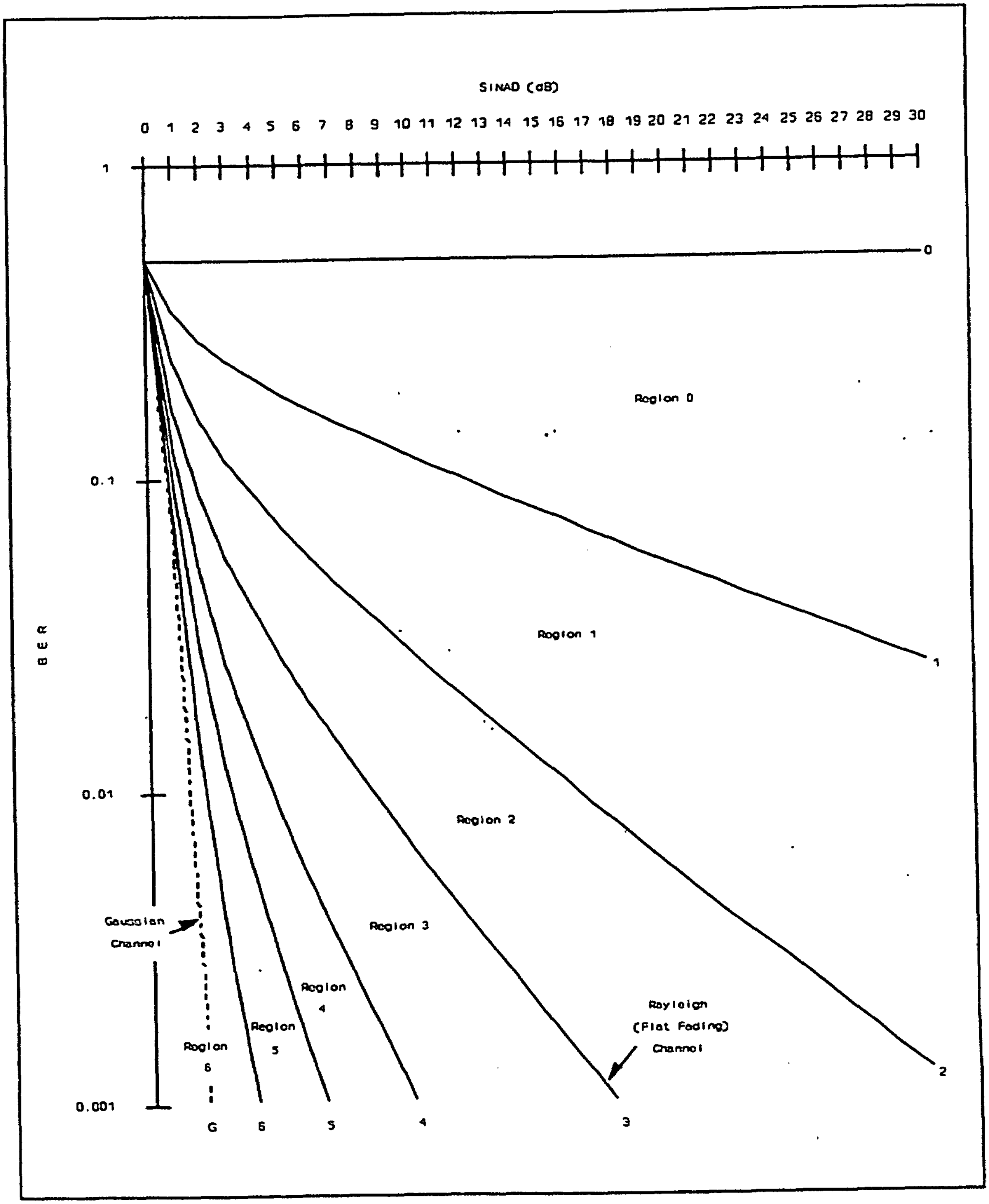

FIGURE 14. Spectral distortion partition of BER versus SINAD sample space.

Spectral distortion measurements shall be histogrammed in accordance with 4.5.3.

b. Points along the lines that separate the regions shown on figure 14 are tabulated in table XI; each column in the table is labeled with the corresponding curve number from the figure.

c. The following simple algorithm, using the data from table XII, may be used to quickly compute spectral distortion.

(1) Measure SINAD and PBER for each word received.

(2) Convert the measurements of each word to LQA codes (range 0-30) in accordance with MIL-STD-188-141.

(3) Use the SINAD code to select a row in table XII.

(4) Find the column in that row that includes the PBER code; the spectral distortion region number at the head of that column is the spectral distortion value for that word. The spectral distortion value is 7 ("no measurement") if either SINAD or PBER is unknown (code 31), or if the SINAD code is 0 ("no signal").

5.5.1.4 Error-free interval. The word error statistics described in table XIII shall be obtained from the receiving Golay decoder and ALE protocol (errors which cannot be corrected in either or both Golay words or in the entire ALE word, count as one word error). Each of the counts shall be accumulated separately for each of the four epochs.

The estimated error-free interval on a channel for any epoch shall be computed as follows:

$$P_e = \frac{Total\ errors}{Total\ words} \qquad P_b = \frac{Burst\ errors}{Total\ errors}$$

$$EFI = \frac{(1/P_e) - 1}{1 - P_b}.$$

5.5.2 Link performance measures. The link performance measures, achievable voice quality, and available data capacity shall represent the combined performance available using any of the channels available to the ALE controller. Achievable voice quality and available data capacity samples for each station listed in the ALQA matrix shall be histogrammed as described in 4.5.3.

TABLE XI. Maximum BER for each spectral distortion region (boundary coordinates).

SINAD (dB)	0	1	2	3	4	5	6	Gaussian
1	0.5000	0.34697	0.24077	0.16708	0.12560	0.09442	0.06957	0.05432
2	0.5000	0.28121	0.15816	0.08895	0.04965	0.02771	0.01187	0.00154
3	0.5000	0.24090	0.11607	0.05592	0.02480	0.01100	0.00300	0.00001
4	0.5000	0.21198	0.08987	0.03810	0.01394	0.00510	0.00095	
5	0.5000	0.18943	0.07177	0.02719	0.00841	0.00260	0.00034	
6	0.5000	0.17094	0.05844	0.01998	0.00529	0.00140	0.00014	
7	0.5000	0.15529	0.04823	0.01498	0.00344	0.00079	0.00006	
8	0.5000	0.14178	0.04020	0.01140	0.00226	0.00045	0.00003	
9	0.5000	0.12986	0.03373	0.00876	0.00154	0.00027	0.00001	
10	0.5000	0.11923	0.02843	0.00678	0.00104	0.00016	0.00001	
11	0.5000	0.10970	0.02407	0.00528	0.00073	0.00010		
12	0.5000	0.10107	0.02043	0.00413	0.00050	0.00006		
13	0.5000	0.09322	0.01738	0.00324	0.00036	0.00004		
14	0.5000	0.08607	0.01481	0.00255	0.00023	0.00002		
15	0.5000	0.07950	0.01264	0.00201	0.00018	0.00002		
16	0.5000	0.07353	0.01081	0.00159	0.00013	0.00001		
17	0.5000	0.06786	0.00921	0.00125	0.00009	0.00001		
18	0.5000	0.06279	0.00788	0.00099	0.00007			
19	0.5000	0.05824	0.00678	0.00079	0.00005			
20	0.5000	0.05372	0.00577	0.00062				
21	0.5000	0.04966	0.00493	0.00049				
22	0.5000	0.04603	0.00424	0.00039				
23	0.5000	0.04264	0.00364	0.00031				
24	0.5000	0.03969	0.00315	0.00025				
25	0.5000	0.03684	0.00271	0.00020				
26	0.5000	0.03420	0.00234	0.00016				
27	0.5000	0.03175	0.00202	0.00013				
28	0.5000	0.02934	0.00172	0.00010				
29	0.5000	0.02714	0.00147	0.00008				
30	0.5000	0.02520	0.00127	0.00006				

TABLE XII. PBER code ranges for each spectral distortion region.

SINAD code	Spectral Distortion Region 0	1	2	3	4	5	6
1		27 - 30	21 - 26	16 - 20	13 - 15	10 - 12	0 - 9
2	30	20 - 29	12 - 19	7 - 11	4 - 6	2 - 3	0 - 1
3	27 - 30	15 - 26	8 - 14	4 - 7	2 - 3	1	0
4	25 - 30	12 - 24	6 - 11	2 - 5	1		0
5	23 - 30	10 - 22	4 - 9	2 - 3	1		0
6	21 - 30	8 - 20	3 - 7	1 - 2			0
7	19 - 30	7 - 18	3 - 6	1 - 2			0
8	18 - 30	6 - 17	2 - 5	1			0
9	17 - 30	5 - 16	2 - 4	1			0
10	16 - 30	4 - 15	1 - 3				0
11	15 - 30	4 - 14	1 - 3				0
12	14 - 30	3 - 13	1 - 2				0
13	13 - 30	3 - 12	1 - 2				0
14	12 - 30	3 - 11	1 - 2				0
15	11 - 30	2 - 10	1				0
16	10 - 30	2 - 9	1				0
17	10 - 30	2 - 9	1				0
18	9 - 30	2 - 8	1				0
19	8 - 30	1 - 7					0
20	8 - 30	1 - 7					0
21	7 - 30	1 - 6					0
22	7 - 30	1 - 6					0
23	6 - 30	1 - 5					0
24	6 - 30	1 - 5					0
25	6 - 30	1 - 5					0
26	5 - 30	1 - 4					0
27	5 - 30	1 - 4					0
28	5 - 30	1 - 4					0
29	5 - 30	1 - 4					0
30	4 - 30	1 - 3					0

TABLE XIII. Word error statistics.

Statistic	Description
Total words	A running count of the number of ALE words received on the channel during the epoch, including words during which word synchronization was achieved.
Total errors	A running count of the number of word errors that have occurred in the epoch on the channel.
Burst errors	A running count of the number of error words that immediately followed another error word.

5.5.2.1 Achievable voice quality.

a. Achievable voice quality shall be measured while the ALE controller is scanning. During each ALQA scan of the available channels (see paragraph b below), the ALE controller shall note which channels are unoccupied. When occupancy of each channel has been evaluated, the most recent voice channel quality measure samples (see paragraph c below) to each station via the unoccupied channels shall be compared; for each station, the channel quality measure sample having the largest value shall be histogrammed as the achievable voice quality sample for that station, for that ALQA scan.

b. If channel occupancy can be accurately determined at the normal ALE scanning rate, the ALQA scan shall coincide with the ALE scan (i.e., an ALQA scan shall be performed during each ALE scan). However, if the equipment available to the ALE controller for measuring channel occupancy requires a longer dwell time on each channel than does normal ALE scanning, the number of channels evaluated on each ALE scan shall be limited so that the ALE scan is not extended beyond a total of 2 C T_{rw}, where C is the number of channels scanned. Because multiple ALE scans are then required to evaluate all channels, this results in an ALQA scan period that is several times longer than the ALE scan period.

c. The voice channel quality measure used for achievable voice quality shall be articulation index if available. Otherwise, SINAD shall be used.

5.5.2.2 Available data capacity. An available data capacity sample shall be computed and histogrammed each time the ALE controller successfully sends a message to another station. (DO: also compute available data capacity samples when messages are sent by other data link controllers.) See table XIV for the applicable symbology. Available data capacity samples require the measurements for the symbols listed in table XIV for each message sent.

TABLE XIV. Available data capacity symbols.

Symbol	Meaning
T_b	Time when the first transmission related to sending the message began (e.g., the call to establish a link for sending the message).
T_f	Time when the (final) data link ACK arrived, indicating that the message had been completely received by the receiving station, and could be discarded at the sending station.
L_m	Number of bits in the message body, exclusive of data link layer overhead bits.
L_s	Sum of the L_m's for all *other* messages (to any destination) waiting to be sent after the current message, as of time T_b.
L_f	Sum of the L_m's for all *other* messages (to any destination) waiting to be sent as of time T_f, including messages not in the queue at time T_b.

The effective data rate R for the message shall be computed as follows:

$$R = \frac{L_m}{T_f - T_b}.$$

Station utilization U shall be computed as follows:

$$U = \frac{L_f - L_s}{L_m}.$$

The available data capacity sample X shall be computed as:

$$X = R(1 - U).$$

For example, consider a 300-character message to be sent as a data text message. L_m in this case is 2100 bits. Assume that two other messages were waiting when link establishment to send this message began, and that they contained a total of 480 characters, so L_s = 3360 bits. Link establishment succeeds on the first channel tried, and the message is sent in the ALE acknowledgement. However, a fade during the message transmission causes an ARQ NAK, a (successful) retransmission and an ACK.

This requires a total of 100 seconds = $T_f - T_b$. During this process, another message has joined the waiting queue; it contains 120 characters, so L_f = 7 (480 + 120) = 4200. For this example,

$$R = \frac{2100}{100} = 21\ bps$$

$$U = \frac{4200 - 3360}{2100} = 0.40$$

$$X = 21(1 - 0.40) = 12.6\ bps.$$

5.5.3 ALQA reporting protocol. The following ALQA orderwire protocol shall be used to request and to report channel quality measure and link performance measure data. ALQA reports shall convey historical data (including measurements of the ALQA request itself) for all channels common to the parties to the exchange. (This protocol is similar to the LQA report protocol described in 5.4.4.)

5.5.3.1 ALQA command word. The ALQA command word (shown on figures 15 through 17 and 19) shall be used both to request and to report ALQA measurements. All instances of the ALQA CMD contain Epoch and Control fields. In requests, the Epoch field shall specify the desired timeliness of data, while in a report, the Epoch field shall indicate the epoch actually used (see table XV). (Note that the Epoch field in a report need not have the same value as in the request.)

TABLE XV. Epoch field encoding.

Epoch Field	Request	Report
00	Data accumulated since startup (epoch 4)	Data from epoch 4
01	Data from current 15 minute interval (epoch 1)	Data from epoch 1
10	Data from most recent epoch with more than zero samples	Data from epoch 2
11	Data from epoch with greatest density of samples (number of samples divided by $N_k t_k$)	Data from epoch 3

The Control field shall describe the format of the reports requested or delivered in accordance with table XVI. The reporting station should always comply with the reporting format requested unless it is not equipped to do so. All implementations of ALQA reporting shall support the minimum interoperability format which corresponds to all control bits set to 0 (i.e., reports in DTM messages containing data only and using default thresholds, as described later).

TABLE XVI. Control bit assignments.

Control bit	Meaning
KL5 (most significant bit)	0 if reports in DTM message 1 if reports in DBM message
KL4, 3, 2	000 data only (no channel or frequency designators) 001 data and channel designator (negative offset) 010 data and channel designator (absolute) 011 data and channel designator (positive offset) 100 data and frequency designator (negative offset) 101 data and frequency designator (absolute) 110 data and frequency designator (positive offset) 111 (reserved)
KL1 (least significant bit)	0 If default thresholds 1 If thresholds follow this CMD

5.5.3.2 Channel quality measure request. Channel quality measure requests shall use the channel quality measure request CMD word as shown on figure 15a. The Control and Epoch fields shall be encoded as described above. Each channel quality measure selector bit (see table XVII) shall be set to 1 to request that the corresponding channel quality measure be reported, or to 0 to suppress reporting of that channel quality measure.

3	7	2	5	2	5
CMD	1100000 ('\':ALQA)	10	Control	Epoch	CQM 1-5

FIGURE 15a. ALQA channel quality measure request CMD format.

TABLE XVII. Channel quality measure selector bit assignments.

Selector Bit	Channel Quality Measure (CQM)
CQM5 (msb)	SINAD
CQM4	P_c = 1 - PBER
CQM3	Articulation Index
CQM2	Spectral Distortion
CQM1 (lsb)	Error-Free Interval

If KL1 is set to 1 in a channel quality measure request (which signals that the requestor wishes to use thresholds other than the default), the channel quality measure request CMD word shall be followed by a DATA word containing the respective thresholds desired, (see figure 15b) encoded as in table XVIII. Threshold fields containing all 1's indicate that the default threshold for the corresponding channel quality measure should be used. Unless otherwise programmed, the default threshold for each channel quality measure shall be that corresponding to code 6 (0110) in table XVIII.

3	2	4	4	4	3	4
DATA	00	SINAD	P_c = 1 0 PBER	AI	SD	0000

FIGURE 15b. ALQA channel quality measure threshold word.

TABLE XVIII. Quantization of channel quality measure thresholds, error-free interval reports, and exceedance percentages.

Code	SINAD (dB)	P_c = 1 - PBER	AI	SD	EFI	AVQ (dB)	ADC	Percent
0000	2	0.700	0.01	0	1	2	1	0
0001	4	0.725	0.05	1	2	4	2	5
0010	6	0.750	0.09	2	5	6	3	10
0011	8	0.775	0.13	3	10	8	4	20
0100	10	0.800	0.19	4	20	10	5	30
0101	12	0.825	0.26	5	50	12	8	40
0110	14*	0.850*	0.33*	6*	100	14*	15*	50
0111	16	0.875	0.40	-	200	16	25	60
1000	18	0.900	0.47	-	500	18	50	70
1001	20	0.925	0.53	-	1,000	20	100	80
1010	22	0.950	0.60	-	2,000	22	200	85
1011	24	0.975	0.67	-	5,000	24	400	90
1100	26	0.985	0.73	-	10,000	26	800	95
1101	28	0.993	0.80	-	20,000	28	1600	97
1110	30	0.999	0.90	-	50,000	30	3200	99
1111	use de-fault	use default	use de-fault	use de-fault	no report	use de-fault	use de-fault	no report
* indicates default								

5.5.3.3 Link performance measure request. Link performance measure requests shall use the link performance measure request CMD word as shown on figure 16. The Control and Epoch fields shall be encoded as described above, except that KL 2-4 shall be set to 0 (channels are irrelevant to link performance measure reports). The D bit shall be set to 1 to request a data link performance measure report, or to 0 to request a voice link performance measure report. The link performance measure Threshold field shall contain the threshold for the selected link performance measure, encoded in accordance with table XVIII. (If both voice and data link performance measure reports are desired, two link performance measure request CMDs shall be sent.)

3	7	2	5	2	1	4
CMD	1100000 (' ` ' :ALQA)	11	Control	Epoch	D	LPM Threshold

FIGURE 16. ALQA link performance measure request CMD format.

5.5.3.4 Channel quality measure reports. The channel quality measure report CMD (figure 17) shall precede channel quality measure reports. The Control field shall specify the format of the reports that follow this CMD word (until any following ALQA report CMD word, if any), and the Epoch field shall indicate the epoch of data used for all reports that follow. The Channels field shall contain a binary count of the number of reports that follow this CMD word.

3	7	2	5	2	5
CMD	1100000 ('`':ALQA)	00	Control	Epoch	Channels

FIGURE 17. Channel quality measure report CMD format.

Channel quality measure reports shall be formatted as illustrated on figure 18, except that channel quality measure fields not requested shall not be present in the reports. Each channel quality measure field is 4 bits, and carries the code from table XVIII corresponding to:

a. The percentage of samples of the channel quality measure from the epoch in use that equaled or exceeded the threshold used for that channel quality measure (for SINAD, P_c, articulation index, or spectral distortion), or

b. The estimated error-free interval.

4	4	4	4	4
SINAD	P_C	AI	SD	EFI

7	4	4	4	4	4
Channel Designator	SINAD	P_C	AI	SD	EFI

20	4	4	4	4	4
Frequency Designator	SINAD	P_C	AI	SD	EFI

FIGURE 18. Channel quality measure report formats.

When a DTM is used to carry ALQA reports, the reports shall be packed bit-by-bit into the 21-bit data fields without aligning each report with the start of a new word.

When the reports do not fill the final ALE word, the remaining bits after the last report shall be filled with 0's. The DBM data block shall be likewise filled with packed reports, with the length field set to indicate the length of reports.

5.5.3.5 Link performance measure reports. Link performance measure reports shall use the link performance measure report CMD word as shown on figure 19. The Control and Epoch fields shall be encoded as described above for link performance measure requests. The D bit shall be set to 1 to indicate a data link performance measure report, or to 0 to indicate a voice link performance measure report. The link performance measure report field shall contain the percentage of time that the link performance equaled or exceeded the threshold specified for the indicated link performance measure on the link between the requesting and reporting stations, encoded in accordance with table XVIII.

3	7	2	5	2	1	4
CMD	1100000 ('\`':ALQA)	01	Control	Epoch	D	LPM Report

FIGURE 19. ALQA link performance measure report CMD format.

5.6 Additional orderwire functions. A variety of orderwire functions in addition to those in MIL-STD-188-141 are described in the following paragraphs. Some are required for support of linking protection, networking, and other functions described in other portions of this standard. The remainder are provided to simplify and to add capabilities to the operation of automated HF radio networks.

5.6.1 Version CMD. The version CMD function is used to request ALE controller version identification. The first character is 'v' to indicate the version family of ALE CMD word functions. The second character shall be set to 's' to select a summary report.

NOTE: The capabilities function in 5.6.2 is a variant of this function that provides more detailed information.

a. The response to a version CMD is a printable ASCII message in manufacturer-specific format that indicates a manufacturers' identification, the version(s) of hardware, operating firmware and software, and/or management firmware and software of the responding ALE controller, as requested by control bits KVC_{1-3} of the version CMD format (see figure 20 and table XIX).

3	7	7	3	4
CMD	1110110 ('v': version CMD)	1110011 ('s': summary)	Comps (KVC)	Formats (KVF)

FIGURE 20. Version CMD format.

TABLE XIX. Component selection.

Bit	Component whose version is requested when bit set to 1
KVC3 (msb)	ALE controller hardware
KVC2	ALE controller operating firmware
KVC1 (lsb)	ALE controller network management firmware (i.e., HNMP)

b. The requesting station specifies acceptable formats for the response in control bits KVF_{1-4} in accordance with table XX. A controller responding to a version function shall attempt to maximize the utility of its response and:

(1) Shall report the version(s) of all of the components requested by the KVC control bits that are present in the controller.

(2) Shall use the ALE message format that represents the highest level of mutual capability of itself and the requesting station by comparing the message types that it can generate with those desired by the requesting station, and selecting the message type in the intersection of these two sets that correspond to the highest-numbered KFV bit.

TABLE XX. Format selection.

Bit	Reporting format desired when bit set to 1
KVF4 (msb)	Reserved (always set to 0)
KVF3	Data Block Message
KVF2	Data Text Message
KVF1 (lsb)	Automatic Message Display Message

5.6.2 Capabilities function. The capabilities function is used to obtain a compact representation of the features available in a remote ALE controller. This function uses a variant of the version CMD word, as shown in figures 21 and 22.

5.6.2.1 Capabilities query. The capabilities query, shown in figure 21, consists of a single ALE CMD word. The second character position shall be set to 'c' to select a full capabilities report (rather than a summary as in the version CMD). The third character position shall be set to 'q' in a capabilities query to request a capabilities report.

3	7	7	7
CMD	1110110 ('v': version CMD)	1100011 ('c': capability)	1110001 ('q': query)

FIGURE 21. Capabilities query CMD format.

5.6.2.2 Capabilities report.

5.6.2.2.1. Capabilities report CMD. The capabilities report shall consist of a CMD word followed by five DATA words, as shown in figure 22. The second character position of the capabilities report CMD word shall be set to 'c' and the third character position shall be set to 'r'. (The DATA preamble in the second and fourth DATA words shall be replaced by REP for transmission, as required by the ALE protocol).

3	7	7	7
CMD	1110110 ('v': version CMD)	1100011 ('c': capability)	1110010 ('r': report)

3	5	8	8
DATA	Scan Rate (SR_{1-5})	Channels Scanned (CS_{1-8})	Max Tune Time (TT_{1-8})

3	4	4	3	5	5
DATA	Turnaround (TTA_{1-4})	Timeout (TWA_{1-4})	Listen (TWT_{1-3})	Polling (PP_{1-5})	LP Levels (LPL_{1-5})

3	6	7	8
DATA	LP Time (LPT_{1-6})	ALE Protocols (VAP_{1-7})	ALQA ($ALQA_{1-8}$)

3	8	8	5
DATA	Orderwire (OW_{1-8})	Relaying (RY_{1-8})	Repeaters (RPT_{1-5})

3	21
DATA	Scheduling (SCH_{1-21})

FIGURE 22. Capabilities report CMD and DATA format.

5.6.2.2.2 Data format. The format of the DATA words in a capabilities report is constant, regardless of the capabilities reported, to simplify the software that implements the capabilities command. The data fields of the capabilities report shall be encoded in accordance with tables XXI, XXII, and XXIII. The values encoded shall represent the current operational capabilities of the responding ALE controller, i.e., the timing or functions currently programmed. All timing fields shall be encoded as unsigned integers.

TABLE XXI. Capabilities report data fields (ALE timing).

Group	Field	Value	Units	Parameter from MIL-STD-188-141A Table "Timing"
ALE Timing	SR_{1-5}	Scan rate	Channels/s	$1/T_d$
	CS_{1-8}	Chan. scanned		C
	TT_{1-8}	Max tune time	100 ms	T_t
	TTA_{1-4}	Turnaround time	100 ms	T_a
	TWA_{1-4}	Activity timeout	$\log_2$ s	$*T_{wa}$
	TWT_{1-3}	Listen time	1 s	T_{wt}

* TWA=$\log_2$ n where n is the number of seconds of no detected activity before timeout.

TABLE XXII. Capabilities report data fields (mode settings).

Group	Bit	Set to 1 if and only if (iff)	Cross Ref: MIL-STD (paragraph)
ALE Protocols	VAP_7 (msb)	Accepting ALL calls	188-141 (Allcalls)
	VAP_6	Accepting ANY calls	188-141 (Anycalls)
	VAP_5	Accepting AMD 2msgs	188-141 (Automatic message display (AMD) mode)
	VAP_4	Accepting DTM msgs	188-141 (Data text message (DTM) mode)
	VAP_3	Accepting DBM msgs	188-141 (Data block message (DBM) mode)
	VAP_2	DTM capabilities	188-141 (Data text message (DTM) mode)
	VAP_1 (lsb)	DBM capabilities	188-141 (Data block message (DBM) mode)
LP Levels	LPL_5 (msb)	Capable of other LP	
	LPL_4	Capable of AL-4 LP	187-721 (AL-4)
	LPL_3	Capable of AL-3 LP	187-721 (AL-3)
	LPL_2	Capable of AL-2 LP	188-141 (AL-2)
	LPL_1 (lsb)	Capable of AL-1 LP	188-141 (AL-1)
Time Exchange	LPT_6 (msb)	Acting as time server	188-141 (Time service response, Time service response (non-protected)
	LPT_5	Active time acq. enable	188-141 (Active time acquisition (protected), Active time acquisition (non-protected)
	LPT_4	Passive time acq. enable	188-141 (Passive time acquisition)
	LPT_3	Will send time broadcasts	188-141 (Time broadcast)
	LPT_2	Time iteration capable	(not yet standardized)
	LPT_1 (lsb)	Precision time capable	(not yet standardized)

TABLE XXIII. Capabilities report data field (feature capabilities).

Group	Bit	Set to 1 iff Feature Implemented	Cross Ref: MIL-STD (paragraph)
Polling	PP_5 (msb)	Full Net Poll	187-721 (Full Net Poll)
	PP_4	Full Group Poll	187-721 (Full Group Poll)
	PP_3	Channel Scan CMD	187-721 (Two Station- Multiple Channel Polling)
	PP_2	LQA Report	187-721 (LQA Report Protocol)
	PP_1 (lsb)	Local Noise Report	187-721 (Local Noise Report)
ALQA	$ALQA_8$ (msb)	Reserved (always set to 0)	
	$ALQA_7$	ALQA SINAD	187-721 (SINAD and PBER)
	$ALQA_6$	ALQA PBER	187-721 (SINAD and PBER)
	$ALQA_5$	ALQA AI	187-721 (Articulation Index)
	$ALQA_4$	ALQA SD	187-721 (Spectral Distortion)
	$ALQA_3$	ALQA EFI	187-721 (Error-free Interval)
	$ALQA_2$	ALQA AVQ	187-721 (Achievable Voice Quality)
	$ALQA_1$ (lsb)	ALQA ADC	187-721 (Available Data Capacity)
Orderwire	OW_8 (msb)	Frequency Select CMD	187-721 (Frequency Select Command)
	OW_7	Channel Select CMD	(not yet standardized)
	OW_6	Modem Negotiation	187-721 (Modem Negotiation and Handoff)
	OW_5	Crypto Negotiation	187-721 (Crypto Negotiation and handoff)
	OW_4	Analog Port Selection	187-721 (Analog Port Selection)
	OW_3	Data Port selection	187-721 (Data Port Selection)
	OW_2	Digital Squelch	187-721 (Digital Squelch)
	OW_1 (lsb)	Power Control	187-721 (Power Control)

TABLE XXIII. Capabilities report data field (feature capabilities) - continued.

Group	Bit	Set to 1 iff Feature Implemented	Cross Ref: MIL-STD (paragraph)
Relaying	RY_8	Indirect Addressing	187-721 (ALE indirect Addressing)
	RY_7	Slave Routing	187-721 (Slave Routing)
	RY_6	Query Addressing	187-721 (ALE query addressing)
	RY_5	Query calling	187-721 (ALE Query Calls, ALE Query Calling Protocol)
	RY_4	Response to Query Calls	187-721 (ALE query calling protocol)
	RY_3	Response to collective addresses in Query Calls	187-721 (ALE query calling protocol)
	RY_2	Relay Quality CMD	187-721 (Relay Quality CMD)
	RY_1	Indirect Calls	187-721 (Indirect Calls)
Repeater	RPT_5	Repeater Control CMD	187-721 (Repeater Operation)
	RPT_4	Frame Repeater	187-721 (Repeater Operation)
	RPT_3	Word Repeater	187-721 (Repeater Operation)
	RPT_2	Bit Repeater	187-721 (Repeater Operation)
	RPT_1	VF Repeater	187-721 (Repeater Operation)
Scheduling	SCH_{21} (msb)	Reserved (always set to 0)	
	SCH_{20}	Adjust Slot Width	187-721 (Adjust Slot Width)
	SCH_{19}	Station Busy	187-721 (Station Busy)
	SCH_{18}	Channel Busy	187-721 (Channel Busy)
	SCH_{17}	Set Dwell Time	187-721 (Set Dwell Time)
	SCH_{16}	Halt and Wait	187-721 (Halt and Wait)
	SCH_{15}	Contact Later	187-721 (Contact Later)
	SCH_{14}	Meet Me	187-721 (Meet Me)
	SCH_{13}	Poll Operator (default NAK)	187-721 (Poll Operator(default NAK))
	SCH_{12}	Request Operator ACK	187-721 (Request Operator ACK)
	SCH_{11}	Schedule Periodic Function	187-721 (Schedule Periodic Function)
	SCH_{10}	Quiet Contact	187-721 (Quiet Contact)
	SCH_9	Respond and Wait	187-721 (Respond and Wait)
	SCH_8	Set Sounding Interval	187-721 (Set Sounding Interval)
	SCH_7	Tune and wait	187-721 (Tune and Wait)
	SCH_6	Set Slot Width	187-721 (Set Slot Width)
	SCH_5	Year and Date	187-721 (Year and Date)
	SCH_4	Zulu Time	187-721 (Zulu Time)
	SCH_3	Do Not Respond	187-721 (Do Not Respond)
	SCH_2	Reserved (always set to 0)	
	SCH_1 (lsb)	Reserved (always set to 0)	

5.6.3 Frequency select command.

a. The frequency select CMD word is formatted as shown on figure 23. A frequency designator (IAW 5.3) is sent in a DATA word immediately following the frequency select CMD; bit W_4 of this DATA word shall be set to 0, as shown.

3	7	6	4	4
CMD	1100110 ('f': frequency)	Control	100 Hz	10 Hz

		Frequency Designator				
Data	0	10 MHz	1 MHz	100 kHz	10 kHz	1 kHz
3	1	4	4	4	4	4

FIGURE 23. Frequency select CMD format.

b. The 100 Hz and 10 Hz fields in the frequency select CMD word contain BCD digits that extend the precision of the standard frequency designator. These digits shall be set to 0 except when it is necessary to specify a frequency that is not an even multiple of 1 kHz (e.g., when many narrowband modem channels are allocated within a 3 kHz voice channel).

c. The control field shall be set to 000000 to specify a frequency absolutely, to 100000 to specify a positive offset, or to 110000 to specify a negative offset.

d. A station receiving a frequency select CMD word shall in general make whatever response is required by an active protocol on the indicated frequency.

e. For example, transmit and receive frequencies for use on a link may be negotiated independently as follows:

(1) The caller selects a frequency believed to be propagating to the distant station (the prospective responder) and places a call on that frequency. The caller embeds a frequency select CMD word in the call to ask the responder to respond on a frequency chosen for good responder-to-caller propagation (probably from sounding data in the caller's LQA matrix).

(2) If the responder hears the call, it will respond on the second frequency, asking the caller to switch to a better caller-to-responder frequency by embedding a frequency select CMD word in its response (also based upon sounding data).

(3) The caller sends an acknowledgment on the frequency chosen by the responder (the original frequency by default), and the full duplex independent link is established.

5.6.4 Mode control. Many of the advanced features of an ALE controller are "modal" in the sense that when a particular option setting is selected, that selection remains in effect until changed or reset by some protocol event. The mode control CMD is used to select many of these operating modes, as described in the following paragraphs. The CMD word shall be formatted as shown in figure 24. The first character shall be 'm' to identify the mode control command; the second character identifies the type of mode selection being made; the remaining bits specify the new setting for that mode.

3	7	7	7
CMD	1101101 ('m': mode control)	Mode ID	Mode Selection

FIGURE 24. Mode control CMD format.

5.6.4.1 Modem negotiation and handoff. An ALE data link can be used to negotiate a modem to be used for data traffic by exchanging modem negotiation messages. A modem negotiation message shall contain one modem selection command.

NOTE: This function may best be implemented in an HFNC to avoid retrofit to existing ALE controllers, and for the greater flexibility inherent in network management information bases.

5.6.4.1.1 Modem selection CMD. The modem selection CMD word shall be formatted as shown in figure 25, and may be followed by one or more DATA words, as described below. The defined modem codes are listed in table XXIV. Codes not defined are reserved, and shall not be used until standardized.

3	7	7	7
CMD	1101101 ('m': mode control)	1101110 ('n': modem select)	Modem Code

FIGURE 25. Modem selection CMD format.

5.6.4.1.2 Modem negotiating. Modem negotiating shall employ modem negotiation messages in the following protocol:

a. The station initiating the negotiation will send a modem selection CMD word containing the code of the modem it wants to use.

b. The responding station(s) may either accept this modem selection or suggest alternatives. A station accepting a suggested modem shall send a modem selection CMD word containing the code of that modem.

c. A station may negotiate by sending a modem selection CMD word containing all 1's in the modem code field, followed by one or more DATA words containing the codes of one or more suggested modems. Modem codes shall be listed in order of preference in the DATA word(s). Unused positions in the DATA word(s) shall be filled with the all 1's code.

d. The negotiation is concluded when the most recent modem negotiation message from all participating stations contains an identical modem selection CMD word with the same modem code (not all 1's). When this occurs, the station that initiated the negotiation will normally begin sending traffic using the selected modem.

TABLE XXIV. Modem codes.

Code	Modem Type
0000000	(Reserved)
0000001	ALE modem
0000010	Serial-tone HF data modem (MIL-STD-188-110A)
0000011	16-tone DPSK HF data modem (MIL-STD-188-110A)
0000100	39-tone HF data modem (MIL-STD-188-110A App B)
0000101	ANDVT
0000110	FSK 170 Hz shift (MIL-STD-188-110A)
0000111	FSK 850 Hz shift (MIL-STD-188-110A)
0001000	STANAG 4285
1111111	Reserved to indicate no modem code
	(All others reserved until defined)

5.6.4.2 Crypto negotiation and handoff. When crypto negotiation and handoff are required, the following applies:

a. An ALE data link can also be used to negotiate an encryption device to be used for voice or data traffic by exchanging crypto negotiation messages. The crypto selection CMD word is formatted as shown in figure 26. The defined crypto codes are listed in table XXV. Codes not defined are reserved, and shall not be used until standardized.

NOTE: This function may best be implemented in an HFNC to avoid retrofit to existing ALE controllers, and for the greater flexibility inherent in network management information bases.

3	7	7	7
CMD	1101101 ('m': mode control)	1100011 ('c': crypto select)	Crypto Code

FIGURE 26. Crypto selection CMD format.

TABLE XXV. Crypto codes.

Code	Crypto Type
0000000	No encryption
1111111	Reserved to indicate no crypto code
	(All others reserved until defined)

b. Crypto negotiation shall employ crypto negotiation messages in the protocol described above for modem negotiation.

5.6.4.3 Analog port selection. The analog port selection command is used to individually enable and disable audio inputs and outputs at a station. The analog port selection CMD word shall be formatted as shown in figure 27. The bits of the analog port field in the CMD are assigned as indicated in table XXVI. A bit set to 1 shall enable the corresponding analog port; a bit set to 0 shall disable the corresponding analog port. The analog ports controlled by the standardized bits shall be those of the radio that is carrying the command. The other bits may be employed to control any other analog ports at a station.

NOTE 1: Multiple inputs and outputs may be simultaneously enabled by this command. If the equipment at a station cannot fully implement a command, the equipment should approximate the requested effect as nearly as possible.

NOTE 2: This functionality may also be accomplished at the HFNC level.

3	7	7	7
CMD	1101101 ('m': mode control)	1100001 ('a': analog port select)	Analog Port Bits

FIGURE 27. Analog port selection CMD format.

TABLE XXVI. Analog port selection bits.

Bit	Analog port assignment
VP_7 (msb)	Operator microphone (input)
VP_6	Line-level input
VP_5	(Local significance)
VP_4	(Local significance)
VP_3	(Local significance)
VP_2	Line-level output
VP_1 (lsb)	Operator speaker/headset (output)

5.6.4.4 Data port selection.

a. The data port selection command is used to specify the destination for the immediately following DTM or DBM. By default, any DTM or DBM message that arrives without an immediately preceding data port selection CMD is assumed to carry a message for the station operator, and is routed to an appropriate data port (e.g., an operator display or a printer). The station operator data port (the default) may also be explicitly specified by preceding a message with a data port selection CMD with a port number of 0. A message destined for an attached network controller shall be preceded by a data port selection CMD with a port number of 1. A message intended for over-the-air fill shall be preceded by a data port selection CMD with a port number of 2 (see figure 28). Other port numbers from 3 through 15 have station-specific meanings.

3	7	7	3	4
CMD	Mode Control (ASCII 'm')	Data Port Select (ASCII 'd')	*	Port No.
110	1101101	1100100	000	
* Reserved block (set to 000)				

FIGURE 28. Data port selection CMD format.

b. Note that the data port selected by a data port selection CMD persists only until the end of the DTM or DBM that immediately follows the data port selection CMD. Thus, a data port selection CMD not immediately followed by a DTM or DBM has no effect.

5.6.4.5 Digital LINCOMPEX zeroization. The digital LINCOMPEX zeroization command is used to zeroize a digital LINCOMPEX system (see figure 29). The subcommand position shall be set to 1111111 to initiate zeroization.

3	7	7	7
CMD	1101101 ('m': mode control)	1111010 ('z': LINCOMPEX zeroize)	Subcommand

FIGURE 29. Digital LINCOMPEX zeroization CMD format.

5.6.4.6 Digital squelch. The digital squelch command format, figure 30, is used for remote control of a radio's audio output. The second character position shall be set to'q' to indicate a digital squelch command. The third character position (subcommand) shall be set to 1111110 to mute the speaker of a distant radio, or to 0000000 to unmute. A receiving ALE controller that cannot mute the radio speaker should respond with a digital squelch command with the third character position set to 1111111. In other cases, no response is necessary from the receiving ALE controller.

3	7	7	7
CMD	1101101 ('m': mode control)	1110001 ('q': digital squelch)	(Subcommand)

FIGURE 30. Digital squelch CMD format.

5.6.5 Power control. The power control orderwire function is used to advise parties to a link that they should raise or lower their RF power for optimum system performance. The power control CMD word format is shown in figure 31. The KP control bits are used as shown in table XXVII.

3	7	3	6	5
CMD	1110000 ('p':power control)	KP1-3	Power	(reserved)

FIGURE 31. Power control CMD format.

TABLE XXVII. Power control CMD bits (KP_{1-3}).

Bit	Value	Meaning
KP_3 (msb)	1	Request to adjust power
	0	Report of current power level
KP_2	1	Relative Power (in dB)
	0	Absolute Power (in dBW)
KP_1 (lsb)	1	Relative Power (dB) is positive
	0	Relative Power (dB) is negative

a. When KP_3 is set to 1, the power control command is a request to adjust the power from the transmitter. If KP_2 is 1, the adjustment is relative to the current operating power, i.e., to raise (KP_1 = 1) or lower (KP_1 = 0) power by the number of decibels indicated in the Relative Power field. If KP_2 is 0, the requested power is specified as an absolute power in dBW.

b. When KP_3 is set to 0, the power control command reports the current power output of the transmitter, in dB relative to nominal power if KP_2 is 1, or in absolute dBW if KP_2 is 0.

c. KP_1 shall be set to 0 whenever KP_2 is 0.

d. Normally, a station receiving a power control request (KP_3 = 1) should approximate the requested effect as closely as possible, and respond with a power report (KP_3 = 0) indicating the result of its power adjustment.

5.6.6 Scheduling functions. Table XXVIII lists the groups of ALE scheduling functions that are defined in the following paragraphs.

TABLE XXVIII. Groups of ALE scheduling functions.

Group	Scheduling functions	Second Character	Date/Time Option	Cross reference
Future Calls	Contact Later Meet Me Quiet Contact	l (1101100) m (1101101) q (1110001)	Yes	5.6.6.6 5.6.6.7 5.6.6.11
Wait on channel	Halt and Wait Respond and Wait Tune and Wait Do Not Respond	h (1101000) r (1110010) t (1110100) x (1111000)	No	5.6.6.5 5.6.6.12 5.6.6.14 5.6.6.18
Congestion Management	Station Busy Channel Busy Set Dwell Time	b (1100010) c (1100011) d (1100100)	No	5.6.6.2 5.6.6.3 5.6.6.4
Slot Width	Adjust Slot Width Set Slot Width	a (1100001) w (1110111)	No	5.6.6.1 5.6.6.15
Periodic Functions	Schedule Periodic Function Set Sounding Interval	p (1110000) s (1110011)	Yes	5.6.6.10 5.6.6.13
Poll Operator	Poll Operator (default NAK) Request Operator ACK	n (1101110) o (1101111)	Yes	5.6.6.8 5.6.6.9
Date and Time	Year and Date Zulu Time	y (1111001) z (1111010)	(Implicit)	5.6.6.16 5.6.6.17

a. Each of these functions employs a scheduling CMD word with the generic format shown in figure 32. The first character in every scheduling CMD is 't' (1110100). The second character in the CMD identifies the specific scheduling function to be performed. For all scheduling functions except the Date and Time group, the third character position contains a time code in accordance with table XXIX. The time offset indicated in the time code shall be added to the time of receipt of the end of the transmission carrying the CMD word (end of T_x) to determine the time T at which the specified function is to be performed (see the relevant paragraph below).

b. In some cases noted in table XXVIII (under Date/Time Option), this third character position may be set to 1111111 (all 1's) to specify that the function be performed at the absolute date and time specified in a DATA word that immediately follows the CMD, instead of at a time offset from the end of the transmission. This date and time DATA word shall be formatted as shown in figure 33. The Month field shall indicate the desired month (1-12), the Day field the desired day (1-31), depending on the month, the Hour field the desired hour (0-23), and the Minute field the desired minute (0-59). The Z bit shall be set to 0 if the specified hour is Zulu time (UTC), or to 1 if the hour is the local time zone of the sending station.

3	7	7	7
CMD	1110100 ('t': scheduling)	Second Character	Time Code or Special

FIGURE 32. Generic scheduling CMD.

TABLE XXIX. Time codes for scheduling.

Time Code Bits	Encoding	Meaning	Range (approx.)
TB7 (msb), TB6	00 01 10 11	Time unit is 1 T_w (approx 1/8 s) Time unit is 8 T_w (approx 1 s) Time unit is 64 T_w (approx 8 s) Time unit is 1024 T_w (approx 2 min)	0-4 s 0-32 s 0-4 min 0-69 min
TB5-TB1 (lsb)	00000 thru 11110 11111	Time offset is indicated multiple of time unit. Use absolute date and time from following DATA word	

3	4	5	1	5	6
DATA	Month	Day	Z	Hour	Minute

FIGURE 33. Date and time word format.

5.6.6.1 Adjust slot width. When sent as part of a transmission that requires slotted responses, this CMD requires that all slots be lengthened by the time offset in the CMD. TB7 shall be set to 0 to limit the slot adjustment to a maximum of 32 seconds. When sent in a transmission that does not require slotted responses, this CMD shall be ignored.

5.6.6.2 Station busy. This CMD may be sent in response to a call when the called station is currently unable to accept the call. The calling ALE controller may elect to call again after time T (the current time plus the time offset in the CMD).

5.6.6.3 Channel busy. This CMD directs an ALE controller not to use a channel until after time T. By default, the channel carrying the CMD is not to be used until after time T; however, a different channel may be designated as busy by placing a channel designator (see 5.3) in ALE word bits W_{4-10} of a DATA word that immediately follows the channel busy CMD. This channel designator shall be interpreted as an absolute channel number (not as an offset from the channel carrying the CMD).

5.6.6.4 Set dwell time. When received following a channel busy CMD, the set dwell time CMD shall cause the receiving ALE controller to increase its scanning dwell time on the designated channel only to the value indicated in the Time Offset field of the set dwell time CMD. TB7 and TB6 shall both be set to 0 to limit the dwell time on a channel to no more than 4 seconds.

5.6.6.5 Halt and wait. An ALE controller receiving this CMD shall stop scan (without tuning or responding) and wait until time T for further transmissions. If none are detected, it shall resume scanning. TB7 shall be set to 0 on transmission, and ignored on reception to limit the waiting period to 32 seconds.

5.6.6.6 Contact later. A station receiving this CMD is requested to call the station sending the CMD at the designated time "T" if the time offset field is not all 1's, otherwise at the date and time in the DATA word that immediately follows the CMD. The call should be placed on the channel carrying the CMD, unless another channel is specified in a DATA word (formatted as in 5.6.6.3). If a date and time DATA word and a channel-designating DATA word are both sent following the CMD, the date and time word shall be sent first.

5.6.6.7 Meet me.

a. A station receiving this CMD is requested to call the station sending the CMD at the designated time "T" if the time offset field is not all 1's, otherwise at the date and time in the DATA word that immediately follows the CMD. The call should be placed on the channel carrying the CMD, unless another frequency is specified in a DATA word (formatted as discussed below). If a date and time DATA word and a frequency-designating DATA word are both sent following the CMD, the date and time word shall be sent first.

b. A frequency other than that carrying the CMD may be designated by placing a frequency designator (see 5.3) in ALE word bits W_{5-24} of a DATA word. Bit W_4 of the DATA word shall be set to 0 to indicate a positive frequency offset, or to 1 to indicate a negative frequency offset from the frequency carrying the CMD.

5.6.6.8 Poll operator (default NAK). An ALE controller receiving this CMD shall prompt the operator to manually acknowledge the transmission. If the operator acknowledges the prompt, the ALE controller shall reply to this CMD with a transmission terminating in THIS WAS and return to scan. Otherwise (either no operator response by time T, or a request for negative acknowledgement), the ALE controller shall respond with a transmission terminating in THIS IS (and continue to listen for transmissions from the calling station until returned to scan by the operator or by the wait for activity timer).

5.6.6.9 Request operator ACK. An ALE controller receiving this CMD shall prompt the operator to manually acknowledge the transmission. If the operator acknowledges the prompt, the ALE controller shall reply to this CMD with a transmission terminating in THIS WAS and return to scan. If the operator requests a negative acknowledgement, the ALE controller shall respond with a transmission terminating in THIS IS and continue to listen for transmissions from the calling station until returned to scan by the operator or by the wait for activity timer. If no operator response is received by time T, the ALE controller shall not respond, and shall immediately return to scan.

5.6.6.10 Schedule periodic function. When received immediately after another scheduling CMD from 5.6.6, this CMD shall cause that CMD to be executed repeatedly as specified by the time offset field in this CMD. If TB1-7 are all 1's (date and time option), the preceding CMD shall be executed daily at the time specified in a date and time DATA word that follows this CMD, starting on the day indicated in that DATA word. If the date and time option is not used, the preceding CMD shall be repeated at the interval given in the time offset field.

5.6.6.11 Quiet contact. A station receiving this CMD is requested to listen for a call from the station sending the CMD at the designated time "T" if the time offset field is not all 1's, otherwise at the date and time in the DATA word that immediately follows the CMD. The call will be placed on the channel carrying the CMD, unless another frequency is specified in a DATA word (formatted as in 5.6.6.7). If a date and time DATA word and a frequency-designating DATA word are both sent following the CMD, the date and time word shall be sent first.

5.6.6.12 Respond and wait. An ALE controller receiving this CMD shall tune (if required) and respond as usual, and wait until time T for further transmissions. If none are detected, it shall resume scanning. TB7 shall be set to 0 on transmission, and ignored on reception to limit the waiting period to 32 seconds.

5.6.6.13 Set sounding interval.

a. An ALE controller receiving this CMD shall set the sounding interval on the designated channel to the time in the Time Offset field. TB7 shall be 1 so that the sounding interval is at least 8 seconds. TB1-6 shall not be all 1's.

b. By default, the channel carrying the CMD is the designated channel; however, a different channel may be selected by placing a channel designator (see 5.3) in ALE word bits W_{4-10} of a DATA word that immediately follows the CMD. This channel designator shall be interpreted as an absolute channel number (not as an offset from the channel carrying the CMD).

5.6.6.14 Tune and wait. An ALE controller receiving this CMD shall stop scan and tune (if required), but not respond, and wait until time T for further transmission. If no transmissions are detected, it shall resume scanning. TB7 shall be set to 0 on transmission, and ignored on reception, to limit the waiting period to 32 seconds.

5.6.6.15 Set slot width. When sent as part of a transmission that requires slotted responses, this CMD requires that all slots be set to the length in the Time Offset field in the CMD. TB7 shall be set to 0 to limit the slot size to a maximum of 32 seconds. When sent in a transmission that does not require slotted responses, this CMD shall be ignored.

5.6.6.16 Year and date. This CMD may be used to request and report the date and time. If the third character position in figure 34 is set to all 1's, the CMD is a request for year and date, and shall not be followed by a DATA word. If the third character position contains a 7-bit integer in the range 0-99, this CMD and a following DATA word (formatted IAW figure 32) report the year, date, and time. Other values in the third character position are reserved, and shall not be used until standardized.

3	7	7	7
CMD	1110100 ('t': scheduling)	1111001 ('y': year and date)	Year (00-99)

FIGURE 34. Year and date CMD.

5.6.6.17 Zulu time. This CMD may be used to request and report zulu time. If the third character position in figure 35 is set to all 1's, the CMD is a request for zulu time, and shall not be followed by a DATA word. If the third character position contains a 7-bit integer in the range 0-119, this CMD and a following DATA word (formatted IAW figure 32) report the date and zulu time with a resolution of 500ms. Other values in the third character position are reserved, and shall not be used until standardized.

3	7	7	7
CMD	1110100 ('t': scheduling)	1111010 ('z': zulu time)	Half Seconds (0-119)

FIGURE 35. Zulu time CMD.

5.6.6.18 Do not respond. When an ALE controller receives this CMD in a transmission, it shall not respond unless a response is specifically required by some other CMD in the transmission (e.g., an LQA request or a DTM or DBM with ARQ requested). In particular, no 3-way ALE handshake need be completed.

5.7 Networking functions. The functions implemented within a networking controller include automatic route and link selection, indirect calling, connectivity monitoring, connectivity exchange, routing queries, repeater control, message store and forward, automatic message exchange, and station status reporting.

5.7.1 Route and link selection. The router is the central entity of the networking controller, in the sense that almost every other networking function either relies upon it or supports it. The router comprises two functions: route selection and link selection. The route selection function finds routes through networks for user and orderwire traffic, using connectivity data from the path quality matrix, operator entries, and broadcast queries to maintain the routing table. The link selection function simply chooses the best data link available to each destination selected by the route selector.

The following examples of network-layer operations refer to the hypothetical network connectivity from station A shown on figure 36. The arrows indicate the direction(s) of connectivity; the pair of numbers on each arrow indicates voice and data path quality, respectively (in accordance with the link quality functions in paragraph 5.4).

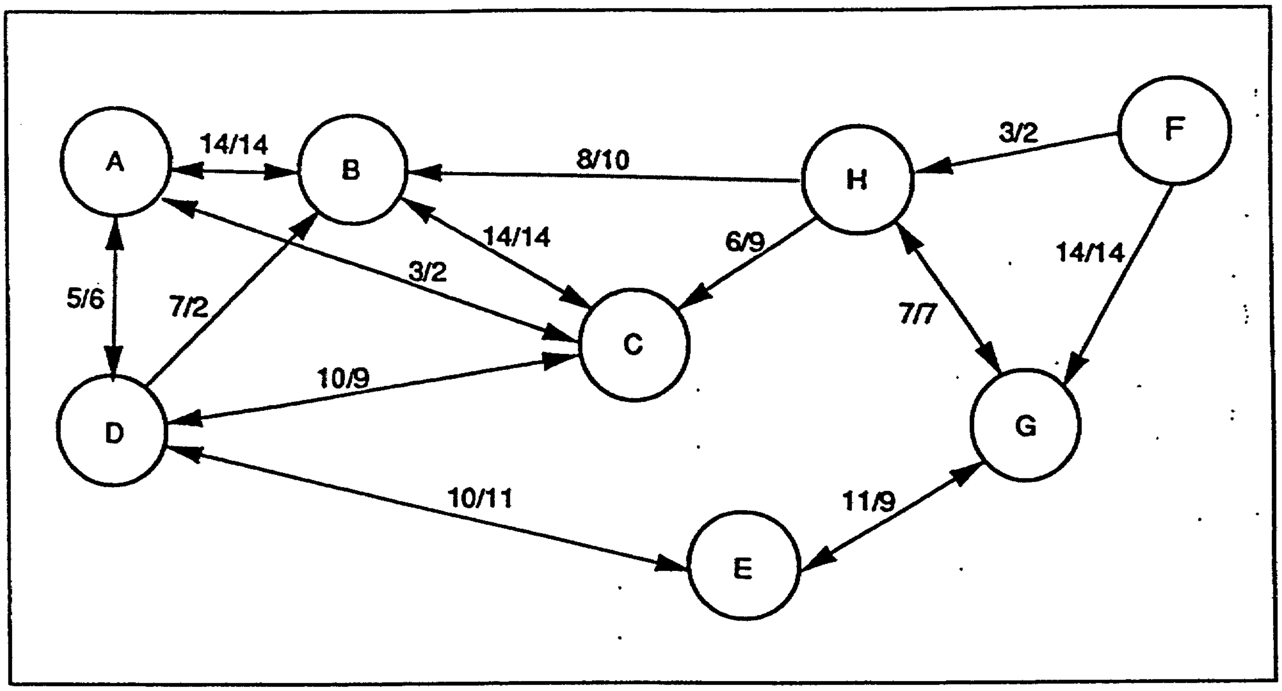

FIGURE 36. Network connectivity example.

5.7.1.1 Path quality matrix. The path quality matrix is organized with a row for each directly reachable relay station, and a column for each destination of interest. When multiple data link controllers are available to the networking controller, a separate path quality matrix may be maintained for each, or a single path quality matrix may be maintained. The single path quality matrix contains the best path scores over all link controllers, along with indications of the specific link controller to use for each path.

A path quality matrix is needed by every networking controller that provides adaptive routing for locally-originated messages, whether or not the station intends to relay messages for other stations.

Figure 37 illustrates how the network connectivity on figure 36 may be summarized in the path quality matrix at station A. The path qualities are computed in accordance with the algorithms given in paragraph 5.7.4.1 and 5.7.4.2. Note that unidirectional path qualities (A to destination) are shown. Normally, path qualities in both directions will be stored and used.

DESTINATION:	B	C	D	E	F	G	H
RELAY:							
B	*14 14 0 1 s	13 13 1 59 m	9 8 2 5 hr	7 7 3 5 hr	- - - -	6 6 4 5 hr	4 5 5 1 d
C	1 1 1 5 hr	3 2 0 30 m	1 1 1 5 hr	0 0 2 5 hr	- - - -	0 0 3 5 hr	0 0 4 5 hr
D	4 1 1 2 hr	4 5 1 3 hr	5 6 0 12 hr	4 5 1 5 m	- - - -	3 4 2 5 hr	1 3 3 5 hr
E	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
F	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
G	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
H	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -

*KEY:

Voice Quality
Data Quality
Relays
Age

FIGURE 37. Path quality matrix.

5.7.1.2 Routing table. A routing table (RT) is maintained by the networking controller for use in route selection. An example routing table is shown on figure 38, corresponding to the path quality matrix example on figure 37.

DESTINATION:	B	C	D	E	F	G	H
ROUTE VOICE TRAFFIC VIA:	*B 14 0 1 s	B 13 1 59 m	B 9 2 5 hr	B 7 3 5 hr	- - - -	B 6 4 5 hr	B 4 5 1 d
ROUTE DATA TRAFFIC VIA:	B 14 0 1 s	B 13 1 59 m	B 8 2 5 hr	B 7 3 5 hr	- - - -	B 6 4 5 hr	B 5 5 1 d

*KEY:

Relay Address
Path Quality
Relays
Age

FIGURE 38. Routing table.

5.7.1.2.1 Organization. The routing table is organized for quickly determining where to send traffic destined for any reachable station. It is indexed by a reachable station address. The entry for each station contains (at least) the best relay(s) for voice and data traffic destined for that station. In addition, routing table entries may contain alternate relays and candidates for indirect calls when no relays are available.

5.7.1.2.2 Manual entries. A means shall be provided for operator entry of routing table data. These entries shall be retained in non-volatile storage when the network controller is powered off and shall not be overwritten by automatic updates to the routing table from path quality matrix data; this may be implemented by flagging non-adaptive routing table entries. The operator shall also be able to view, edit, and delete manual routing table entries. The requirements of this paragraph do not apply when the mission, power, or weight limitations contraindicate.

5.7.1.2.3 Automatic updates. When adaptive routing is employed, alternative routes to reachable destinations shall be re-evaluated whenever new path quality data arrives (e.g., via CONEX), and the routing table shall be updated as appropriate.

5.7.2 Indirect calling. When a link controller fails to establish a link requested by the networking controller, the routing table (and path quality matrix as required) may be used to identify candidate station(s) for indirect calling. Initiation of an indirect call by the networking controller may be automatic upon linking failure or it may be initiated by the operator. When an automatic indirect call succeeds in establishing a link with a candidate station, the operator should be notified that the link established is to a third party rather than to the desired destination.

5.7.3 Network layer header. All messages sent from one networking controller to another are preceded by a single ASCII character denoting the type of message to follow. When a networking controller receives a message, it examines this one-character header to determine the format and protocol to use in interpreting the remainder of the message.

The defined network layer header characters are listed in table XXX. Header characters not listed are reserved and shall not be used until standardized.

TABLE XXX. Network layer header characters.

Header	Message Type
C	Connectivity exchange
M	User message (with AME header)
R	Relay management
S	Station status message

5.7.4 Connectivity exchange. The CONEX protocol allows relay stations to exchange lists of other stations they can contact. However, CONEX exacts a price in overhead channel usage that may be unacceptable under many conditions. Normally, relay stations use static routing table entries with notification-based protocols (see 5.7.6.6.3 and 5.7.7) and HF network management requests. CONEX is useful only for those relay stations equipped with a Level 3 or 4 HFNC (see table II), and is recommended only for those networks that cannot use normal routing table maintenance (also see 5.7.4.1b).

a. Networking controllers exchange the contents of their path quality matrices using the following CONEX protocol. Note that CONEX messages may be carried on any type of data link that connects the parties to the exchange. Because these messages may be relatively large, a high speed modem should be used for CONEX whenever possible; the ALE modem should only be used when no other data link is available.

b. A CONEX report pertains to the path from one station to another, which may consist of a single link (a "direct path") or of multiple links (an "indirect path") through one or more intermediate (relay) stations. In all cases, each CONEX report includes the number of relay stations included in the path, estimates of the path quality for voice and for data, and the age of the oldest data used to estimate these path qualities.

5.7.4.1 Voice path quality. The voice quality for a path is an estimate of the end-to-end SINAD of the path. For SINAD less than 2 dB, the voice path quality is 0; for 2 through 26 dB, the quality is 1/2 SINAD (in dB); for SINAD greater than 27 dB, the quality is 14; and when the end-to-end SINAD is unknown, the quality is 15 (1111) (default value). Voice quality shall be computed as follows:

a. For a single-link path, the mean SINAD for that link (median SINAD if ALQA data is available) shall be obtained from the link controller and converted directly to a path quality code.

b. For a multi-link path, the voice quality obtained in a CONEX report from the best relay station for the ultimate destination shall be combined with the quality of the best link to that station to obtain the resulting voice path quality as specified in table XXXI. (Note that a multi-link path will never have quality 14.) The "best relay" is the station among all potential relays that gives the highest result quality after the qualities of links to those stations have been included.

5.7.4.2 Data path quality.

a. The data quality for a path is an estimate of the efficiency of the path in passing data traffic. The data path quality code used is based upon estimates of the time required to pass messages over each link in the path; the resulting code reflects several measures of importance to data networks: data throughput, message latency, and resource utilization (stations and channels).

TABLE XXXI. Voice path quality cascading.

Quality 1	Quality 2	Result Quality	Quality 1	Quality 2	Result Quality
0	Any	0	6	11	5
1	Any	0	6	12	5
2	Any	0	6	13	5
3	3	0	6	14	5
3	4	1	7	7	5
3	5	1	7	8	5
3	6	1	7	9	6
3	7	1	7	10	6
3	8	1	7	11	6
3	9	1	7	12	6
3	10	1	7	13	6
3	11	1	7	14	6
3	12	1	8	8	6
3	13	1	8	9	6
3	14	1	8	10	7
4	4	2	8	11	7
4	5	3	8	12	7
4	6	3	8	13	7
4	7	3	8	14	7
4	8	3	9	9	7
4	9	3	9	10	7
4	10	3	9	11	8
4	11	3	9	12	8
4	12	3	9	13	8
4	13	3	9	14	8
4	14	3	10	10	8
5	5	3	10	11	8
5	6	3	10	12	9
5	7	4	10	13	9
5	8	4	10	14	9
5	9	4	11	11	9
5	10	4	11	12	9
5	11	4	11	13	10
5	12	4	11	14	10
5	13	4	12	12	10
5	14	4	12	13	10
6	6	4	12	14	11
6	7	4	13	13	11
6	8	5	13	14	12
6	9	5	14	14	13
6	10	5	15	Any	15

b. Computing the end-to-end data path quality through one or more relay stations shall proceed as follows. Assume that station A receives a CONEX report from B about the best data path from B to X. Station A computes its path quality to X through B by combining the quality of its link to B with the report from B about B's best path to X:

   (1) Station A computes the quality of its link to B as described in paragraph e below, and compares the result to the quality of the path from B to X as reported by B.

   (2) If either quality is 0, the result is 0. Likewise, if either is 31 (unknown), the result is 31.

   (3) In all other cases, the quality of the path from A to X through B is 1 less than the lower path quality of the two components.

c. The quality of a single data link is computed from the nominal data rate and measured error characteristics of that link obtained from the link controller. The result of the following formula shall be truncated to an integer in the range of 0 through 30, inclusive (e.g., if the result is less than zero, 0 shall be used).

   Data link quality = 7 + Nominal Speed - ARQ Repeats.

d. The "nominal speed" term in the formula is obtained from the nominal data rate (in bits per second (bps)) as follows. The result shall be rounded to the nearest integer. Note that the logarithm is taken with a base of 2.

   Nominal speed = $\log_2$ (data rate/75 bps).

e. The "ARQ repeats" term in the formula is the mean number of error-induced retransmissions per message of messages sent over that link during the past hour. If no messages were sent over the link during the past hour, the ARQ repeats term may be estimated using the BER of the link (measured before error correction):

BER	ARQ Repeats Estimate
<0.1	0
$0.1 \leq$ BER ≤ 0.199	$\frac{BER - 0.1}{0.2 - BER}$
> 0.199	100 (link unusable)

Table XXXII illustrates the use of this formula:

TABLE XXXII. Examples of data path quality computations.

Link Type	Nominal Data Rate	Nominal Speed	ARQ Repeats (measured)	BER	ARQ Repeats (estimated)	Data Link Quality
DTM	53.6	0	0			7
(ALE Modem)	53.6	0		0.1181	0.22	6
HF Data	2400	5	0.1			11
Modem	2400	5		0.167	2.03	9
Wireline	9600	7		0.0105	0.00	14
Modem	9600	7	1.2			12

5.7.4.3 CONEX message format.

a. A CONEX message consists of a header, identifier(s) of the net or specific stations reported, and reports of path quality to those stations. When a net is named, the reports for the stations in the net are listed in the standard order for that net, without sending the individual station identifiers. A flow diagram for the structure of a CONEX message is shown on figure 39. CONEX messages are formatted in even multiples of 8 bits to simplify the insertion of these reports into the natural data blocks of the links likely to be available.

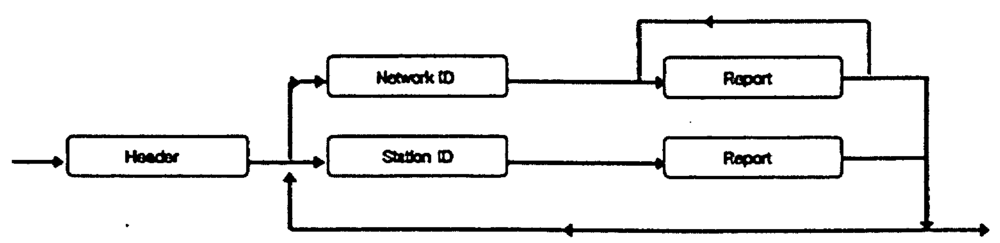

FIGURE 39. Structure of CONEX message.

b. The CONEX message header contains a 16-bit Control field, followed by the name of the sending station, as shown on figure 40. The first bit is set to 1. The second bit is set to 1 to request CONEX from responding stations, or to 0 to suppress such responses. The third bit is set to 1 to indicate that CONEX reports follow the sending station name; if this bit is 0, no reports are included in this message. The next five bits in the Control field contain a count of the characters in the sending station name (a count of 0 indicates a 32-character address).

The second 8 bits of the header begin with 2 bits set to 1 and 0 respectively, followed by the Max Age and Max Relays fields. The Max Age and Max Relays fields apply to CONEX requests; the responding station shall only return reports whose Age and Relays fields do not exceed these limits (all 1's in a field means no limit). The Control field is followed by the number of ASCII characters indicated in the Count field, with a 0 most significant bit (msb) placed before each 7-bit character.

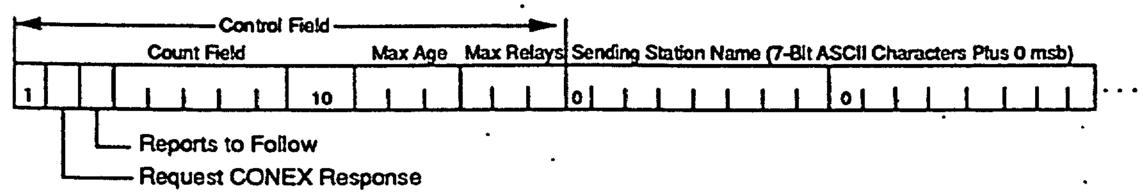

FIGURE 40. CONEX header.

c. Station and network IDs have a structure similar to the CONEX header. Each begins with an 8-bit Control field, which is followed by the ASCII characters composing the name of that station or network (see figure 41). The first bit is set to 1. The second bit is set to 0 for an individual station identifier, and to 1 for a network identifier. The third bit is set to 0 in the last ID in the CONEX message, and to 1 for all of the preceding station and network IDs. The last five bits in the Control field contain a count of the characters in the station or network name. The Control field is followed by the number of ASCII characters indicated in this count, with a 0 msb placed before each 7-bit character.

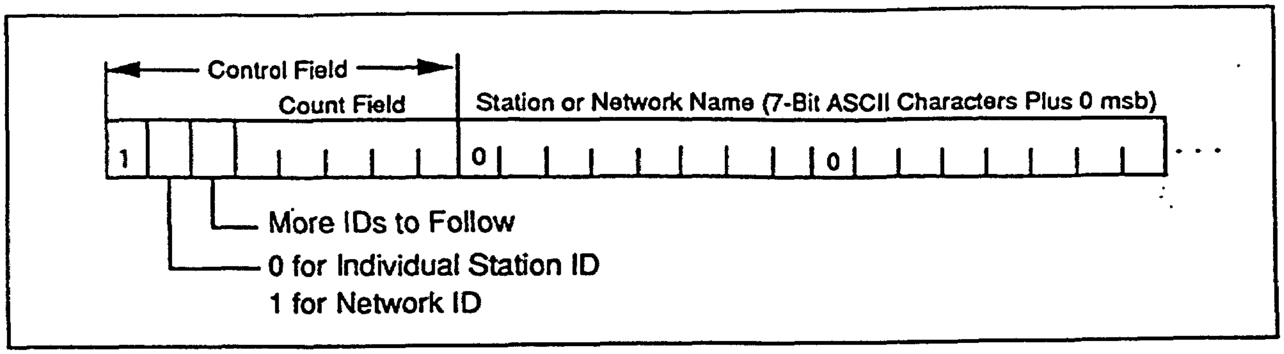

FIGURE 41. CONEX station or network ID.

d. Each report in a CONEX message refers to the best path from the sending station to a specified destination. When the report is preceded by a station ID, the report pertains to the best path to that station. When the report is one of a sequence of reports following a network ID, the destination station is known implicitly from the position of the report in that sequence.

e. Each report contains four fields as shown on figure 42: the minimum number of relays between the sending station and the destination station (3 bits); end-to-end quality of the best path(s) to the destination for voice or data use (4 bits for voice quality and 5 bits for data quality); and the age of the oldest data used to compute the voice and data path qualities (3 bits). Note that the first bit is always set to 0.

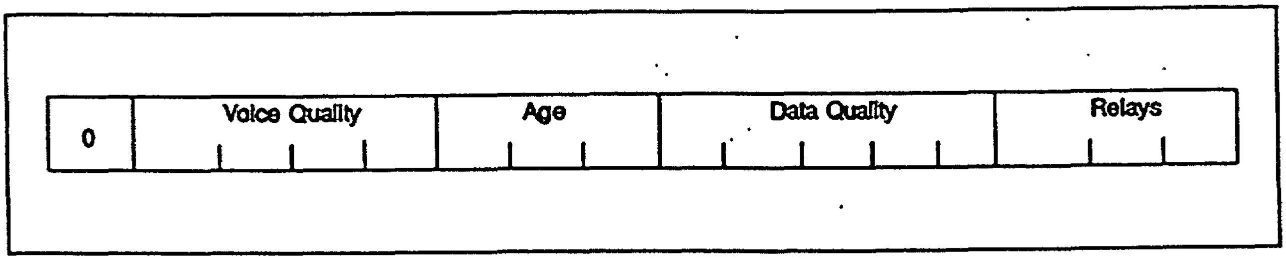

FIGURE 42. CONEX report.

f. The Age field uses the same encoding as in the LQA report (5.4.4). For 0 through 5 relays in the path, the Relays field contains the number of relays. For 6 or more relays, the Relays field contains 110 (6). When the number of relays is unknown, the Relays field is set to 111 (7).

5.7.4.4 CONEX broadcast.

a. Stations may periodically broadcast CONEX messages containing reports of path quality to selected destinations (e.g., net control stations, gateways to other networks, or distant network members that are difficult for some members to reach). The rate of such broadcasts, the channels used, and the stations included in the CONEX report may be selected by the operator or may be determined adaptively by the networking controller. A CONEX broadcast will typically use an ALE scanning call to a net or group. The CONEX message may be sent using DTM or DBM with the ALE modem; however, an HF data modem should always be used when available.

b. A station receiving a CONEX broadcast should update its path quality matrix using the data received along with link quality data from the link controller receiving the broadcast, as described above.

5.7.4.5 CONEX handshake. A CONEX handshake is used to exchange connectivity data among networking controllers. The request bit is set to 1 to request connectivity, and the Max Age and Max Relays fields may be used to restrict the number of reports received. ALE is used to establish the link(s) used, as required; the CONEX messages may be conveyed using either the ALE modem (with DTM or DBM) or a data modem.

5.7.5 Message delivery. In the open systems interconnection (OSI) reference model, the network layer performs end-to-end message delivery, using one or more data links in tandem to carry each message. When HF links are employed, the inherent error rates involved require the use of connection-oriented data links for efficient use of the medium. Such data link protocols guarantee that those blocks of a message that are delivered to the network layer at the destination arrive in order and without duplication. (The DTM and DBM ALE protocols using CRC and ARQ satisfy these requirements, as do other data link protocols used in advanced modems.)

However, data links occasionally fail, so the data link layer cannot guarantee message delivery within a bounded time. A mechanism is required at the network or transport layer to detect and deal with data link failures through the use of retransmission, alternate routing, etc. In the existing DoD internet, this function is performed in the transport layer. Therefore, the HF network layer need only provide datagram service, and its principal function is message routing.

5.7.5.1 AME header. The AME header carries the information used by the network layer for message routing and delivery. This header immediately follows the single-character network layer header (which will be 'M' to indicate that an AME header follows). The AME header contains the following fields:

Quality of Service (QOS)	A single bit indicating whether to emphasize speed of delivery (QOS = 0) or minimum probability of loss or error (QOS = 1) in handling the message.
Precedence	A 3-bit code with 0 as lowest precedence. Used for queuing at relay nodes and determining order of link establishment, order of delivery, etc.
Port	A 4-bit code designating destination port within network controller, analogous to network service access point (NSAP) in the OSI model. Assigned port numbers are listed in table XXXIII.
Header Length	An 8-bit count of the bytes in the AME header, starting with the precedence/port byte and ending with the last character of the source address record.
Message Length	A 16-bit count of the bytes in the transport message following the AME header (does not include the network layer header or AME header bytes).
Relay(s)	Zero or more address records (see address record format description). When relays are specified, they may be either suggested relays or mandatory relays. When mandatory relays are specified, the message must be routed through the relays listed in the order given. Suggested relays are offered for consideration by the route selector in addition to alternatives found in the routing table.
Destination(s)	One or more address records. The message body should be delivered to all destination addressees.
Source	One address record, specifying the address of the station that originated the message.

An address record is structured as an 8-bit flag, followed by a network layer address of ASCII characters with a 0 msb placed before each 7-bit character. The msb of the flag is a 1. The next two bits encode the record type: 0 for a source address record, 1 for a mandatory relay, 2 for a suggested relay, and 3 for a destination. The five least-significant bits contain a count of the characters in the address. Address characters have msb = 0. An example of an AME header and address record is shown on figure 43.

TABLE XXXIII. Port numbers in AME header.

Port Number	Transport Message Destination
0	Operator Terminal
1	Automatic Message Exchange Control Channel
2	Operator Storage
3	HF Transport Protocol (HFTP)
4	Connectionless Network Protocol (CLNP)
5	Internet Protocol (IP)
6	HF Network Management Protocol (HNMP)
All Others	Reserved Until Standardized

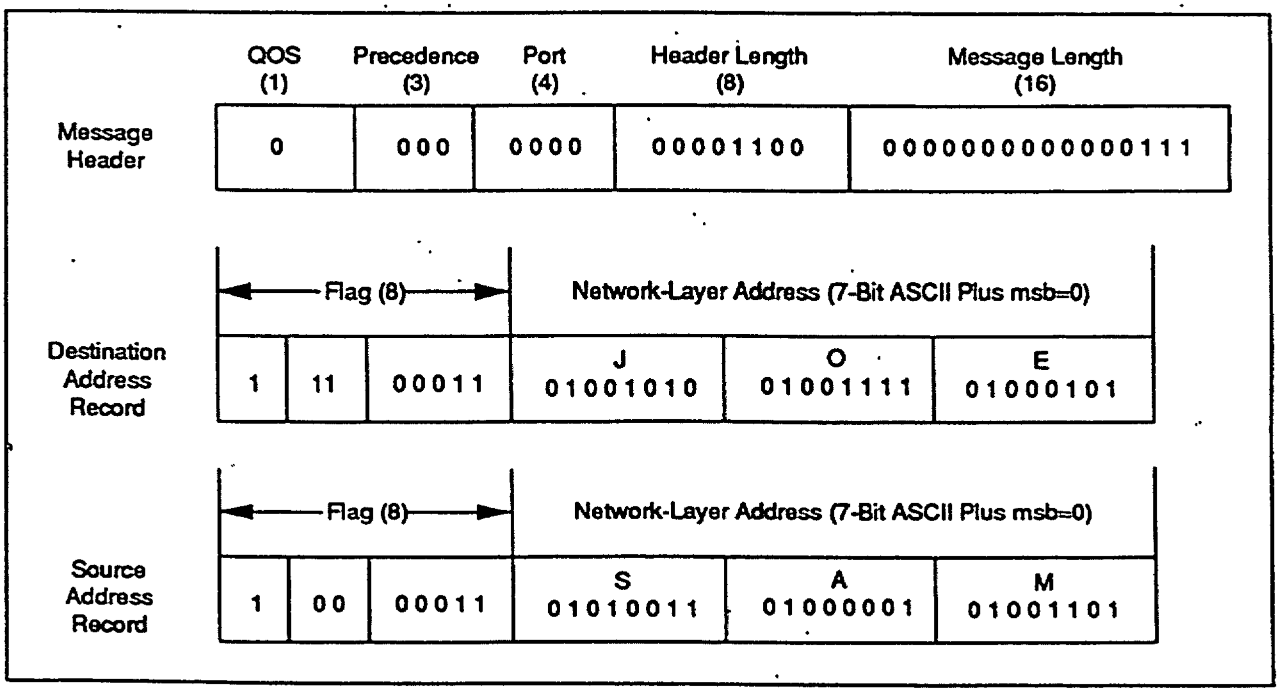

FIGURE 43. Example AME message header and address record.

5.7.5.2 Message store and forward. The store and forward process accepts messages from, and delivers messages to, users (or transport-level processes). Each transport message to be sent is accompanied by the network layer addresses of its destination(s). For each transport message to be sent, the store and forward function groups the network layer destination address(es) according to the first relay on the path to each addressee (obtained from the route selection function), or the final destination if a direct path is the best path. For each such group, an AME header is formed. The header contains the destinations that share an initial relay station. The transport message is appended to this header to compose a network message. These network messages are passed to the local AME process for delivery.

As network messages arrive from other stations and are delivered to the store and forward function by the local AME process, the AME header of each is removed and processed as follows:

a. If any of the destination addresses in the header are self addresses, the embedded transport message is delivered locally as specified in other fields (precedence and port) of the header.

b. All self addresses are removed from the header.

c. If any destinations remain, those addresses and the transport message are handled as discussed above for a new outgoing message.

5.7.5.3 Null store and forward function. A null store and forward function may be used in place of the message store and forward process described above when automatic message routing is not needed. The null store and forward function shall form AME headers for outgoing messages and process the AME headers from incoming messages as follows.

5.7.5.3.1 Outgoing messages. For each outgoing message, the null store and forward function shall create an AME header with pre-programmed values in all fields, except that the header length and message length fields shall be computed for the actual message and AME header. The user (or transport layer process) shall be able to override the default values. Normally, the user will override only the default destination address, the precedence, and the port fields. A user may insert relay addresses for manual source-routing. If the user is able to override the source address, this capability should normally be restricted to selecting one of a set of pre-programmed addresses (to preclude impersonation of other stations).

5.7.5.3.2 Incoming messages. The destination and relay address records in the AME header of each incoming message shall be examined. If a self address is found in any of these address records, the message and the AME header shall be delivered to the user. (This permits users to manually relay messages.)

5.7.5.4 Automatic message exchange. AME is the network layer function concerned with single-link message delivery. It works with either a full store and forward process or a null store and forward process. In the following paragraphs, the term "store and forward process" refers to either implementation of the store and forward functionality.

NOTE: AME provides a simple datagram service, with no acknowledgments, error checking, or flow control.

5.7.5.4.1 Outgoing messages. Each network message passed to the AME process from the store and forward process contains an AME header and a transport message. The AME process shall interpret the first address record in the AME header as the desired destination for that message.

Outgoing messages from the store and forward process shall be queued by the AME process for transmission in order of precedence. The AME process requests a link to the destination of each message from the link selection function. When the link selection function indicates that a link to that destination is available, the AME process shall attach a network layer header (the character "M") to the front of the message, translate the network layer address to a data link layer address appropriate for the selected data link controller, and provide the network message and the translated address to that controller for transmission.

If a direct link cannot be established to the destination, the AME process shall take one of two actions:

a. Return the message to the store and forward process as undeliverable (appropriate if the store and forward process can attempt alternate routing).

b. Store the message for later delivery when a link can be established.

In the latter case, messages should be stored in separate queues for each destination so that only one series of linking retries is made for each destination (rather than one for each queued message). The first retry shall be made after a time sufficient for a busy station to have resumed listening for linking attempts. To minimize use of the spectrum for futile linking attempts, subsequent retries shall occur at intervals sufficient for propagation to have measurably improved. (The retry interval may be shortened when a queue contains high-priority messages.)

When contact is eventually made with the desired destination, whether through a successful linking retry or through connectivity discovered by reception of a message from that station, messages queued for that destination shall be sent in decreasing priority order.

5.7.5.4.2 Incoming messages. Incoming messages are delivered to the AME process when their network layer header is "M" (user messages). The AME process shall simply strip this single-character network layer header and pass each received message to the store and forward process for processing.

5.7.6 Relay management protocol. The HF relay management protocol (HRMP) shall be used by HF networking controllers to inquire about connectivity through prospective relay stations, to manage repeater operation, and to preempt repeater circuits, as described in 5.7.6.6. HRMP is a connectionless protocol, although it can be used to set up analog tandem circuits or data virtual circuits.

Every HRMP message refers to three stations: the first is the Relay station (actual or potential); the second is the Control station managing the relay; the third is the Distant station to which access is provided by the relay. HRMP messages are exchanged between the Control station and the Relay station.

HRMP messages shall be formatted as shown on figure 44. The fields in HRMP messages shall be encoded as described in the following paragraphs.

Msg Dest	Msg Source	Desired Dest	Msg ID	Msg Length	Command	Arguments	Checksum

FIGURE 44. HF relay management protocol message format.

5.7.6.1 HRMP address field. Three station addresses are present in every HRMP message: that of the station sending the message (Msg Source), that of the station to which an indirect path is sought or desired (Desired Dest), and that of the station receiving the message (Msg Dest). The Desired Dest shall always be the Distant station. The Msg Source and Msg Dest shall be the

Control and Relay stations, respectively, for Control-to-Relay messages, and vice versa for Relay-to-Control messages.

The addresses of all three stations shall be encoded as AME address records in accordance with 5.7.5.1.

5.7.6.1.1 Message destination. The Msg Dest field on figure 43 shall contain the address of the Relay station, with a suggested Relay flag, when the message direction is Control-to-Relay. For Relay-to-Control messages, the Msg Dest field shall contain the address of the Control station with a source flag.

5.7.6.1.2 Message source. The Msg Source field on figure 43 shall contain the address of the Control station, with a source flag when the message direction is Control-to-Relay. For Relay-to-Control messages, the Msg Source field shall contain the address of the Relay station with a suggested Relay flag.

5.7.6.1.3 Desired destination. The Desired Dest field on figure 43 shall always contain the address of the Distant station, with a Destination flag.

5.7.6.2 HRMP message identification field. The Msg ID field shall contain an 8-bit number used by the Control station to match responses with requests. Responses from the Relay station shall contain the same Msg ID as is found in the corresponding Request from the Control station. Messages from the Relay station other than responses shall set this field to all 1's.

5.7.6.3 HRMP length field. The Msg Length field shall contain the number of bytes in the entire HRMP message, from the first byte of the Msg Dest field through the last byte of the Checksum.

5.7.6.4 HRMP commands. The HRMP command field shall contain one of the 8-bit codes listed in table XXXIV. (Unlisted codes are reserved and shall not be used until standardized.) The use of these commands is described in 5.7.6.6.

TABLE XXXIV. Relay management commands.

Code	Command	Arguments
0	ACK	(None)
1	Query	Type, QOS, precedence
2	Query-response	Type, QOS, precedence
4	Connectivity-change	Connectivity code
5	Monitor-connectivity	Cx Monitor
8	Repeater-status	Rept. No., type, QOS, status
9	Repeater-request	Type, QOS, precedence
10	Repeater-lost	Rept No., reason code
11	Repeater-status-request	Repeater number
13	Release-repeater	Repeater number
255	NAK	Reason code

The encoding of the arguments to these commands is given in table XXXV. (Unlisted codes are reserved and shall not be used until standardized.) Arguments shall be sent in the order listed in table XXXIV.

TABLE XXXV. Encoding of HRMP arguments.

Argument	Format	Encoding
Reason code	8-bit unsigned	0 - No connectivity 1 - Precedence too low 2 - Inappropriate 255 - Not equipped
Type	2-bit unsigned	0 - Analog repeater 1 - Digital repeater (Usually frame repeater) 2 - Store and forward
QOS	6-bit field	Each bit independently selects a quality-of-service aspect; if bit = 1, better than normal performance in this aspect is requested QOS1: (msb) Delay QOS2: Throughput QOS3: Reliability QOS4: Noise QOS5: (Reserved) QOS6: (lsb) (Reserved)

TABLE XXXV. Encoding of HRMP arguments - continued.

Argument	Format	Encoding
Precedence	8-bit unsigned	0 - Routine (lowest) 64 - Priority 128 - Immediate 192 - Flash 250 - Flash override 254 - Reserved for inter-network control use 255 - Reserved for network control use *
Connectivity	8-bit unsigned	0 - Discovered direct connectivity 1 - Discovered indirect connectivity 254 - Lost direct connectivity (have indirect) 255 - Lost all connectivity
CX Monitor	8-bit unsigned	0 - Broadcast all changes of connectivity to distant station 1 - Broadcast only loss or discovery of connectivity: do not report transactions between direct and indirect 128 - Report all changes in connectivity 129 - Report only loss or discovery 255 - Do not report connectivity changes
Repeater No.	8-bit unsigned	Repeater reference number assigned by relay station

TABLE XXXV. Encoding of HRMP arguments - continued.

Argument	Format	Encoding
Status	8-bit unsigned	0 - Repeater fully-operational 1 - Requesting link to distant station 2 - Link to distant station failed; attempting to re-establish link 3 - Repeater preempted 255 - Repeater not available
* NOTE: Any number from 1 through 253, except those standardized herein (0, 64, 128, 192, and 250) may be used for user unique precedence requirements.		

5.7.6.5 Checksum. The 16-bit checksum shall be computed in accordance with 5.7.9.

5.7.6.6 HRMP operation. Allowed exchanges are listed in the following paragraphs for each of the classes of relay control actions supported by the HRMP. HRMP exchanges are one of two types:

a. Request-response. A control station sends a request to a Relay station and starts a timer. If a response is received before the timer expires, the protocol completes successfully. Otherwise, the Control station should abort the exchange. Lack of a response indicates loss of connectivity to the Relay station; thus, a retransmission should not be initiated until sufficient time has elapsed for connectivity to be restored (either improved propagation or resumption of operations at the Relay station).

b. Notification. A Relay station sends an unsolicited message to a Control station to announce an event asynchronously. Such events include preemption of a repeater in use by the Control station or loss of connectivity to a Distant station being monitored at the request of the Control station.

5.7.6.6.1 Routing queries. A station seeking to find an indirect path to a Distant station sends a query to prospective relay(s). A station receiving a query shall respond with a NAK in any of the following cases:

a. It lacks the facilities to provide the services requested (reason code = not equipped).

b. It has facilities, but they are not available for a request of the stated precedence (reason code = precedence too low).

c. It has available facilities, but has no connectivity to the requested Distant station (reason code = no connectivity).

A station having available facilities that at least approximate the requested service and having connectivity to the requested Distant station, shall return a query response that describes the type and quality of service it can provide. Note that routing queries may be made for either message store and forward service or repeater service.

5.7.6.6.2 Repeater control. Both analog and digital repeaters may be remotely controlled through the use of the Repeater control commands. When a repeater is engaged using HRMP, the Relay station shall assign a repeater number (analogous to a virtual circuit number) for unambiguous reference to the circuit established.

a. A repeater request shall specify the type and quality of service desired (just as in a query). If the repeater can be engaged, the Relay station shall return a repeater status response which contains the assigned repeater number and type and quality of service actually provided. Otherwise, (see conditions in 5.7.6.6.1) a NAK shall be returned.

NOTE: A repeater request specifying store and forward shall elicit a NAK with a reason code of "inappropriate" because the store and forward function cannot be seized.

b. A repeater status request sent by a Control station to inquire about the operational status of a previously engaged repeater shall carry the repeater number assigned when it engaged that repeater. The Relay station shall respond with a NAK if the specific repeater is not currently assigned to the Control and Distant stations specified in the message; otherwise, it shall respond with a repeater status message that describes the type, quality of service, and current status of the specific repeater.

c. A Control station shall release an engaged repeater by sending a release repeater message. The Relay station shall send a NAK under the conditions described above for repeater status requests; otherwise, the Relay station shall terminate the link to the Distant station, disengage the repeater, and return a repeater status message containing a status code of "repeater not available."

d. When a Relay station cannot sustain a previously engaged repeater service, it shall send a repeater lost message to the affected Control and Distant stations. For each intended recipient of the repeater lost message, the address of that station shall be encoded as the Msg Dest using a source address record, and the third party to the repeater service shall be encoded as the Desired Dest using a Destination address record. If the repeater service is terminated because of loss of connectivity, the reason code shall be "no connectivity." If the repeater was preempted, the reason code shall be "precedence too low."

Loss of a link to one party to a repeater service shall not result in a repeater lost message and termination of the repeater service until attempts to automatically re-establish the link have failed. During link re-establishment, the repeater status shall be reported as code 2 in responses to repeater status requests.

5.7.6.6.3 Connectivity monitoring. Connectivity monitoring is a notification-based alternative to connectivity exchange (5.7.4). A Monitor Connectivity message requests that the named Relay station monitor (or cease monitoring) its connectivity to the named Distant station. Notification options include broadcasting connectivity changes to all stations, or reporting changes to a named control station, or cease reporting changes in its ability to reach that Distant station. If the Distant Station field contains the network broadcast address (5.7.8), the Relay station shall perform the indicated command for all stations.

Notification of a change in connectivity shall be sent in a connectivity change message. A connectivity change message may be broadcast by addressing it to the network broadcast address (5.7.8). The arguments defined for the monitor connectivity and connectivity change messages support two levels of detail in this service: notification only of loss and discovery of connectivity, or notification of transitions between direct and indirect connectivity as well.

5.7.7 Station status protocol. The HF station status protocol (HSSP) shall be used to notify network members of changes in the operating mode of a station. HSSP messages shall be formatted as shown on figure 45.

Source Addr	D	New Status	Event Time	Duration	Checksum

FIGURE 45. Station status message format.

a. The Source Addr field shall contain the address of the station sending the message, encoded in an address record (see 5.7.5.1) with a source flag.

b. The D bit shall be set to 1 if and only if the Duration field is present.

c. The 7-bit New Status field shall report the new status of the reporting station as of the date and time indicated in the Event Time field, using the codes listed in table XXXVI.

TABLE XXXVI. Station status codes.

Code	New Status
0	Normal operations
1	Assumed net control (from non-net control stations)
2	Relinquishing net control (from net control station)
3	Radio silence
4	Reduced power
5	Alternate scan set 1
6	Alternate scan set 2
7	Alternate scan set 3
127	Out of service

d. The Event Time field (24 bits) shall contain the date and time that the new status will be effective for the station in accordance with figure 46, except that an Event Time field containing all 1's indicates that the new status is effective immediately after the message was sent. The Event Time shall be encoded in Zulu time (i.e., universal time, coordinated (UTC)), with the year digit holding the least-significant digit of the event year.

4	4	5	5	6
Year (0 - 9)	Month	Day	Hour	Minute

FIGURE 46. Event time encoding.

e. The optional Duration field (24 bits) shall be encoded in accordance with figure 46 to indicate the expected duration of the status change.

f. The 16-bit Checksum shall be computed in accordance with 5.7.9.

NOTE: No length field is needed to determine the number of bytes contained in an HSSP message because the only variable-length field in the message is the Source address record, which contains an internal length field.

5.7.8 Network broadcast address. Where permitted by network layer protocols, the broadcast address "@ ? @" (identical to ALE ALLCALL address) may be used to collectively refer to all reachable stations.

5.7.9 Checksum computation. The 16-bit Checksum in network layer messages shall be computed as the 16-bit 1's complement of the one's complement sum of all relevant 16-bit words (either all words in the AME header or all words in the message for HRMP or HSSP). If the checksum is to be computed over an odd number of bytes, the final byte shall be padded on the right with a 0-filled byte. For purposes of computing the checksum, the Checksum field itself shall be filled with 0 bits.

5.7.10 Data transmission order. The order of transmission of the headers and data composing the messages described in this section (i.e., connectivity exchange, AME, relay management, and station status messages) is resolved to the octet or character level.

The bytes of these messages shall be transferred in the order left-to-right then top-to-bottom, just as English words are read. In the case of multibyte fields, this means that the most significant (i.e., left-most) byte is transferred first.

CONEX messages consist of 7-bit "characters" while messages from the other protocols consist of 8-bit bytes. In all cases, the bytes (or characters) of these messages shall be transferred in the order left-to-right then top-to-bottom, just as English words are read. In the case of multi-byte (multi-character) fields, this means that the most-significant (i.e., left-most byte (character) is transferred first.

NOTE 1: The order of bit transmission within these units is determined by the data link protocol used and is transparent to network layer protocols. For example, ALE conveys data most significant bit first, while the Data Link Protocol (described in TR No. ASQB 94142) and most computer serial ports convey data least significant bit first. Although this Data Link Protocol orders multibyte values within its own header least significant byte first, network layer messages are conveyed to data link protocols as individual bytes (i.e., multibyte fields appear only as a sequence of bytes to the data link protocol), and are carried on the data link in the order determined by the network layer entity.

NOTE 2: The HF Data Link Protocol is defined in U.S. Army Information Systems Engineering Command (USAISEC) Technical Report TR No. ASQB 94142. This technical report is included as appendix A to this standard.

5.8 <u>Network management</u>. Programs that provide network management functionality are not standardized. Interoperation among such network management systems, however, requires the standardization of protocols for examining and changing the state of network elements, and of the abstract data objects (management information) manipulated using the HNMP protocol. The protocol requirements are identified in 5.8.2, and the management information requirements are defined in 5.8.3.

5.8.1 <u>Terminology</u>. Managed network elements (e.g., radios, ALE controllers, data modems, and networking controllers) are monitored and controlled by embedded network management agents (processes) which have access to the operating data of the elements and can initiate actions in those elements. Network management stations communicate with the agents to request the values of operating data, and to request that operating data be changed. Actions in management elements are produced as side effects when operating data are changed. For example, changing the antenna Mode value for a rotatable antenna causes the antenna to rotate (see MIB, in appendix B, for the definition of antenna mode).

5.8.2 Management protocol. SNMPv2, in accordance with (IAW) RFC 1441 through 1452 shall be employed for HF network management, with the following additional requirements (see paragraph 4.8.3).

a. An agent receiving a SetRequest that selects a non-existent row in a table shall automatically create the requested row subject to resource availability, setting column objects in the new row to their default values unless other valid values are specified in the SetRequest message. However, if any value in the SetRequest message specifies an invalid value for any column object in the new row, the new row shall not be created, and a GetResponse message shall be returned indicating the erroneous variable binding.

b. Table rows invalidated by a SetRequest shall not be reported in responses to GetNextRequests (i.e., from the point of view of management stations, invalidated rows are deleted from the table).

c. Object identifiers for objects defined in the HF Management Information Base (MIB) may be encoded for transmission *within HF networks only* using the truncated encoding scheme of 5.8.3.2. Gateways that connect HF networks to non-HF networks, however, shall ensure that object identifier encodings in messages entering non-HF networks use the full encoding of ISO/International Electrotechnical Commission (IEC) 8825; SNMP messages entering HF networks may be translated to use truncated encodings.

d. Retransmission timeouts in network management programs shall be adjusted to allow time for link establishment, and for the transmission of requests and responses over modems that may be able to achieve throughputs of 100 bps or less.

5.8.2.1 Inside local HF station. The relationship of the network management protocol to the other protocols in use within an HF station is shown in figure 47. HNMP requires only a connectionless datagram transport service (e.g., the UDP). Consequently, figure 47 shows HNMP using UDP for a Transport-layer protocol, IP for an Internet-layer protocol, and the HF AME protocol (5.7.5) as the Network-layer protocol. IP datagrams sent through the HF AME protocol shall use port number 5 in the network message header (AME header). Figure 47 also shows integration of IEEE 802 protocols as an illustration of the use of HNMP over an Ethernet local area network. Other network protocols may be integrated similarly.

5.8.2.2 Outside local HF station. When interoperation with management stations outside the local HF sub-network is not required, UDP and IP may be eliminated to reduce the overhead of network management messages. In this case, messages shall be directed to AME port number 6, which is a direct connection to HNMP.

Application	HNMP		
Presentation			
Session			
Transport	UDP		
Internet	IP		
Network	AME		
Data Link	ALE	DLP App A	IEEE 802.2
Physical	ALE Modem	MIL-STD-188-110A Modem	IEEE 802.3 (CSMA/CD)
	MIL-STD-188-141A Radio		

FIGURE 47. Interrelationship of protocols.

5.8.3 Management information. SNMP functions by reading and writing data structures defined for each item of controlled equipment. These data structures are defined using an abstract syntax so that the details of how the data are stored by individual network components are hidden. For example, aleScanRate (the rate at which an ALE controller scans channels as defined in the HF MIB) is simply defined to be an integer, with no indication of byte order, or even the number of bytes used to represent it on any particular ALE controller.

a. Furthermore, some ALE controllers may store channel dwell time instead of scan rate, in which case a conversion from dwell time to or from scan rate is made whenever aleScanRate is read or written. This illustrates the fact that the objects manipulated by a network management station need not correspond directly to the internal data structures of managed elements. A principal function of agents in managed elements is the translation between the abstract objects used in the management protocol and the actual data structures used in equipment.

b. The objects that may be read and written using HNMP are defined in modules using Abstract Syntax Notation One (ASN.1), ISO/IEC 8824. RFC-1450 defines the objects commonly used to manage TCP/IP internets. The standard objects for HF network management are identified in the HF MIB, paragraph 5.8.3.1. Objects specific to each manufacturer's equipment are specified in a MIB provided by that manufacturer. A management station integrates MIB modules from the elements it manages, resulting in access to a wide-ranging and dynamic set of management data. The structure of MIBs is defined in RFC-1442.

c. When data is exchanged over the air (or some other medium), all parties involved in the exchange shall use the same encodings for the data. The HNMP encoding rules are specified in 5.8.3.2.

5.8.3.1 HF MIB. The HF MIB is defined in U.S. Army Information Systems Engineering Command (USAISEC) Technical Report ASQB 94089. This technical report is included as appendix B to this standard. This MIB module contains groups of objects for radios (and related RF equipment), ALE controllers, linking protection, HF data modems (and associated data link controllers), and networking controllers. HF equipment complying with this paragraph shall implement the corresponding group of objects from the HF MIB, although access to these objects may be provided by proprietary protocols rather than HNMP (requiring proxy management, paragraph 5.8.4). As a DO, new equipment should support HNMP directly.

5.8.3.2 Encoding rules. Object names and values sent in HNMP messages shall be encoded IAW the Basic Encoding Rules for ASN.1, found in ISO/IEC 8825, with an optional truncated encoding for OBJECT IDENTIFIERs of objects from the HF MIB, as specified in the following text. Such truncated encodings shall not be used in messages outside HF networks.

a. The object names used in variable bindings in HNMP messages are OBJECT IDENTIFIERs, which authoritatively identify each object named by specifying the location of its definition in a tree of standards. For objects defined in the HF MIB, the OBJECT IDENTIFIER *may* employ a truncated path that begins in the HF MIB, using the unique code 123 (decimal) to indicate that the path to the definition begins in the HF MIB. For example, the ALE self address table may be identified as 123.2.16.

b. For an object defined for general use (i.e., not HF-specified), HNMP messages shall carry the normal OBJECT IDENTIFIER for the object. For example, the sysDescr object shall be identified as 1.3.6.1.2.1.1.1 (which traces the following path: iso(1) org(3) dod(6) internet(1) mgmt(2) mib-2(1) sys(1) sysDescr(1)).

5.8.4 Proxy management. When elements do not implement HNMP, they may still be managed by using proxy agents that translate the standard HNMP messages into proprietary messages understood by the non-HNMP ("foreign") elements.

NOTE: As HNMP management of HF radio networks is phased in, few network elements will initially implement HNMP. Proxy agents will be needed to extend the management capability to current-generation equipment. As a general rule, the proxy agent for any foreign network element should reside in the lowest-level controller (see figure 47) that has a control path to that element.

a. In operation, HNMP traffic that is directed to a foreign element will be delivered to the proxy agent. The proxy agent shall translate the request into an appropriate message for the target element, in terms of the native control protocol for that element, and pass the translated message to the foreign element over any available control circuit. Responses received from the foreign agent shall be translated into HNMP messages and passed to the requesting management station.

b. For efficiency purposes, proxy agents may cache frequently requested variables from foreign elements so that some traffic on the control paths within a station is eliminated.

NOTE: Variable caching necessitates messages from the foreign element to the caching proxy agent to either update or invalidate cached copies when cached variables are changed by other than the proxy agent (e.g., from an element front panel).

5.8.5 Access control. Access to the management information of network elements is controlled in HNMP at two levels.

a. The first level is an administrative model that restricts the objects at each element that are accessible to other parties and the operations that may be performed by those parties.

b. The second level of access control is authentication of messages, that is, determination that a message actually comes from the party named in the message.

5.8.5.1 Administrative model. HNMP agents and management applications shall employ the administrative model of RFC-1445. Object identifiers for parties and contexts shall be assigned by network administrators, who shall in turn obtain space in the tree of object identifiers from the preparing activity of this standard. Transport domain identifiers specific to HF networks are defined in the HF MIB (appendix B).

5.8.5.2 Authentication. The following three authentication schemes should cover the range of requirements for HF networks. Management stations shall employ only the trivial authentication protocol in HNMP messages, unless the addressed party is known to support a more secure authentication protocol. All HNMP agents must therefore support the trivial authentication protocol, although the access permitted trivially-authenticated parties to management information may be restricted.

NOTE: Since HNMP uses a broadcast medium, it is susceptible to injection of false messages by hostile forces. HF networks should strive for the highest possible level of authentication necessary for the mission to minimize this risk.

5.8.5.2.1 Trivial authentication. When trivial authentication is employed, an agent receiving an HNMP message shall compare the Transport-layer address of the originator of the message to a list of authentic Transport-layer addresses for the party sending the message. If a match is found, the agent shall assume the message is authentic. When Transport-layer addresses are not used, agents may either use lower-layer addresses for authentication, or simply assume that all messages are authentic, as determined by network management policy for each network.

5.8.5.2.2 Personal identification number (PIN) authentication. An intermediate level of security may be achieved through the use of PIN authentication. When PIN authentication is employed, network management programs shall prompt the station operator to enter a PIN, and shall insert this PIN as the authInfo in every SnmpAuthMsg that carries a request protocol data unit (PDU). Agents receiving these requests shall compare this PIN to a list of authentic PINs for the named party as in 5.8.5.2.1 above.

Response and trap messages from agents shall carry the serial number of the responding device in place of a PIN. These serial numbers should be verified using a local table before assuming that a response or trap message is authentic.

NOTE: This scheme can be easily spoofed by duplicating PINs and serial numbers intercepted from prior traffic. Because SetRequests may be more important to authenticate than responses and traps, the lists of valid PINs should be varied with time to heighten protection against bogus request messages.

5.8.5.2.3 Cryptographic authentication. A secure authentication scheme for SNMP is specified in RFC-1446, section 3. This digest authentication protocol includes a *digest* of each authenticated message at the beginning of the message (authInfo in the SnmpAuthMsg). This digest is computed from the message contents and a secret initialization vector in such a way that it is considered computationally infeasible to "spoof" the authentication system. A time-of-day mechanism is included as well to limit the effects of replay attacks.

When cryptographic authentication of HNMP traffic is required, the digest authentication protocol of RFC-1446 shall be employed, using the MD-5 Message Digest Algorithm of RFC-1321. Initialization vector distribution is beyond the scope of this standard.

5.8.6 Traps. HNMP messages containing traps are sent by managed elements to management applications to announce exceptional events, such as equipment failures or degradation of operating parameters beyond programmed thresholds. Trap messages may be used to reduce the required rate of polling for most such events.

5.9 Multi-media operation. HFNCs (level 2 or above) shall be capable of automatically routing voice and data traffic via any available data link(s).

a. Level 2 HFNCs (with static routing tables) must be programmed to use specific media for each destination node. This may be accomplished by any combination of manual or remote programming (e.g., using HNMP).

b. Level 3 and above HFNCs shall automatically evaluate links of any medium for adaptive routing using the Path Quality formulas (paragraphs 5.7.1 and 5.7.4.2).

NOTE: The CONEX messages that carry the data necessary for path quality calculations will be less costly in terms of overhead on high-band-width alternate media than on HF links. In many applications, connectivity exchanges should be restricted to such high-bandwidth links, with query and notification-based protocols employed generally to discover and adapt to changing employed generally to discover and adapt to changing network topology and connectivity (see 5.7.6.6.1 Routing Queries, 5.7.6.6.3 Connectivity Monitoring, and 5.7.7 Station Status Protocol).

c. Level 4 HFNCs shall implement the IP and the Internet Control Message Protocol (ICMP), and shall be capable of routing traffic via any available subnet.

5.10 HFNC interface to local equipment (station data bus). The protocols specified in this section provides an optional interoperable mechanism to support the functionality specified in 4.7.1 through 4.7.3 for interconnecting an HFNC to one or more external link controllers (see figure 48), as well as to other external equipment.

NOTE: Use of this optional communication interface is dependent on the system configuration and performance requirements. This interface will not normally be used between devices interconnected by a high-speed "backplane" bus.

The specific functions specified in 4.7.1 and 4.7.2 should be implemented using HNMP and the following objects from the HF MIB:

a. Link control should use the *aleConnectionTable* for management of ALE links; and *hfdlpLinkState* and *hfdlpOtherAddress* for management of HF data link protocol (HFDLP) links.

b. Link quality reporting should use the *aleLqaMatrix* for link quality data.

Access to these MIB objects in local equipment will employ HNMP messages sent directly to those devices using the station data link protocol specified in 5.10.2. These messages will not use the network-layer header, AME header, and optional IP and UDP headers that are needed for sending messages through the network. That is, these are not "network messages."

Network messages (messages sent to other stations) should use the station network message format specified in 5.10.1. Network messages in this format are carried over the station data bus (5.10.3) within the data link frames of the Station Data Link Protocol (see 5.10.2 and figure 50).

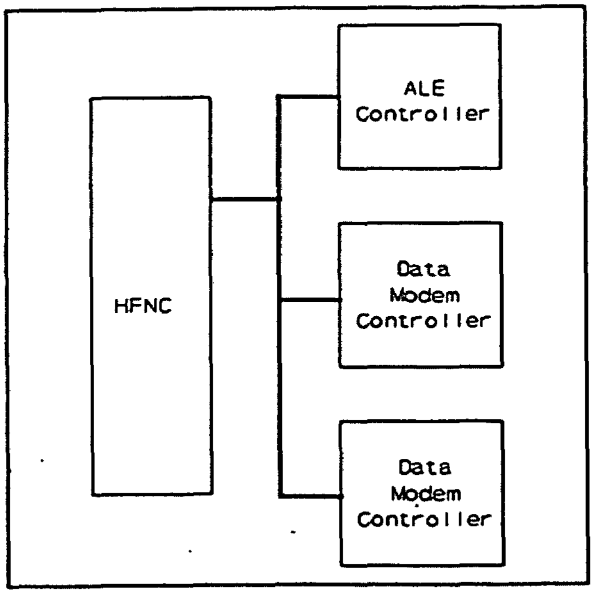

FIGURE 48. Station data bus.

5.10.1 Station network message format. The standard format for network messages passing between HFNCs and link controllers is shown in figure 49. The first octet contains a count of the number of address octets in the link layer address of the distant station (destination of a message from HFNC to link controller, or source of a message from link controller to HFNC). This is followed by the indicated number of address octets, which is in turn followed by the network layer header and the remainder of the body of the network message.

Addr Length	Link Layer Address	Network Layer Header	Message . . .

FIGURE 49. Station network message format.

When a link controller receives a network message that specifies a destination to which it is not currently linked, a request to establish that link should be inferred.

5.10.2 Station data link protocol. The point-to-point protocol (PPP) HDLC-like framing in accordance with RFC-1662 is recommended for use as a station data link protocol (SDLP) to carry traffic among devices in a station. In this scheme, HNMP and network messages are encapsulated within PPP packets, which are in turn carried in the Information field in HDLC frames (see figure 50).

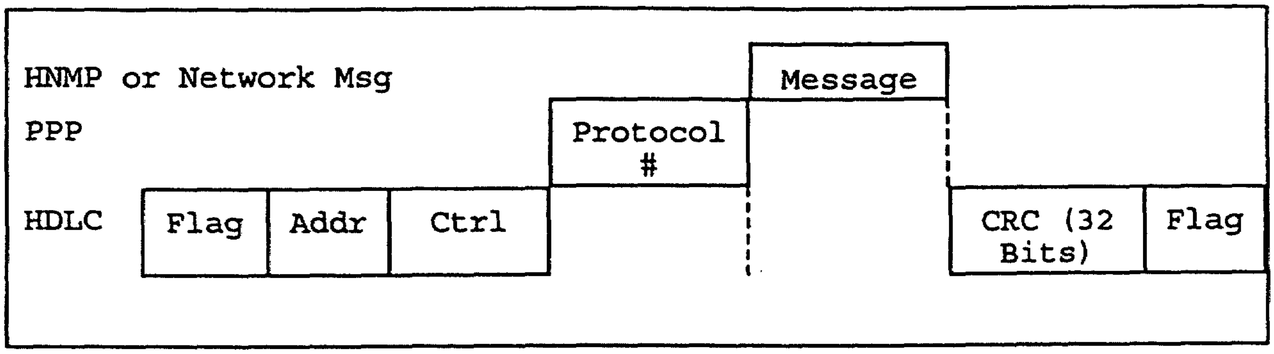

FIGURE 50. <u>SDLP frame structure</u>.

Some modifications to this scheme are necessary for SDLP, as detailed below. Padding at the end of the PPP packet is neither necessary nor desirable, and shall not be inserted.

NOTE: Padding can complicate the task of the receiving device.

5.10.2.1 <u>HDLC mode for SDLP</u>. Links established by the HFNC shall operate in HDLC Normal Response Mode (NRM) in accordance with ISO/IEC 3309:1991, in which the HFNC acts as the "primary"

device and polls the other "secondary" devices. The full range of HDLC frame types is used for SDLP, rather than solely Unnumbered Information frames as specified in RFC-1662.

Octet stuffing in accordance with RFC-1662 shall be used for transparency. This eliminates the need for bit stuffing (commonly required in other implementations of HDLC).

NOTE: The underlying physical layer will normally be asynchronous (rather than octet or bit-synchronous).

5.10.2.2 <u>Bus arbitration</u>. Devices within the station shall be assigned one-octet HDLC addresses (the lsb must be 1), with address 1 reserved for the HFNC. The address field in the HDLC frames shall always contain the address of the secondary device (not the HFNC).

PPP links within a station shall be established only by the HFNC; other devices shall transmit frames on the station data bus only in response to "poll" frames from the HFNC (i.e., frames from the HFNC having the poll/final (P/F) bit in the HDLC Control field set to 1).

5.10.2.3 PPP numbers. HNMP messages directed to local devices shall be sent using the network control PPP number assigned for HF (see Assigned Numbers RFC). Note that HNMP messages directed to *remote* devices will be embedded within network messages, following AME and possibly other headers.

Network messages shall use the network-layer PPP number assigned for HF AME.

5.10.2.4 PPP configuration options. The following options (at least) should be configured during SDLP link establishment:

a. Cyclic Redundancy Check (CRC). Default is 16-bit CRC. SDLP implementations should negotiate use of 32-bit CRC in accordance with RFC-1570.

b. Maximum Received Unit (MRU). Default is 1500 octets. SDLP implementations should negotiate an MRU appropriate to the station error environment.

5.10.2.5 SDLP link establishment. The following sequence of frames shall be sent on the station data bus to establish a link from the HFNC to a link controller.

a. The HFNC selects a link controller by sending a Set Normal response mode (SNRM) HDLC frame addressed to that link controller with the P/F bit set to 1.

b. The link controller responds with an unnumbered acknowledge (UA) HDLC frame with the P/F bit set to 1.

c. The HFNC attempts to open a PPP connection by sending an Information HDLC frame that contains a link control protocol (LCP) Configure-Request packet. This packet will specify the PPP configuration options (if any) that the HFNC wishes to change from their default values.

d. The link controller responds with an Information HDLC frame that carries its response to the Configure-Request (often a Configure-Ack). The HDLC frame from the HFNC is acknowledged in the HDLC header of the response.

e. Additional PPP LCP packets may be exchanged to continue to negotiate, or to authenticate the link establishment. (The details of HDLC Normal Response Mode are implied and not repeated here.)

The SDLP link is established when LCP Configure-Ack packets have been sent and received. Thereafter, HDLC Information frames are used to carry PPP packets carrying HNMP and network messages as described in 5.10.3.

NOTE: Because the HFNC must poll a link controller before the link controller may transmit, links may remain in existence between uses, and this link establishment procedure need not be executed before each message is transferred.

5.10.3 Station physical layer. The physical layer protocol of the station data bus employs full duplex asynchronous transmission of 8-bit characters (octets) with no parity and one stop bit. The least significant bit of each octet shall be sent first. All devices should support a data rate of 9600 bps; other data rates are optional (DO: automatically send and adapt to the data rate in use).

The electrical interface shall be RS-485. The only circuits required are Transmitted Data (balanced), Received Data (balanced), Signal Ground, and Protective Ground. The HFNC shall drive the Transmitted Data circuit, and the other devices shall drive the Received Data circuit.

5.10.4 Examples. Figure 51 shows an example application of the station data bus concept in a large, unmanned ("lights out") communication station. Because of electrical loading, more than a single station data bus would be required to connect the Message Switch/Node Controller to all of the assets shown.

Figure 52 shows a conceptual "pop-up menu" oriented user interface for remotely controlling such a station. For each "level" of equipment, the operator selects devices by choosing from a menu of available devices of each type (e.g., crypto, modems, and radios), and links them together by clicking a mouse button between the rectangles shown. Each connection displayed is numbered with the index of the corresponding entry in the connection table for the site (see appendix B of HF MIB).

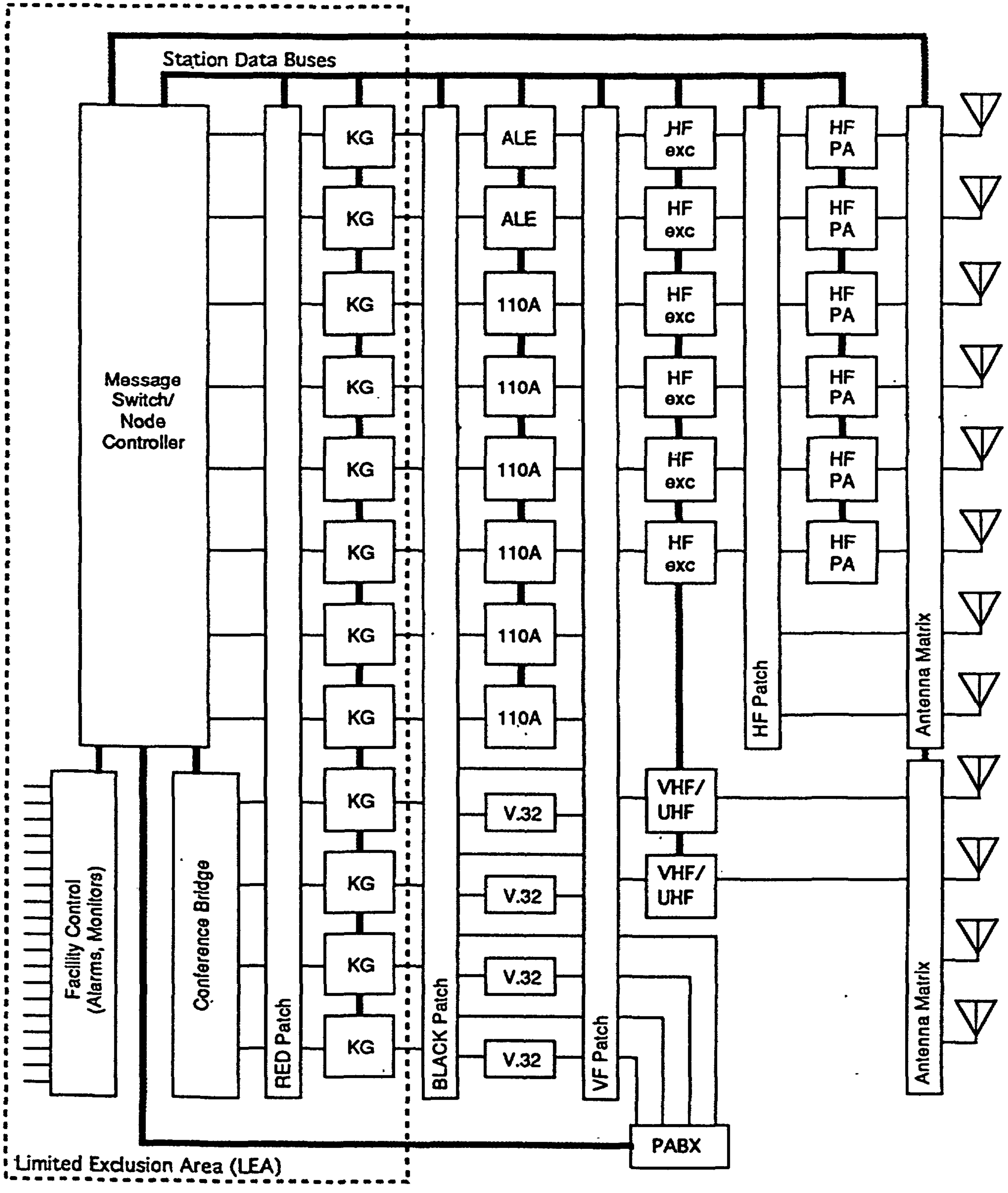

Figure 51. Station data bus example.

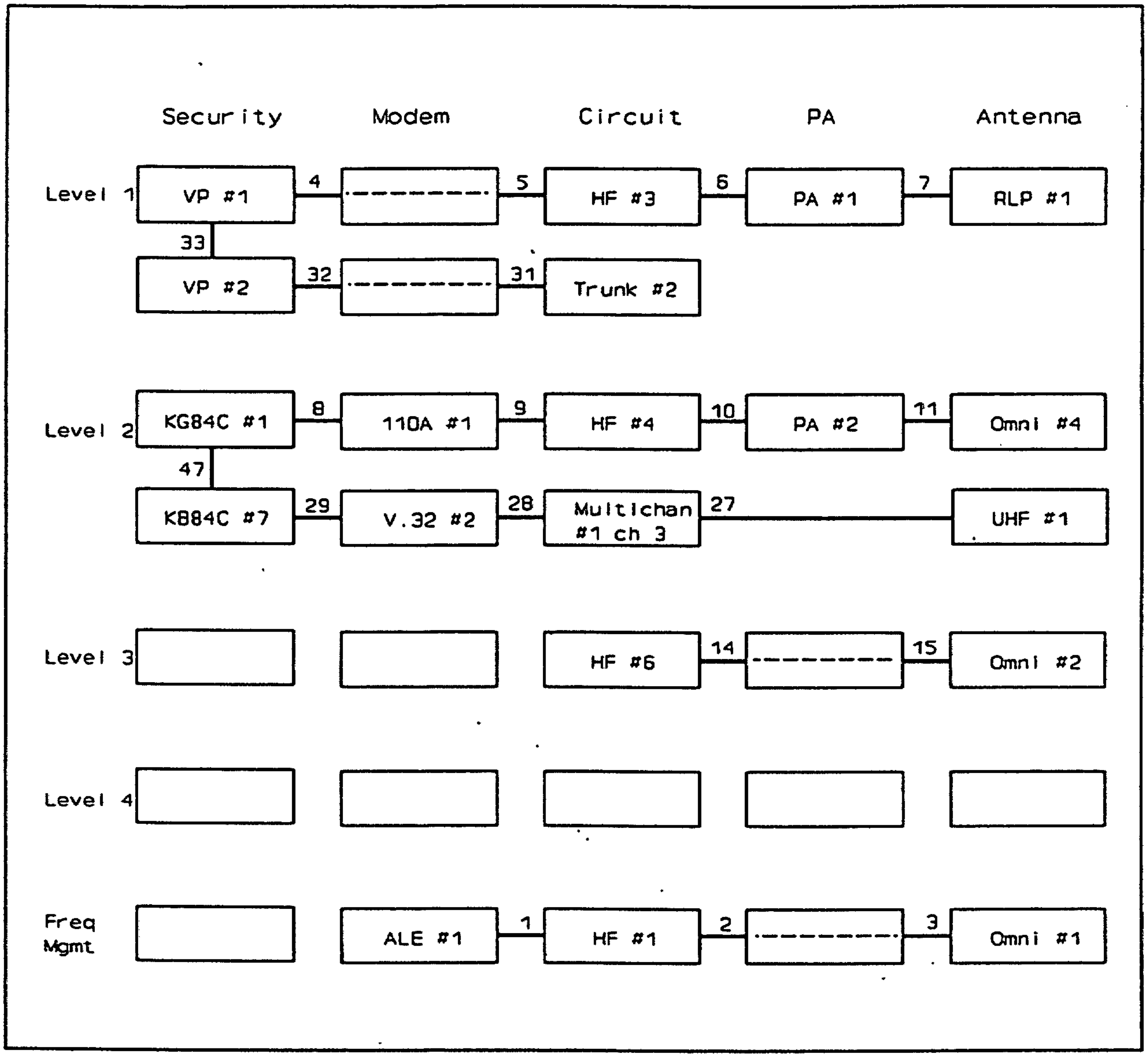

FIGURE 52. Menu-driven remote tech control.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use.

6.1.1 General.

a. The purpose of this document is to provide the technical parameters for the functions and features of advanced adaptive HF radio and to provide logical and cohesive guidelines for both industry and the Government.

b. There is no requirement for linking protection to be a part of a user's acquisition unless the user has an identified need. Optional levels of linking protection are identified and detailed. These options, AL-1 and AL-2, provide an inexpensive, least protected mode and a more sophisticated protection mode. The users should establish their application level based on minimum essential requirements.

c. The user may not have a requirement for some of the features and functions included in this document. The user should establish the requirement for each function or feature called out in an acquisition based on minimum essential requirements.

6.1.2 Functions carrying high overhead costs. Several of the functions specified in this standard are intended for use only in specific circumstances, and could cause severe congestion if used in most networks. Procuring activities should identify a clear requirement for the following functions before acquisition.

6.1.2.1 Polling and connectivity exchange. Polling should be used sparingly, because its overhead burden grows as the square of the number of stations in the network. Simulations have shown that polling and CONEX will seriously degrade network availablility for networks of more than about 10 stations. This is because (1) channel usage for polling and CONEX functions and (2) through the suspension of station scanning while using these protocols.

6.1.2.2 LQA reporting. LQA reports can provide valuable link quality information in cases of non-reciprocal propagation. These reports are useful only if they carry recently measured data. Except for very small networks with very small volumes of user traffic, the overhead transmissions required to supply this data may be excessive. LQA reporting should be used primarily for optimizing point-to-point links that must support traffic in both directions, and for cases of a single station that has a much higher noise floor than other network members.

6.1.2.3 ALQA. Full benefit of the ALQA techniques can be obtained only by more extensive data collection than is required for the standard LQA technique. For example, a station receiving a sound could continue to measure the sound until it ends, rather than departing after two good words are received. This action lowers the effective scanning rate, requiring longer call times. A 10-station, 10-channel network would need to double the call duration to maintain its linking probabilities.

Because ALQA data is measured using the ALE modem, ALQA channel evaluations may not correlate well with the performance of other modems on the channels. Thus, ALQA should only be used when all of the following conditions are met:

a. Channel quality must be determined with greater precision than is available with standard LQA.

b. Traffic volume is sufficiently light that the overhead required for data measurement is tolerable.

c. Only the ALE modem will be used for data traffic.

In most networks carrying substantial data traffic volumes, an HF data modem will be employed. The adaptivity inherent in data link protocols for such modems may make ALQA redundant for these links.

6.1.3 Interaction matrix. The complexity of the adaptive features and functions may be confusing to the user of this standard. Certain parts of the technical features are dependent on other features defined within this standard and MIL-STD-188-141. This dependency is not always apparent to the user or the acquisition activity. The following matrix provides the interaction dependencies known, as of the publication date.

Interaction Matrix: General Features

Feature	Paragraph	Requires	Notes
1. Automated Network Management	4.8.5.8	HNMP [28] and HF MIB [29]	
2. Remote Control of Station Equipment	*	HNMP [28] and HF MIB [29]	*Feature supported, but no paragraph with this title.
3. Remote Data Fill	*	HNMP [28] and HF MIB [29]	*Feature supported, but no paragraph with this title.
4. Any-media Networking	4.9.5.9	IP [14], AME [24] (For use of HF), HRMP [26] and HSSP [27] (for topology monitoring) Robust networking using all available media CONEX [19] is also useful.	Robust networking using all available media; CONEX [19] is also useful.
5. Fully-automated Message Handling	*	Message Store and Forward [22], Route Selection [20]	*Level 2 HFNC [16] provides the features for fully-automated (but not adaptive) message handling.
6. Adaptive Routing	*	Routing Queries [7]	*Path Quality Matrix [18] and CONEX [19] provide increased functionality, with increased overhead.
7. Routing Queries	5.7.6.6.1	HRMP [26]	
8. Connectivity Monitoring	5.7.6.6.3	HRMP [26]	HSSP [27] recommended also.
9. Repeater Control	5.7.6.6.2	HRMP [26]	
10. Full-duplex Independent Operation	5.6.3	Frequency Select Command [35]	
11. Internet Services	*	TCP [12]	*For example, FTP, SMTP, Telnet (defined in RFCs).

Interaction Matrix: General Features - continued.

Feature	Paragraph	Requires	Notes
12. TCP	*	IP [14]	*Defined in RFC-793.
13. UDP	*	IP [14]	*Defined in RFC-768
14. IP	*	AME [24] (For use of HF, HFNC [16]	*Defined in RFC-791 (ICMP in RFC-792)
15. Indirect Calling	4.6.1, 5.7.2	ALE Controller (For Link Establishment)	Level 2 (or higher) HFNC [16] recommended for selecting alternate station.
16. HFNC	4.6.2	(See Table II for levels of functional capability) Requires at least one link controller, including ALE, HFDLP [32], or other media.	SDLP [31] recommended for link controller interface. MIL-STD-188-110A modem and HFDLP [32] recommended for message transfer over HF links (versus ALE modem with DTM [49] or DBM [48].
17. Routing Table	4.6.2.1.1 5.7.1.2	HFNC [16]	
18. Path Quality Matrix	4.6.2.1.1 5.7.1.1	HFNC [16]	CONEX [19] may be used to dynamically update path qualities.
19. CONEX	5.7.4	Network Layer Header [21]	Normally uses Path Quality Matrix [18]; may instead use only link controller data.
20. Route Selection	4.6.2.2, 5.7.1	Routing Table [17]	
21. Network Layer Header	5.7.3	HFNC [16]	
22. Message Store and Forward	4.6.2.3, 5.7.5.2	AME [24]	
23. Null Store and Forward	5.7.5.3	AME [24]	
24. AME	4.6.2.4	AME Protocol [25], and either Message Store and Forward [22] or Null Store and Forward [23]	Automatic Message Exchange.

Interaction Matrix: General Features -continued.

Feature	Paragraph	Requires	Notes
25. AME Protocol	5.7.5.1 and 5.7.5.4	Network Layer Header [21]	
26. HRMP	5.7.6	Network Layer Header [21]	
27. HSSP	5.7.7	Network Layer Header [21]	
28. HNMP	5.8.2, Appendix A	AME [24] for HF Links; UDP [13] and IP [14] when using Internet; UDP+IP+AME when internetworking via HF.	MIL-STD-188-110A modem and HFDLP [32] should be used over HF links (rather than ALE modem with DTM [49] or DBM [48]).
29. HF MIB	5.8.3, Appendix B		
30. Interface to Link Controllers	4.7		SDLP [31] recommended protocol for interface to link controllers.
31. SDLP	5.10		Station Data Link Protocol.
32. HFDLP	Appendix A	MIL-STD-188-110A serial-tone modem.	HF Data Link Protocol will work over other modems, but is optimized for the 110A serial-tone modem.
33. Linking Protection (LP)	4.2., 5.1	Time Exchange Protocol [34] (for synchronization).	
34. Time Exchange Protocol	5.2		Time service protocol is usually sufficient for LP.
35. Frequency Select Command	5.6.3	ALE Controller, Frequency Designators [36]	
36. Frequency Designators	5.3a	ALE Controller	
37. Channel Designators	5.3b	ALE Controller	

Interaction Matrix: General Features - continued.

Feature	Paragraph	Requires	Notes
38. LQA Matrix	5.4.1	At lease one source of data: Basic LQA [51], Polling [41], LQA Reporting [45], or ALQA [47].	LQA Matrix is required in MIL-STD-188-141A ALE controllers.
39. Passive LQA	4.4.1	ALE Controller	
40. Sounding	5.4.2	ALE Controller	
41. Polling	4.4.2	At least one Polling Protocol from [24-26]	
42. Individual Poll	5.4.3.1	ALE Controller	
43. Multi-station, Single-channel Polling	5.4.3.2	ALE Controller that supports Star Net Calls [53] or Star Group Calls [52]	
44. Two-station Multi-channel Polling	5.4.3.3	ALE Controller	Frequency Designators [36] or Channel Designators [37] required to select channels outside current scan list.
45. LQA Reporting	4.4.3	LQA Report Protocol [46]	
46. LQA Report Protocol	5.4.4	MIL-STD-188-141A ALE Controller with LQA Matrix [38], and either DTM [49] or DBM [48].	Frequency Designators [36] or Channel Designators [37] required to report channels outside current scan list.
47. ALQA	4.5, 5.5	ALE Controller	Advanced LQA
48. DBM	"80.5	ALE Controller	Data Block Message Greater throughput than DTM [49], but less than MIL-STD-188-110A.
49. DTM	"80.4	ALE Controller	Data Text Message.
50. AMD	"80.3	ALE Controller	Automatic Message Display.

Interaction Matrix: General Features - continued.

Feature	Paragraph	Requires	Notes
51. LQA	**60.6, 80.2	ALE Controller	Link Quality Analysis.
52. Star Group Calls	**70.6.3	ALE Controller	
53. Star Net Calls	**70.6.2	ALE Controller	
54. Individual Calls	**70.4	ALE Controller	
55. Allcalls	**60.5.4.3	Individual Calls [54]	
56. Anycalls	**60.5.4.4	Individual Calls [54]	
57. Wildcard Addressing	**60.5.4.5	Individual Calls [54]	
58. Sounding	**70.5	ALE Controller	

** Note: these paragraphs refer to MIL-STD-188-141A, appendix A.

6.2 Tailoring. This document cannot be tailored further than the proper selection made from the intended use paragraph above.

6.3 Subject term (key word) listing.

Adaptive HF radio
ALE
ALQA
Application level
Articulation Index
Automatic link establishment
Channel quality measure
Connectivity exchanges
Epoch
Error-free interval
HF interface
Forward error correction
HFNC
HFNP
Histogram
Link performance measure
Linking protection
Link quality functions
LQA
Multi-media

Networking controller
Networking functions
Polling protocols
Protection interval
SINAD
SNMP
Spectral distortion
Time protocols

APPENDIX A

USAISEC TECHNICAL REPORT

"HF DATA LINK PROTOCOL"

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TECHNICAL REPORT

HF DATA LINK PROTOCOL

JULY 1994

STAMIS DIRECTORATE

DEPARTMENT OF THE ARMY
U.S. ARMY INFORMATION SYSTEMS ENGINEERING COMMAND
FORT HUACHUCA, ARIZONA 85613-5300

HF DATA LINK PROTOCOL

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High Frequency (Radio) Industry Association (HFIA)

and

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TR No. ASQB 94142

TECHNICAL REPORT

HF DATA LINK PROTOCOL

JULY 1994

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FIGURES

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HF DATA LINK PROTOCOL

1. INTRODUCTION

This report describes the characteristics, interoperability requirements, and performance requirements of the high frequency (HF) data link protocol (HFDLP). The HFDLP supports a data link layer protocol as defined by the International Organization for Standardization (ISO) network reference model. This protocol, when used in conjunction with an appropriate modem, provides a method for transmitting error-free data over an HF radio circuit.

2. DEFINITIONS

2.1 Terms. When used in this report, the following terms have the meanings indicated.

Byte	A field or number composed of eight bits; synonymous with the term *octet* used in other standards.
Control frame	A frame carrying control information between HFDLP terminals.
Data frame	A frame carrying user data.
Data series	A sequence of data frames sent contiguously in a single transmission. The data frames in a data series may carry discontiguous portions of a message.
Frame	An indivisible unit conveyed over a data link, which carries either control information or user data in a standardized format.
Herald	A control frame that announces the intention of sending subsequent data frames.
Receive terminal	The terminal which receives data frames and sends herald and data acknowledgments. When the link is reversed, this becomes the transmit terminal.
Transmit terminal	The terminal sending heralds and data frames. When the link is reversed, this becomes the receive terminal.

2.2 Acronyms and abbreviations. The following acronyms and abbreviations are used in this report.

ACK	acknowledgment
ALE	automatic link establishment
ARQ	automatic repeat request
ASCII	American Standard Code for Information Interchange
bps	bits per second
CRC	cyclic redundancy check
DLP	data link protocol
HF	high frequency
HFDLP	HF data link protocol
ID	identification
IEC	interexchange carrier
I/O	input/output
ISO	International Organization for Standardization
NAK	negative acknowledgment
OSI	open systems interconnection
P/O	part of
RF	radio frequency
s	second
sync	synchronization

3. OVERVIEW

3.1 Modes. The data link protocol (DLP) defined in this report provides three modes of operation. These modes provide a variety of data transfer methods intended to meet the requirements of most data transfer applications over the HF channel. The modes within this DLP are designed to provide a wide range of performance with varying degrees of implementation complexity. The primary mode of operation is the automatic repeat request (ARQ) mode, which provides for error-free point-to-point data transfer. The two secondary modes of operation are the Broadcast mode and the ARQ circuit mode. The Broadcast mode allows unidirectional data transfer to multiple (as well as to single) receivers. The ARQ circuit mode allows a link to be established and maintained in the absence of traffic.

3.2 Implementation. The protocol modes defined in this report are nonmandatory. However, all terminals (message processors) that provide the HFDLP shall, as a minimum, fully implement the ARQ mode and the Broadcast mode. The ARQ circuit mode is optional in all terminals.

3.3 Functionality.

3.3.1 Open systems interconnection (OSI) compatibility. The HFDLP provides the functionality required to support a data link service as defined in ISO/Interexchange Carrier (IEC) 8886.3. The HFDLP defined in this report does not provide this service directly.

3.3.2 Physical circuit. Implementations of the HFDLP shall operate over both simplex and duplex physical circuits. The HFDLP was developed for the serial-tone modem specified in MIL-STD-188-110A and proposed FED-STD-1052, but is usable over other physical circuits as well.

3.3.3 Priority. Implementations of the HFDLP shall transfer higher priority messages before lower priority messages.

3.3.4 Preemption. The HFDLP provides mechanisms for preemption (in either the forward or reverse direction) of a lower priority message to transfer a higher-priority message (mandatory), and the resumption of the transfer of the lower-priority message after the complete transfer of the higher-priority message (optional). The protocol provides a means for the receiving terminal to specify the resumption point within the preempted message, or to request complete retransmission if the preemption resulted in the disposal of the preempted message.

3.3.5 Flow control. The HFDLP provides a method for the receive terminal to control the rate at which the sending terminal sends the messages. Implementations of the HFDLP shall respond to flow control requests as specified in 4.1.2.3.2.2. Generation of flow control requests is optional.

3.3.6 Channel optimization. The HFDLP provides a means for optimizing the performance of the protocol under varying channel conditions, through manipulation of transmission parameters such as data rate, frame size, number of data frames in each transmission (series), and the size of the modem interleaver.

3.3.7 Order of transmission. Data and control fields shall be transmitted least-significant bit first in all cases. Control fields that contain multi-byte data, such as addresses, shall be transmitted least-significant byte first. User data bytes shall be sent in the order received from the user (or higher-layer protocol).

4. DETAILED REQUIREMENTS

4.1 Protocol frames. The HFDLP shall be implemented through an exchange of protocol frames, from one message processor to another message processor, over a physical channel. The protocol frames shall include a method for detecting uncorrected bit errors induced by the physical channel.

4.1.1 General frame format. The HFDLP frame format shall be as shown in Figure 1.

Sync Mismatch Bit	Frame Type Bit	Frame Headers and Data	CRC

Figure 1. Basic protocol frame format

4.1.1.1 Frame synchronization (sync) pattern. Each new transmission over the physical channel shall begin with a three-byte (24-bit) frame synchronization pattern to identify the following traffic as HFDLP processed traffic. The frame sync sequence in hexadecimal format shall be "5C5C5C." The sync pattern shall be transmitted such that the first eight bits in order of transmission are "00111010."

If a transmission contains more than one frame, a two-byte sync sequence shall be inserted between each pair of adjacent frames. This pattern shall be "5C5C."

4.1.1.2 Sync mismatch bit. The first bit following the last synchronization byte shall be set to a logic 1 to signify the end of the synchronization pattern and the start of the protocol frame.

4.1.1.3 Frame type bit. The second bit of each frame shall be the frame type indicator bit. This bit shall be set to logic 0 to indicate that the current frame is a data frame or set to logic 1 to indicate that the current frame is a control frame.

4.1.1.4 Frame headers and data. The Frame Headers and Data field shall immediately follow the Frame Type bit and shall contain either control frame headers or data frame headers and data. The length of the Frame Headers and Data field for control frames is either fixed at 486 bits or variable depending upon the number of header fields contained within the control frame (see Control Mode, 4.1.2.1.2). The length of the Frame Headers and Data field for data frames (number of data bytes per data frame) shall be as specified in the herald announcing the data series.

4.1.1.5 Cyclic redundancy check (CRC) error control checksum. A 32-bit cyclic redundancy check (CRC) following the Frame Headers and Data field shall conclude each protocol frame. After initially setting all 32 bits to one, the CRC shall be calculated using all bits of the frame starting with the sync mismatch bit and ending with the last bit of the Frame Headers and Data field. The generator polynomial for CRC calculation shall be:

$$x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^{8}+x^{7}+x^{5}+x^{4}+x^{2}+x+1.$$

NOTE: The calculation and transmission of the CRC shall be in accordance with FED-STD-1003A, August 1981, paragraph 5.1.

4.1.2 Control frame format. Figure 2 defines the format of the HFDLP control frames. The fields of the control frame are described in the following paragraphs. Some fields are not always present (see 4.1.2.6).

Header Name	*Field Name*	*Bits*	*Possible Values*
Frame header	Sync mismatch bit	1	1 (Always 1)
	Frame type	1	0=Data frame 1=Control frame
Control frame header	Protocol version	2	Set to 0 for this version of HFDLP
	Control mode	2	0=ARQ mode with variable-length control frames 1=Broadcast mode (fixed-length control frames, no ARQ) 2=ARQ circuit mode (variable-length control frames) 3=ARQ mode with fixed-length control frames
	Negotiation mode	1	0=Negotiate changes only 1=Negotiate before every data series
	Extended addressing flag	1	0=2 byte addressing 1=18 byte addressing
	Source address	16	0000 through FFFF hex (see 4.1.2.1.5)
	Destination address	16	0000 through FFFF hex (see 4.1.2.1.6)
Link management	Link state	2	0=Calling 1=Call acknowledge 2=Linked up 3=Dropping link
	Link timeout	4	Maximum retry time (see 4.1.2.2.2)

Figure 2. Control frame format

Header Name	*Field Name*	*Bits*	*Possible Values*
Data transfer	ACK/NAK type	2	0=Null-ACK 1=Data-ACK 2=Data-ACK-request 3=Herald-ACK
	ACK+flow control/extended address	256	(See 4.1.2.3.2)
	ACK sequence number	1	Changes state for each new data-ACK frame
HERALD	Data rate format	1	0=Absolute data rate 1=Relative rate
	Data rate	3	Code / Absolute format / Relative format 0 / 75 bps / ÷8 1 / 150 bps / ÷4 2 / 300 bps / ÷2 3 / 600 bps / No change 4 / 1200 bps / x2 5 / 2400 bps / x4 6 / 4800 bps / x8 7 / No recommendation
	Interleaver length	1	0=Short interleaver 1=Long interleaver
	Data bytes per data frame	10	56 through 1023 decimal (see text)
	Frames in next data series	8	0 through 255 decimal (see text)
Message management	Transmit message ID	8	0 through 255
	Transmit connection ID	8	0 through 255
	Transmit message size	24	Message size in bits
	Transmit message next byte location	21	Position of next byte in message
	(Reserved)	3	Reserved for future use (set to 0)
	Transmit message priority	8	0 through 255; 0 is lowest priority message
	Receive message next byte location	21	Position of next byte required by receive terminal
	(Reserved)	3	Reserved for future use (set to 0)

Figure 2. Control frame format - continued

Header Name	*Field Name*	*Bits*	*Possible Values*
Extended function	User ID	14	Free format user ID
	Function bits	50	Not defined
(Part of frame header)	CRC	32	

Figure 2. Control frame format - continued

4.1.2.1 Control frame header. The fields described below follow the Sync Mismatch Bit and Frame Type Bit in control frames.

4.1.2.1.1 Protocol version. The two bits following the frame type bit shall contain a code representing the version of the HFDLP implemented on the terminal sending the frame. Implementations of the HFDLP specified in this report shall set this field to "00."

4.1.2.1.2 Control mode. The control mode field shall be used to specify the mode under which the data link will operate after establishment. Four control modes are supported: (a) ARQ mode with variable-length control frames; (b) Broadcast mode; (c) ARQ circuit mode; and (d) ARQ mode with fixed-length control frames.

a. A value of 0 in the control mode field shall indicate the ARQ mode with variable-length control frames. In this mode, the control frames may be of variable lengths up to 520 bits as described in 4.1.2.6.1.

b. A value of 1 in the control mode field shall indicate the Broadcast mode (see 4.2.3.2). In this mode, the receive terminal(s) shall send no acknowledgment of the control or data frames transmitted. The transmit terminal shall send only 520-bit fixed-length control frames.

c. A value of 2 in the control mode field shall indicate the terminal is operating in the ARQ circuit mode with variable-length control frames (see 4.2.3.3).

d. A value of 3 in the control mode field shall indicate the ARQ mode with fixed-length control frames. If, during negotiation, either terminal requests fixed-length control frames, both terminals shall transmit only 520-bit control frames.

4.1.2.1.3 Negotiation mode. By default, terminals are required to send a herald to re-negotiate the parameters for data transfer only when those parameters will change for the following data series (see 4.2.3.1.1). However, if a terminal receives a control frame with the negotiation mode flag set to logic 1, it shall send a herald before every data series subsequently sent on that link until it receives a control frame with the negotiation mode flag set to logic 0.

4.1.2.1.4 Extended addressing flag. The extended addressing flag shall be used to define the format of the sending and receiving terminal addresses within the control frame. This flag shall be set to 0 when an ACK bit map is required (i.e., when the ACK/NAK type is data-ACK).

When set to logic 0, the Extended Addressing Flag shall indicate that the addresses are restricted to two bytes and are contained in the Source Address and Destination Address fields of the frame header. In this case the 256 bits of the ACK+Flow Control/Extended Address field are available for data frame acknowledgments and flow control (see 4.1.2.3.2).

When set to logic 1, the Extended Addressing Flag shall indicate that extended source and destination addressing is being used. In this condition, the source and destination addresses can each be up to eighteen bytes long. The Source Address and Destination Address fields shall contain the two least-significant bytes of the extended address. Up to sixteen more-significant bytes of the addresses shall be contained in the ACK+Flow Control/Extended Address field of the data transfer header. The source address shall be placed in the first (least significant) 128 bits of the ACK+Flow Control/Extended Address field. The destination address shall be placed in the last (most significant) 128 bits of the ACK+Flow Control/Extended Address field. When addresses are shorter than eighteen characters, the most significant characters shall contain the NULL American Standard Code for Information Interchange (ASCII) character. See Figure 3 for an extended addressing example.

Header Name	*Field Name*	*Bits*	*Value*
Frame header	Sync mismatch bit	1	
	Frame type	1	
Control frame header	Protocol version	2	
	Control mode	2	
	Negotiation mode	1	
	Extended addressing flag	1	1
	Source address	16	D C
	Destination address	16	Z Y
Link management	Link state	2	
	Link timeout	4	

Figure 3. Extended addressing example: from ABCD to WXYZ

Header Name		Field Name	Bits	Value
Data transfer		ACK/NAK type	2	
		(ACK+Flow Ctrl/Extended address) Source extended address characters	128	B A . .
		Destination extended address characters	128	X W . .
		ACK sequence number	1	0
	HERALD	Data rate format	1	
		Data rate	3	
		Interleaver length	1	
		Data bytes per data frame	10	
		Frames in next data series	8	
Message management		Transmit message ID	8	
		Transmit connection ID	8	
		Transmit message size	24	
		Transmit message next byte location	21	
		(Reserved)	3	
		Transmit message priority	8	
		Receive message next byte location	21	
		(Reserved)	3	
Extended function		User ID	14	
		Function bits	50	
(P/O frame header)		CRC	32	

Figure 3. Extended addressing example: from ABCD to WXYZ - continued

4.1.2.1.5 Source address. When the Extended Addressing flag is 0, the Source Address field shall contain a two-byte address of the terminal sending the frame. When the Extended Addressing flag is 1, the Source Address field shall contain the two least-significant bytes of the extended address of the sending terminal. (Sixteen more-significant bytes of the sending terminal's extended address are contained in the ACK+Flow Control/Extended Address field in this case.)

4.1.2.1.6 Destination address. When the Extended Addressing flag is 0, the Destination Address field shall contain a two-byte address of the terminal to receive the frame (destination). When the Extended Addressing flag is 1, the Destination Address field shall contain the two least-significant bytes of the extended address of the destination terminal. (Sixteen more-significant bytes of the destination terminal's extended address are contained in the ACK+Flow Control/Extended Address field in this case.) A destination address of all 1's shall be interpreted as a broadcast address.

4.1.2.2 Link management header. These fields are used by the link establishment protocol (see 4.2.2).

4.1.2.2.1 Link state. The Link State field shall contain the current linking status of the terminal. Terminals exchange their respective link states as part of the link management protocol. The following states are defined:

a. A value of 0 in the Link State field shall indicate that the terminal does not currently have a link established and is attempting to initiate a link with another terminal.

b. A value of 1 shall indicate that the terminal does not currently have a link established and is acknowledging a call from another terminal signifying that it is willing to establish a link with the calling terminal.

c. A value of 2 shall indicate that the terminal has successfully concluded the link establishment protocol and is linked to another terminal.

d. A value of 3 shall indicate that the terminal is dropping an established link.

4.1.2.2.2 Link timeout field. The four bits following the Link State field shall contain the Link Timeout field, which indicates the time that the terminal sending the control frame will wait for a valid response to the frame before dropping the link. This field shall be computed before the initial transmission of each control frame taking into consideration the number of retries the terminal is willing to perform and any data rate reductions that will be used for retries (see 4.2.4.3). This computed time shall be rounded up to the next multiple of 30 s, and encoded as the number of 30-second intervals minus one. Thus a timeout of 25 second (s) is encoded as 0, and 78 s is encoded as 3. All transmissions of a control frame (including retries) shall carry the same Link Timeout value.

4.1.2.3 Data transfer header fields.

4.1.2.3.1 ACK/NAK type. This field shall indicate the type of acknowledgment being sent.

a. Null acknowledgment. A value of 0 (null-ACK) in this field indicates a "null" acknowledgment. This value shall be sent whenever an acknowledgment is not intended or required by context. This value shall be sent in response to a herald when the receive terminal is not willing to accept the offered data series.

b. Data acknowledgment. A value of 1 (data-ACK) indicates that the control frame contains an acknowledgment of a data transfer series. In this case the ACK-bit-map (4.1.2.3.2.1) is present and contains the ARQ bits.

c. Data-ACK request. A value of 2 (data-ACK-request) indicates that the transmit terminal is requesting the retransmission of an expected data-ACK control frame.

d. Herald acknowledgment. A value of 3 (herald-ACK) indicates acknowledgment of a herald from the other terminal.

4.1.2.3.2 ACK+flow control field. The ACK+Flow Control field shall be used to specify which frames of the prior data transfer series were received error free and which frames require retransmission. A position-based relationship is employed in the definition of this field. The least-significant bit of this field (first bit sent) is bit number 255, the next bit sent is number 254, and so on; the most-significant bit is bit number 0.

NOTE: The ACK+Flow Control field is also used for addressing when the extended addressing bit is set to logic 1; see 4.1.2.1.4.

4.1.2.3.2.1 ACK bit map. When the ACK/NAK Type field is set to 1 (data-ACK), bits 1 through 255 of the ACK+Flow Control field compose an ACK bit map, with each bit corresponding to the data frame having the same data frame sequence number (see 4.1.3.2) as that bit (e.g., bit 1 corresponds to data frame 1 and so on).

a. A logic 0 in the ACK bit map indicates that the associated data frame was missed or received with errors and should be retransmitted.

b. A logic 1 indicates that the frame was received error free and does not require retransmission.

All bits numbered higher than the number of data frames in the previous data transfer series shall be set to logic 0.

4.1.2.3.2.2 Flow control flag. When the extended addressing bit is set to logic 0, bit number 0 of the ACK+Flow Control field shall be used as a Flow Control flag. When the Flow Control flag is set to logic 1, the transmit terminal shall send only unacknowledged data frames (no new data frames) until flow control is lifted in accordance with 4.2.3.1.4.

4.1.2.3.3 ACK sequence number. The ACK sequence number bit is used to distinguish between successive different ACK bit maps (see 4.1.2.3.2.1). The first ACK bit map of each message corresponds to ACK sequence number 0, with successive ACK bit maps required by the ARQ protocols using sequence numbers alternating between 0 and 1. If an ACK bit map is retransmitted, the ACK sequence number shall not change. This bit shall be set accordingly in data-ACK control frames, and shall be set to 0 in other control frames.

4.1.2.3.4 Herald. The herald fields are used to negotiate parameters of subsequent data series.

4.1.2.3.4.1 Data-rate format. This bit specifies the format of the data-rate field that follows. A logic 0 in this field indicates that the data-rate field specifies absolute data rate. A logic 1 indicates that the data-rate field specifies relative data rate. The transmit terminal shall use the absolute data rate format for at least its first transmission on a link.

4.1.2.3.4.2 Data rate. This field shall be used in herald and data-ACK-request frames to specify the data rate of the following data series, and in herald-ACK or data-ACK frames (with null heralds) to recommend a data rate for the next data series. The encoding of this field is specified in Figure 4.

Code	*Absolute format*	*Relative format*
0	75 bps	÷8
1	150 bps	÷4
2	300 bps	÷2
3	600 bps	No change
4	1200 bps	x2
5	2400 bps	x4
6	4800 bps	x8
7	No recommendation	No recommendation

Figure 4. Code definitions for data-rate formats

4.1.2.3.4.3 Interleaver length. This bit is used by the transmit terminal to distinguish between the short interleaver and the long interleaver mode of the HF serial (single-tone) waveform. The announcement convention shall be the same as defined above for data rate. For the purpose of this protocol, the short interleaver setting specifies the 0.6 second interleaver. When this protocol is used with any other waveform, the interleaver length field has no defined meaning, and shall be set to 0. The interpretation of this field shall be consistent with that described in 4.1.2.3.4.2.

4.1.2.3.4.4 Data bytes per data frame. The data bytes per data frame field shall contain a binary number in the range of 56 to 1023 (decimal), inclusive, specifying the size, in bytes, of the data frames announced by this control frame. The number of bytes in each data frame shall not be changed if any of the frames in the following series are retransmissions of earlier frames.

4.1.2.3.4.5 Frames in next data series. This field shall be used by the transmit terminal to specify the number of data frames contained in the next data series following this herald. If this field is set to 0, the entire herald is a null herald and does not announce a data series.

4.1.2.4 Message management header fields. The message management header fields contain data that identify and specify the user message being transferred. (See definitions of "transmit terminal" and "receive terminal" in 2.1).

4.1.2.4.1 Transmit message identification. The transmit message identification field shall contain an eight-bit message number that uniquely identifies each message sent over the data link. This message number shall be incremented for each new message transmitted. When the transfer of a message is interrupted by a preemption or link outage, the same message number shall be used upon resumption of the message transfer as was used prior to the interruption in order to allow the receive terminal to associate the resumed message with the previously received portions of the message. The message number shall range from 0 to 255 (decimal).

4.1.2.4.2 Transmit message connection. The transmit message connection field shall be used by terminals that support multiple data link connections to identify the data link connection to which the transmit message is associated. Up to 255 connections are available.

4.1.2.4.3 Transmit message size. This field shall specify the total length of the current message in bits. The range of this field is 0 to 16,777,215, with the extreme values given special meanings:

a. The remainder of the message management transmit header fields shall be ignored if the transmit message size field contains a zero value.

b. If the transmit message size field contains the value 16,777,215 (all 1s), the size of the message is unbounded. Use of this code places the HFDLP into "bit pipe" mode; subsequent use of any other message size terminates this mode.

4.1.2.4.4 Transmit message next byte location. The transmit message next byte location field shall be used by the transmit terminal to specify the starting byte location within the complete message of the data series being announced. This field shall be set to zero at the beginning of each new message transmission. Upon resumption of an interrupted or preempted message, the transmit terminal shall use this field to indicate the restart position within the interrupted message; the byte position shall be the first byte of the earliest frame not acknowledged. This field may wrap around through 0 in bit pipe mode.

4.1.2.4.5 Transmit message priority. This field shall be used to specify the priority of the transmit data message. Priorities range from 0 through 255 (decimal). A lower numeric value in the priority field shall specify a lower priority message. Terminals shall use this information to negotiate the transfer of higher priority traffic in advance of lower priority traffic.

4.1.2.4.6 Receive message next byte location. The Receive Message Next Byte Location value shall be used by the receive terminal to specify to the transmit terminal the required starting byte position in the message being offered. This byte position shall be the first byte of the earliest frame not received. For new messages, this field shall be set to zero. The receiver shall set this value to a number greater than or equal to that specified in the Transmit Message Size field (divided by eight to convert to bytes) if it is unwilling to accept the message being offered.

Upon resumption of an interrupted or preempted message, this value shall be used to specify the restart position of the interrupted message. The receive terminal shall set this field to the value specified in the Transmit Message Size field divided by eight if it has already received the entire message being offered.

4.1.2.5 Extended function fields. The Extended Function fields within the control frame are used to allow additional functions to be added to the message processing terminals at a future date. The Extended Function fields also support an orderwire data link between two linked terminals. All extended functions including the orderwire mode are optional.

4.1.2.5.1 User identification (ID). The User ID field shall contain a manufacturer identification code or 0 (see 4.2.4.2). It is recommended that manufacturers register their code with the custodian of the standard resulting from this report for the purpose of interoperability. A User ID greater than 0 shall indicate an operating version that is specialized to the designated user and is not necessarily interoperable with other users.

4.1.2.5.2 Function bits. If the user ID field is set to 0, the function bits may contain orderwire data, which should be routed by the receive terminal to its local input/output (I/O) channel. This allows a low data rate communications channel between the two terminals to run in parallel with other control frame traffic. Orderwire data shall consist of seven-bit ASCII characters packed into the function bit field. Unused bits shall be set to 0 (producing ASCII NULL characters). Other uses are reserved.

4.1.2.6 Control frame lengths.

4.1.2.6.1 Variable-length control frames. When operating in ARQ mode with variable-length control frames or in ARQ circuit mode, control frames shall be one of four different lengths depending on the content of the control frame. The allowable frame lengths and the control fields available in each frame size are listed in Figure 5. Shaded areas in the figure indicate control fields that are present in the control frame for the frame type listed.

a. Type 1 control frames are the shortest control frames allowable. These frames contain Frame and Link Management headers defining the link state of the transmit terminal, the link operating mode, and the ACK type indicator. Type 1 control frames can be used to send null-ACKs, data-ACK-requests, and herald-ACKs.

b. Type 2 control frames contain all fields of the type 1 frame plus the Data ACK+Flow Control/Extended address field and the Herald fields. In addition to the uses of the type 1 frames, these type 2 frames can be used for data-ACKs and heralds.

c. Type 3 control frames add the Message Management header fields to the type 2 control frames, and can be used to implement all capabilities of the protocol, with the exception of the extended functions (e.g., User ID and orderwire data transfer).

d. Type 4 control frames are 520 bits long and contain all control fields.

4.1.2.6.2 Fixed-length control-frames. All control frames transferred over the HF data link in ARQ mode with fixed-length control frames or in Broadcast mode shall be 520 bits long (i.e., Type 4) and shall contain all of the control fields described in 4.1.2.

4.1.3 Data frame format. Data frames transferred over the HF data link shall be formatted in accordance with Figure 6. Data frame length shall be variable, as specified in the herald control frame that announces one or more data series.

Header Name	*Field Name*	*Bits*	*Type 1*	*Type 2*	*Type 3*	*Type 4*
Frame header	Sync mismatch bit	1				
	Frame type	1				
Control frame header	Protocol version	2				
	Control mode	2				
	Negotiation mode	1				
	Extended addressing flag	1				
	Receiver address	16				
	Transmitter address	16				
Link management	Link state	2				
	Link timeout	4				
Data transfer	ACK/NAK type	2				
	ACK+Flow Control/Extended address	256				
	ACK sequence number	1				
Herald	Data rate format	1				
	Data rate	3				
	Interleaver length	1				
	Data bytes per data frame	10				
	Frames in next data series	8				
Message management	Transmit message ID	8				
	Transmit connection ID	8				
	Transmit message size	24				
	Transmit message next byte location	21				
	(Reserved)	3				
	Transmit message priority	8				
	Receive message next byte location	21				
	(Reserved)	3				
Extended function	User ID	14				
	Function Bits	50				
(P/O frame header)	CRC	32				
Total frame size			48	328	456	520

NOTE: Shaded areas indicate fields included in control frame.

Figure 5. Control frame sizes

Header Field Name	*Field Name*	*Bits*	*Possible Values*
Frame header	Sync mismatch bit	1	1 (Always 1)
	Frame type	1	0=Data frame
Reverse channel control frame recommendation	Data rate format	1	0=Absolute data rate 1=Relative rate
	Data rate	3	Code / Absolute format / Relative format 0 / 75 bps / ÷8 1 / 150 bps / ÷4 2 / 300 bps / ÷2 3 / 600 bps / No change 4 / 1200 bps / x2 5 / 2400 bps / x4 6 / 4800 bps / x8 7 / No recommendation
	Interleaver length	1	0=Short interleaver 1=Long interleaver
	(Reserved)	1	Reserved for future use (set to 0)
Data frame header	Data frame sequence number	8	0 through 255; identifies data frame within series
	Message byte offset	21	Position of frame in message (byte 0 is first byte)
	(Reserved)	3	Reserved for future use (set to 0)
Data		Variable	User data
P/O frame header	CRC	32	(See 4.1.1.5)

Figure 6. Data frame format

4.1.3.1 Reverse channel control frame recommendation. These fields shall be used by the transmit terminal to recommend the data rate and interleaver for data-ACK control frames.

4.1.3.2 Data frame sequence number. The transmit terminal shall sequentially number each data frame within a data transfer series, starting at the value specified in the Frames In Next Data Series field of the most recent herald and decrementing to one in the last frame of the series. The transmit terminal shall place this number in the Data Frame Sequence Number field of the data frame. The receive terminal shall use this number to construct the position-based ACK-bit-map (4.1.2.3.2.1) for the data acknowledgment reply.

4.1.3.3 Message byte offset. This field shall be set by the transmit terminal to the relative start position within the complete message of the data contained in this data frame. The receive terminal shall use this information to assist in the reassembly of the message. Data frames within a series shall be arranged in order of increasing message byte offset.

4.1.3.4 Data. The Data field shall contain the message data. The length of the data field shall be as specified in the Data Bytes Per Data Frame field contained in the data transfer header of the most recent herald.

4.2 Protocol suite. The HFDLP comprises a suite of protocols that operate in concert to provide the reliable data link service functions required by ISO/IEC 8886.3. The protocol suite consists of message management, link establishment, and data transfer protocols. The three protocols are loosely coupled, and proceed concurrently through an orderly exchange of control frames as defined in the following paragraphs.

4.2.1 Message management protocol. HFDLP terminals shall use the message management protocol to coordinate the transfer of data messages, priority preemption of message transfer, and the resumption of preempted messages. The message management protocol shall be implemented through an exchange of control frames containing the message management header fields (see 4.1.2.4). The message management header fields contain a complete definition of the message to be transferred or resumed. Terminals shall be able to selectively accept or reject messages over the data link based upon the message source, priority, length, or connection number.

4.2.1.1 Message announcement. A terminal shall announce a message to be transferred over the HF data link by transmitting a control frame with a message management header that defines the parameters of the offered message. The transmit terminal shall specify the message identification number, message priority, total message size, and the relative starting point within the message. Terminals shall specify a starting point of zero for all new messages. Transmit terminals may specify an arbitrary start position for messages restarted after a link interruption (due to preemption or link failure); however, the receive terminal start position shall override the position specified by the transmit terminal. Terminals that support multiple data connections shall specify the connection number of the offered message in the announcing message management header; others shall always set the Transmit Connection ID field to 0. (Message announcement control frames shall also contain a herald describing the first data series to be transferred in accordance with 4.2.3.1.1.)

4.2.1.2 Message acceptance. A terminal operating in one of the ARQ modes shall signify its acceptance of an announced message (except in immediate mode message transfer, (see 4.2.2.4) by sending a control frame containing a herald-ACK in response to the herald frame. If other than a Type 1 control frame is sent (e.g., in ARQ mode with fixed-length control frames), the Message Management header fields should duplicate the corresponding fields in the announcing frame. See 4.2.1.4 for the case of a receive terminal with higher-priority traffic, and 4.2.1.6 for negotiation of starting byte offset in a resumed message. The receive terminal may request a change in the parameters announced in the herald (see 4.2.3.1.1.2).

4.2.1.3 Message refusal. A terminal operating in one of the ARQ modes (except in immediate mode message transfer, 4.2.2.4) shall refuse the announced message by returning a control frame with the message management field Receive Message Next Byte Location set to a value greater than or equal to the announced Transmit Message Size divided by eight. A refused message may be discarded by the transmit terminal.

4.2.1.4 Priority resolution. Terminals shall resolve data link contention by exchanging message management headers announcing the highest priority traffic available for transfer. The terminal with the highest priority traffic shall be allowed to use the data link first. Thus, a terminal receiving announcement of a lower-priority message shall preempt that incoming message in accordance with 4.2.1.5.2, except that the Message Management header shall be sent with a null-ACK to refuse the first data series (rather than the data-ACK needed when preempting a message in progress).

If both terminals have traffic of equal priority, the terminals may optionally share the data link on an equal basis. In such sharing, the two terminals alternate the transmission of data series. Each data-ACK includes a herald. The terminal receiving the data-ACK/herald responds with a herald-ACK. The terminal receiving this herald-ACK responds by transmitting its data series. The terminal receiving the data series responds with a data-ACK/herald, and the link direction reverses again.

4.2.1.5 Message preemption. The message management protocol allows terminals to preempt lower priority traffic with a new message of higher priority. Preemption shall be supported in both the forward direction (higher priority traffic in the same direction as the preempted traffic) and the reverse direction (higher priority traffic in the direction opposite to the preempted traffic).

4.2.1.5.1 Forward preemption. A transmit terminal shall preempt the ongoing transfer of a message with a higher priority message by sending a new Message Management header announcing the new message. The Message Management header announcing the new message should be sent at the first logical opportunity for a control frame transfer. The receive terminal can refuse the offered message as described above. Upon acceptance of the preempting message, the transmit terminal shall suspend transfer of the preempted message until the higher priority traffic is transferred. Terminals shall only preempt ongoing message transfers in the forward direction with messages of higher priority than the preempted message. Nested preemption is allowed provided the preemption meets this relative priority requirement. If a terminal resumes preempted messages, it shall resume them in the reverse order of preemption, i.e., the most recently preempted message shall be resumed first. This ensures that the relative priority requirement is maintained throughout the preemption and resumption process.

4.2.1.5.2 Reverse preemption. A receive terminal shall preempt the transfer of an incoming message by sending a Message Management header announcing a higher priority message at the first available opportunity. The transmit terminal can refuse the offered message as described above. Upon acceptance, the terminals shall reverse the link direction and transfer the higher priority message until completion; transfer of the preempted message may then be resumed.

4.2.1.6 Message resumption. A terminal may resume the transfer of a preempted message after the completion of the higher priority traffic (or of an interrupted message after link recovery) by sending a Message Management header announcing the resumption of the message. The Message Management header shall contain the same message identification data as the original announcement of the message with the exception of the Transmit Message Next Byte Location field. The transmit terminal shall specify the starting location within the message upon resumption to be the first byte of the message not acknowledged by the receive terminal prior to the preemption (or link failure). The receive terminal may override this starting position by sending a Message Management header specifying the desired start position in the Receive Message Next Byte Location (may be 0 to force restart instead of resumption). All bytes of the message following the negotiated starting position shall be sent. (The transmit terminal should not assume that the receive terminal has retained any frames beyond the negotiated starting position.)

4.2.1.7 Null message management headers. When none of the above conditions apply, no Message Management header need be sent. If a full-length control frame is sent in this case, the Message Management header fields shall be set to all 0's by the transmit terminal; the receive terminal ignores Message Management headers having Transmit Message Size set to 0.

4.2.2 Link establishment protocol. HFDLP terminals employ the optional link establishment protocol to coordinate terminal state and resolve access contention prior to initiating the transfer of data over the link. The link establishment protocol is implemented through an orderly exchange of control frames containing the Link Management header fields. During the link establishment phase, the two terminals attempting to link will exchange terminal addresses and link state information in accordance with the protocol rules. This is to ensure that both terminals are fully aware of the link state of the other terminal and therefore do not attempt to transfer data before the other terminal is ready to accept the data. The link establishment phase is optional and can be bypassed. When the link establishment phase is bypassed, the terminal shall set the Link State field in all control frames to the "link-up" state. "Immediate" message transfer refers to this bypass mode of operation (see 4.2.2.4).

4.2.2.1 Link establishment states. The link establishment protocol requires the two terminals attempting to link to sequence through a set of link states, as defined below, to ensure that both terminals reach the link-up state before either attempts to transfer data traffic.

4.2.2.1.1 Idle. The idle state of the link establishment protocol is the resting state of the protocol. The terminal shall reside in this state whenever it has no traffic to send and is not being called by another terminal. Terminals shall also return to the idle state upon link failure.

4.2.2.1.2 Calling. A terminal shall enter the calling state when it is requested to establish a link with another terminal by one of the data link users associated with the terminal. When in the calling state, the terminal shall send 520-bit control frames containing the following:

a. A Frame header indicating the Control Mode of the link it wishes to establish and the addresses of itself and the distant terminal (short or extended).

b. A Link Management header indicating its Link State (calling) and its Link Timeout.

c. A Message Management header announcing the (first) message that it wishes to transfer to the destination.

d. An Extended Function header containing the User ID of the calling terminal.

After sending the control frame, the terminal shall wait for a response from the called terminal. Upon reception of a valid control frame from the called terminal containing a Link Management header acknowledging the link request, the terminal shall advance to the link-up state. If the terminal does not receive a timely call acknowledgment frame, it shall retry the call (see 4.2.4).

4.2.2.1.3 Call acknowledge. A terminal shall enter the call acknowledge state upon reception of a valid control frame containing a Link Management header indicating that a terminal is attempting to establish a link with it. When in the call acknowledge state, the terminal shall send control frames in response to the calling terminal's control frame that indicate the local Link State and Link Timeout and the accepted link modes and characteristics. If the calling terminal accepts variable-length control frames, a Type 1 control frame may be returned to accept the announced message, data series, and User ID (overrides to Control Mode and Negotiation Mode may be included in a control frame of any size). If a longer control frame is sent, refer to the descriptions of the other protocols for contents of the Message Management and Data Transfer headers.

The extended function header, if present, shall contain a User ID set to one of the following:

a. 0, indicating the interoperable mode (which overrides any other User ID), or

b. identical to the User ID of the calling terminal to accept the corresponding specialized mode.

After sending the control frame, the terminal shall wait for a response from the calling terminal.

If the acknowledging terminal does not receive a timely valid reply to its response and it has higher priority traffic (i.e., it initiated reverse preemption), it shall retransmit the call acknowledge announcing this traffic after the response timeout in accordance with 4.2.4.

If it does not have higher priority traffic, it shall await a repetition of the call. If it has not received a repeated call within the Link Timeout specified in the call frame, it shall return to the idle state.

4.2.2.1.4 Link-up state. The link-up state is the fully operational state of the terminal. The terminal may begin the data transfer protocol when it reaches the link-up state. The terminal shall enter the link-up state upon receipt of a valid control frame indicating that the other terminal is in either the call acknowledge or link-up state, or upon receipt of a local request for "immediate" message transfer when it is in the idle state (see 4.2.2.4). When in the link-up state, the terminal shall include a Link Management header in all control frames sent indicating that its link state is "link-up." The terminal may implement any operational feature of the data transfer and message management protocols when in this state.

The terminal shall remain in the link-up state until the link is dropped (or fails) then it shall return to the idle state.

4.2.2.2 Link failure. If the link fails while in progress (detected by link timeout), the protocol will act as if the link was aborted and the terminal shall return to the idle state. (As an option, the terminal may first attempt to reestablish the link to continue the message transfer.) The terminal should be capable of signaling this sudden change in status to a higher-layer controller and to the operator. As a design objective, the successfully received portion of the uncompleted message that was in progress when the link failed should be retained at the receive terminal in the same manner as a preempted message. The length of time to hold the uncompleted message should be an operator-selectable parameter.

4.2.2.3 Link termination. The link may be dropped due to a local request, a link timeout, or the absence at both terminals of messages to be sent (when not in Circuit Mode). Terminals should send a control frame with Link State set to "dropping link" before dropping the link.

4.2.2.4 Immediate mode. An immediate mode message transfer bypasses link establishment and the initial data transfer negotiation. The first transmission shall begin with a 520-bit control frame carrying a Link State of link-up, a Message Management header announcing a message, and a herald describing the characteristics of the first data series, with the User ID field normally set to 0. This control frame shall be immediately followed by two sync bytes, followed immediately by the first data series of the announced message, with no change in data rate. Following this first data series, the data transfer protocol shall use either ARQ mode or ARQ circuit mode.

4.2.2.5 State sequence rules. Figure 7 summarizes the state actions and transition rules of the link establishment protocol.

State	*Action*	*Transition Criteria*	*Next State*
Idle	None	Receive link request from local operator or connection (normal)	Calling
		Receive link request from local operator or connection (immediate)	Link-up
		Receive valid control frame with proper address, link state=calling	Call acknowledge
		Receive valid control frame with proper address, link state=link-up	Link-up (immediate mode; send no herald ACK)
Calling	Emit link establishment header with link state="Calling"	Response timeout expired	Same state
		Neighbor link state=calling	Call acknowledge
		Neighbor link state=call acknowledge	Link-up
		Neighbor link state=link-up	Same state

Figure 7. State sequence, link-establishment protocol

State	*Action*	*Transition Criteria*	*Next State*
		Link timeout expired	Idle
Call acknowledge	Emit link establishment header with link state="Call acknowledge"	Response timeout expired	Same state
		Neighbor link state=calling	Same state
		Neighbor link state=call acknowledge	Link-up
		Neighbor link state=link-up	Link-up
		Arrival of data series heralded in call	Link-up
		Link timeout expired	Idle
Link-up	Emit link establishment header with link state="Link-up"	Neighbor link state=link-up	Link-up
		Transmit terminal timeout expired (repeat countdown>0)	Link-up (retransmit)
		Link timeout expired	Idle or calling*
		Neighbor link state=calling	Call acknowledge
		No more traffic to send	Idle
		Neighbor link state=dropping link	Idle

* Idle to abort transfer; calling to continue message after link recovery

Figure 7. State sequence, link-establishment protocol - continued

4.2.3 Data transfer protocol. HFDLP terminals shall use the following data transfer protocol to deliver data over an established data link. The data transfer protocol is implemented through the exchange of control frames and data frames over the data link. The data transfer protocol includes three different transfer modes: ARQ mode; Broadcast mode; and ARQ circuit mode. These modes are defined in the following paragraphs.

4.2.3.1 ARQ mode. The ARQ mode comprises three phases: the negotiation phase; the data transfer phase; and the data acknowledgment phase. Negotiation may be combined with data acknowledgment (e.g., to reverse the link for high-priority reverse-channel traffic).

4.2.3.1.1 Negotiation phase. HFDLP terminals shall use the negotiation phase of the data transfer protocol to resolve flow control and the transfer specifications of the data link connection prior to the transfer of data frames over the link. The negotiation phase starts with the transmission of a control frame containing a Data Transfer header (a herald) announcing a data series to be transferred and ends with the transmission of an acknowledgment of the herald control frame signifying acceptance of the announced data series.

The negotiation phase is required in the following circumstances:

a. Before the first data frames are sent over a link (except immediate mode message transfers) (see 4.2.2.4).

b. Before any change in previously negotiated values in the herald fields, except that no negotiation is necessary to change only the data rate and frames-in-next-series if the following rules are followed:

(1) If the data rate increases by 2^n, the frames-in-next-series value must increase by the same factor, keeping the ratio of frames-in-next-series to data rate constant. If this would result in a frames-in-next-series value greater than 255, frames-in-next-series shall be set to 255, but the ratio of frames-in-next-series to data rate without this limiting operation shall be stored for future reference.

(2) If the data rate decreases by 2^n, the frames-in-next-series value must decrease by the same factor (then rounded down to the nearest integer), keeping the ratio of frames-in-next-series to data rate constant, except that if the previous frames-in-next-series value was 255, the new frames-in-next-series value shall be computed from the new data rate using the previously stored ratio of frames-in-next-series to data rate (see above), constrained as before to be no greater than 255.

c. Before each data series if the most recent control frame from the terminal that will receive the data frames contained Negotiation Mode equal to 1.

d. When flow control prevents the transfer of any data frames.

4.2.3.1.1.1 Initiation. A terminal shall initiate the negotiation phase of the protocol by transmitting a control frame containing a herald that announces the data rate, interleaver setting, number of frames in the data series, and the number of data bytes per data frame. The receive terminal shall answer the herald with one of two responses:

a. a herald-ACK signifying acceptance of the offered data series, or

b. a null-ACK indicating that the receive terminal cannot accept the offered data series.

The transmit terminal shall retransmit the herald if it does not receive a valid response within the response timeout period (see 4.2.4). Note that a transmit terminal may respond to a herald-ACK by immediately transmitting a new, different herald (e.g., for forward preemption). The receive terminal must, therefore, treat each herald received as if it contained new information and not merely as an identical repetition of a previously-received herald.

4.2.3.1.1.2 Acceptance. A receive terminal shall signify its acceptance of the data series offered in a herald frame by sending a herald-ACK frame in response. The herald-ACK frame may be Type 1 if not otherwise constrained by the need to negotiate data transfer characteristics or by control mode. The receive terminal may negotiate (override) any of the herald fields, except that Data Bytes per Data Frame may not be changed if any data frames from a previous data series are to be resent in the current data series. Upon receipt of the herald-ACK frame, the transmit terminal will normally transition to the data transfer phase and begin transferring the data frames of the accepted series.

4.2.3.1.1.3 Data refusal. A HFDLP terminal shall refuse an offered data series by sending a null-ACK frame in response to a herald frame announcing a new data series. If the cause for refusal is a temporary lack of local buffer space, the receive terminal shall set the flow control flag (see 4.1.2.3.2.2) in the null-ACK. In this case, the transmit terminal should retransmit the herald frame in order to determine when the flow control restriction is lifted (see 4.2.3.1.4).

4.2.3.1.2 Data transfer phase. Upon transition to the data transfer phase, the transmit terminal shall transmit the data frames announced in the acknowledged herald. The transmit terminal shall transmit the total number of data frames announced in the herald without delay or interruption.

All data frames shall be of the same size as were announced in the herald. This implies that the last data frame of a message may need to be padded with fill bits. The receive terminal will use the transmit message size information (see 4.1.2.4.3) to determine where the message is to be truncated in order to remove the fill bits from its output data stream.

4.2.3.1.3 Data acknowledgment phase. The data acknowledgment phase shall begin after the last data frame of the data series has been transmitted. The transmit terminal shall stop transmission and wait for the data-ACK frame from the receive terminal. The data-ACK frame shall contain an ACK-bit-map indicating which data frames were received error free and which frames require retransmission. The transmit terminal shall prepare a new data series containing all prior frames requiring retransmission and enough new data frames to fill the data series. Unless negotiation is required (see 4.2.3.1.1 b - d), the terminals shall return to the data transfer phase upon completion of the data acknowledgment phase.

If the transmit terminal fails to receive a data-ACK frame from the receive terminal within the response timeout period (see 4.2.4), it shall transmit a data-ACK-request frame to inform the receive terminal that a data-ACK was not received. Receipt of an data-ACK-request by a receive terminal shall cause it to resend the last data-ACK frame sent. If the ACK sequence number received by the transmit station is incorrect, the receive terminal must have missed the entire preceding data series, which should therefore be resent by the transmit terminal.

4.2.3.1.4 Flow control. A receive terminal may impose flow control by returning a control frame (null-ACK, data-ACK, or herald-ACK) with the flow control flag (4.1.2.3.2.2) set to 1. The flow control flag is present only when the extended addressing flag is 0.

If the ACK-bit-field in a data-ACK with a flow control flag set to 1 indicates that some data frames should be retransmitted, the transmit station shall resend those data frames. In no case shall a transmit station send *new* data frames in response to a control frame containing a flow control flag set to 1.

When a transmit terminal is under flow control and has no unacknowledged data frames to resend, it shall poll the receive terminal by sending heralds describing the data remaining to be sent. The receive terminal shall maintain flow control as necessary by responding to heralds with null-ACKs (with the flow control flag set to 1 if using other than Type 1 control frames).

A receive terminal shall lift flow control by responding to a frame from the transmit terminal with a control frame containing a flow control flag set to 0. The type of control frame sent to lift flow control shall be an appropriate response to the frame from the transmit terminal (e.g., a herald-ACK for a herald, or a data-ACK for resent data frames).

4.2.3.2 Broadcast mode. The Broadcast mode shall be used for one-way transfer of data from a single transmitting terminal to one or more receiving terminals. Since multiple terminals can receive the data, acknowledgments of the data frames are not allowed. A terminal shall initiate a broadcast transmission by transmitting a 520-bit control frame containing appropriate Data Transfer and Message Management header fields. The Link State shall be set to "linked-up" and the Control Mode shall be set to "Broadcast." The terminal shall immediately follow the control frame with data frames. Receive terminal(s) shall not respond to a Broadcast mode transmission with data acknowledgment frames. This process shall be repeated until the entire message is transmitted. Herald frames between each data series are optional.

NOTE: Broadcast mode is essentially ARQ mode with fixed-length control frames and no acknowledgments from receive terminals.

4.2.3.3 ARQ circuit mode. The ARQ circuit mode shall operate identically to the variable-length control frame ARQ mode, except that terminals shall maintain the link in the absence of user data until directed to drop the link by the user. Terminals shall maintain the data link connection in the absence of data by sending herald and null-ACK control frames that announce no message. Terminals shall respond to this null herald by sending a null-ACK control frame along with a herald of their own. Terminals should use the error statistics of the null herald/null-ACK exchange to maintain a valid estimate of the supportable data rate of the data link. When available, new user data shall be announced according to the requirements of the ARQ data transfer mode. Note that the ARQ circuit mode does not include a fixed-length control frame option.

4.2.4 Timeouts. Timeouts serve two functions in the HFDLP: they ensure that terminals do not wait indefinitely for responses, and that transmissions from terminals that simultaneously attempt to link with each other have a low probability of colliding at *every* retransmission and therefore failing to link.

4.2.4.1 Turn-around times. After reception of a valid transmission, a terminal shall initiate the responding radio frequency (RF) transmission no sooner than 1 second and no longer than 10 seconds after cessation of the received RF signal.

4.2.4.2 Response timeout. After each valid reception the terminal shall establish a time at which it will take action if further valid receptions are not forthcoming. These times differ for transmit terminals and receive terminals (defined in 2.1). A further distinction must be made between *acknowledged* transmit terminals and *prospective* transmit terminals. When a receive terminal determines that it has traffic to send that is of equal or higher priority than the current transmit terminal (e.g., when such higher-priority traffic is delivered to it by the local user), it heralds this event following the next legitimate reception from the transmit terminal. Until this receive terminal receives an acknowledgment of its new status, this terminal is a prospective transmit terminal. A terminal that has received acknowledgment of its transmit terminal status is an acknowledged transmit terminal.

NOTE: Under certain conditions there may be no acknowledged transmit terminal.

During link establishment, terminals in the call acknowledge state act as either receive terminals (if not attempting reverse preemption) or as prospective transmit terminals (if preempting).

Timeout values shall be set as follows for the interoperable mode (User ID = 0):

a. After each legitimate reception, an acknowledged transmit terminal shall set a response timeout equal to the *ending* time of its responding transmission plus 25.4 s.

b. Following each retransmission (or the initial transmission of a data-ACK-request), an acknowledged transmit terminal shall set its response timeout to the *starting* time of that transmission plus 48.8 s.

c. A prospective transmit terminal shall set its response timeout to 48.8 s after the *starting* time of its transmission, whether this transmission follows a legitimate reception or was a retransmission following a missed response.

d. A receive terminal shall set its response timeout following each legitimate reception from the transmit terminal to a value equal to the *ending* time of its transmission in response to the reception plus the estimated ending time of its next reception plus the most recent Link Timeout value received from the transmit terminal during the current link. If expecting a control frame, 25.4 s shall be allowed for the next transmission; otherwise (data series expected), the time allowed for the next transmission shall be the sum of a 10 s turnaround time plus N + 1 interleaver times, where N is the number of interleavers of the announced size required to hold the announced data series.

e. After a call (or immediate transmission) a terminal shall set its timeout to be 25.4 s after the *end* of the first transmission. If no valid reception has occurred prior to this timeout, the terminal shall act in accordance with paragraph 4.2.4.4. After retransmissions the timeout shall be set to the *starting* time of the retransmission plus either 48.8 s, 63.8 s, or 78.8 s. The choice among these three values shall be randomly generated in such a manner that each has approximately equal probability of being selected, with little correlation among the choices either at a single terminal or between pairs of terminals.

Terminals may use timings different from those above only if they have negotiated a non-zero user-ID field which is associated with different timing rules. (Manufacturers are encouraged to publish generally-useful sets of timing rules for industry-wide implementation.)

4.2.4.3 Link timeout. The link timeout shall be computed as the time from the end of the first transmission of a frame until all retransmissions that would result from no response to that frame have been completed, including the response timeout after the last retransmission, and accounting for any automatic data rate or interleaver changes that would be performed by that station.

4.2.4.4 Action following timeout. The action taken by a terminal when no legitimate response is received shall be as follows:

a. If a transmit terminal (acknowledged or prospective) has received no signal by the time specified by the Response Timeout, it shall decrement its internal retry countdown and transmit a frame that requests a retransmission from the other terminal. If the missing response is a data-ACK frame, the transmit terminal shall send a frame with the ACK/NAK type set to data-ACK-request. If the missing response is a herald-ACK, it shall repeat the herald frame. If the missing response is that associated with a call (or an immediate transmission), the repeated frame shall be the call (or the herald that was transmitted at the start of the immediate transmission).

b. If a transmit terminal (acknowledged or prospective) receives a transmission with an invalid CRC (e.g., its modem synchronized to a received preamble, but the CRC in the received frame was invalid), including a transmission that begins before but concludes after the Response Timeout, it shall take the actions specified in the preceding paragraph, except that the transmission shall take place as soon as possible within the constraints imposed by paragraph 4.2.4.1.

c. Upon expiration of the Link Timeout, a transmit terminal shall drop the link and either return to the idle state, discarding any unfinished message with notification to the (local) source of that message, or request re-establishment of the physical-layer link (possibly through an automatic link establishment (ALE) controller) with the intent to resume the message if re-linking is successful.

d. A receive terminal that has not received a valid transmission prior to the expiration of its response timeout shall drop the link in accordance with 4.2.2.2. A receive terminal *may* respond immediately (within the constraints imposed by paragraph 4.2.4.1) to transmissions with invalid CRC, as defined above in paragraph b. If the receive terminal is in the process of reception when the timeout expires, it shall complete the reception but shall drop the link if no valid CRC is obtained.

e. In general, whenever a terminal receives a valid transmission (i.e., contents that are reasonable in context of the protocol and valid CRC), it shall reset its retry countdown to its original value and set the Response Timeout in accordance with 4.2.4.2.

4.2.5 Full-duplex operation. The formats and protocols for full-duplex operation shall be identical to that specified for simplex operations except that timeouts and retransmissions for one traffic direction must work around the data series transferred in the other direction. Simultaneous traffic should be supported whenever traffic of any priority exists at both terminals. Note that reverse link preemption is not needed in full-duplex operation.

4.3 Examples. Figure 8 illustrates typical data transfers over the data link. Each square in the figure represents a control or data frame.

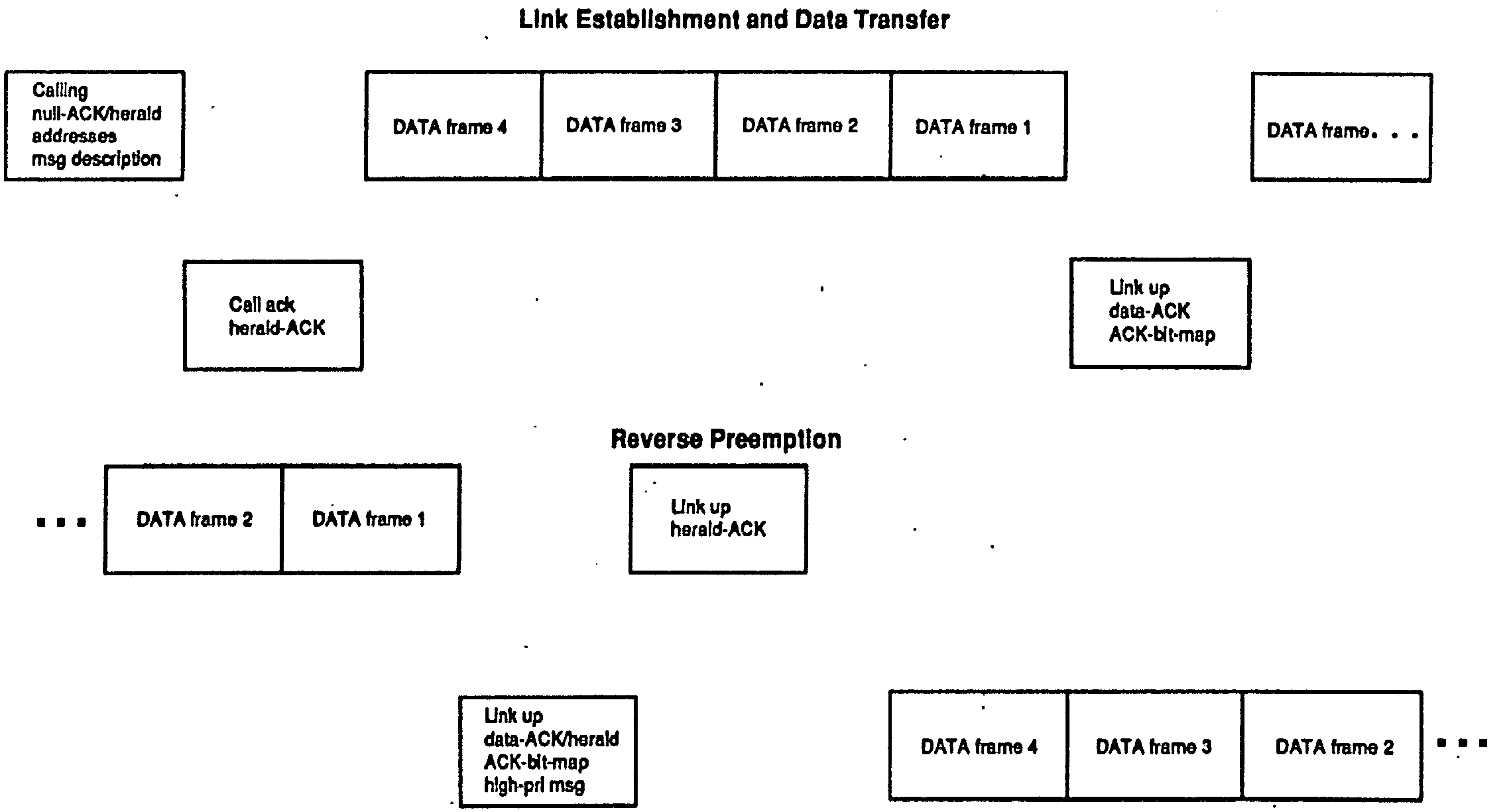

Figure 8. Examples of HFDLP operation

5. IMPLEMENTATION GUIDELINES

Although the HFDLP has been designed to operate with any arbitrary modem waveform, it has been optimized to operate over HF radio channels with the inherent high error rate encountered on these channels. It is expected that the protocol will be most often used with the HF serial (single-tone) waveform. The following paragraphs provide insight and guidance in implementing the HFDLP using the HF serial (single-tone) modem waveform.

5.1 Adapting data rate. A simple but effective algorithm for adapting the data rate of the modem during data link operation is as follows:

a. If all of the frames are transferred without error, the data rate should be raised.

b. If fewer than 50% of the frames are transferred without error, the data rate should be lowered.

5.2 HF serial (single-tone) interleaver capacity. Figure 9 lists the capacity of the serial (single-tone) modem interleaver buffers as a function of interleaver size and data rate. The length of serial (single-tone) modem transmissions is always an integer number of interleaver intervals. When calculating the transmission time of a block of data of a given length, one must take into consideration that in addition to the total number of interleaver intervals required to transmit the user data presented to the modem, the modem will precede the data transmission with a preamble phase equal to one interleaver interval and will append 176 bits. Figure 9 lists the total capacity of the interleaver buffer for each data rate, the minimum number of interleaver intervals required to transmit the 176 postamble bits and also the number of bits remaining within the minimum number of interleaver intervals for user data after the postamble is accounted for.

Interleaver Size	*Data Rate*	*Bits/Interleaver*	*Minimum Number of Interleavers*	*Information Bits Available in the Minimum Number of Interleavers*
Short (0.6 s)	75	45	4	4
	150	90	2	4
	300	180	1	4
	600	360	1	184
	1200	720	1	544
	2400	1,440	1	1,264
Long (4.8 s)	75	360	1	184
	150	720	1	544
	300	1,440	1	1,264
	600	2,880	1	2,704
	1200	5,760	1	5,584
	2400	11,520	1	11,344

Figure 9. Serial (single-tone) interleaver buffer capacity

APPENDIX B

USAISEC TECHNICAL REPORT

"MANAGEMENT INFORMATION BASE FOR AUTOMATED HF RADIO NETWORKS"

TR No. ASQB 94089

U S A I S E C

TECHNICAL REPORT

MANAGEMENT INFORMATION BASE FOR AUTOMATED HF RADIO NETWORKS

NOVEMBER 1994

Distribution Statement A: Approved for public release; distribution is unlimited. Requests for this document shall be referred to: Commander, U.S. Army Information Systems Engineering Command, ATTN: ASQB-OST, Fort Huachuca, Arizona 85613-5300.

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and

HFIA

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ABSTRACT

Management of high frequency (HF) radio networks through the use of the Simple Network Management Protocol (SNMP) requires the formal definition of the data objects to be remotely read and written by a network management program. This report defines the Management Information Base (MIB) for automated HF radio networks.

INTRODUCTION

Automation of HF radio networks to date has simplified the tasks related to establishing links using HF radios. However, the automatic link establishment (ALE) technology that hides the complexities of linking has generated a new problem in radio network management: the automatic controllers use a number of intricate data structures that must be kept consistent throughout a network if operations are to proceed smoothly. Some steps toward reducing the impact of this problem have been included in MIL-STD-187-721.

An aspect of network management that has not been addressed by the current HF standards is the need to observe network connectivity and equipment status from network control sites so that corrective action can be initiated promptly when malfunctions or other disruptions occur. Managers of packet networks have been at work on network management problems for some time, so it makes sense to look at the procedures used in these more mature automated networks to see whether they have technology that could be usefully applied to the management of HF networks.

Perhaps the best-known of the packet network technologies is the Internet suite of protocols (including the transmission control protocol (TCP) and the internet protocol (IP)), which grew out of the Department of Defense (DoD)-sponsored Advanced Research Projects Agency Network (ARPANET) research. The network management approach used in the Internet and associated sub-networks is based upon the Internet-standard Network Management Framework which was developed in the late 1980s. This technology is more often referred to by the protocol that it employs for managing network nodes, the SNMP [RFC-1157].

SNMP was designed so that it explicitly minimizes the number and complexity of management functions realized by the management agent itself. That is, the development costs of including SNMP in managed equipment are minimized at the expense of (perhaps) increasing the complexity of the software for network management stations. However, the ratio of managed nodes to management stations is large so the benefit of widespread implementation has greatly outweighed the cost of implementing the management software.

To briefly summarize the salient points of the SNMP approach:

a. Network management stations monitor and control network elements by communicating with agents in those elements.

b. This interaction uses SNMP [RFC-1157] to get and set the values of defined data objects. Agents may also send trap messages to management stations to announce important events asynchronously.

c. The defined data objects are described in the MIB [RFC-1213], which is currently strongly oriented toward the TCP/IP protocol suite, but is easily extensible. Object definitions are expressed formally in abstract syntax notation 1 (ASN.1) [ISO 8824].

d. Object names and values are encoded in accordance with a set of ASN.1 Basic Encoding Rules [ISO 8825].

e. When elements do not implement SNMP, they may still be managed by using proxy agents that translate the standard SNMP messages into proprietary messages understood by the non-SNMP elements.

f. Authentication is included in the standard, although current practice uses only trivial authentication. The mechanism is extensible using ideas similar to HF linking protection (LP).

g. SNMP requires only a connectionless datagram transport service (e.g., the user datagram protocol (UDP) in the Internet, or a similar protocol on top of HF automatic message exchange (AME) in MIL-STD-187-721).

h. SNMPv2, in accordance with RFC 1441-1452 shall be employed for HF network management with the following additional requirements:

(1) An agent receiving a SetRequest that selects a non-existent row in a table shall automatically create the requested row subject to resource availability, setting column objects in the new row to their default values unless other valid values are specified in the SetRequest message. However, if any value in the SetRequest message specifies an invalid value for any column object in the new row, the new row shall not be created, and a GetResponse message shall be returned indicating the erroneous variable binding.

(2) Table rows invalidated by a SetRequest shall not be reported in responses to GetNextRequests; that is, from the point of view of management stations, invalidated rows are deleted from the table.

(3) Object identifiers for objects defined in the MIB may be encoded for transmission *within HF networks only* using the truncated encoding scheme. Gateways that connect HF networks to non-HF networks, however, shall ensure that object identifier encodings in messages entering non-HF networks use the full encoding of ISO/IEC 8825; SNMP messages entering HF networks may be translated to use truncated encodings.

(4) Retransmission timeouts in network management programs shall be adjusted to allow time for link establishment and for the transmission of requests and responses over modems that may be able to achieve throughputs of 100 bits per second (bps) or less.

MANAGEMENT INFORMATION

SNMP functions by reading and writing data structures defined for each item of controlled equipment.

These data structures are defined using an abstract syntax (ASN.1) so that the details of how the data are stored by individual network components are hidden.

For example, aleScanRate (the rate at which an ALE controller scans channels) is simply defined to be an integer, with no indication of byte order, or even the number of bytes used to represent it on any particular ALE controller. Furthermore, some ALE controllers may store channel dwell time instead of scan rate, in which case a conversion from dwell time to or from scan rate is made whenever aleScanRate is read or written.

ENCODING RULES

When data are exchanged over the air (or some other medium), it is necessary that all parties to the exchange use the same encodings for the data.

The ASN.1 encoding rules [ISO 8825] name each object by tracing a path through a tree of standards to finally reach the leaf that defines that object. It seems reasonable, while within an HF network, to truncate this path to that portion that lies within the HF MIB, and use a special flag (i.e., the octet 123) to denote this. This is expected to reduce, by 4, the number of bytes needed to name each object, without compromising the interoperability of the proposed HF radio networks implementation of SNMP, described in this paper.

HNMP

SNMP version 2 (SNMPv2) modified for use in HF networks is called the HF Network Management Protocol (HNMP). The variations on SNMPv2 introduced for HF use are intended to reduce the amount of overhead bandwidth consumed by the network management protocol. These variations are as follows:

a. Object identifiers for objects defined in the HF MIB shall be encoded for transmission using the truncated encoding scheme described above.

b. A GetRows variant of the GetBulk message is used for efficient retrieval of rows of tables.

c. A PIN authentication is available. MD5 authentication is optional.

The GetRows operation is similar to the SNMPv2 GetBulk operation, except that the response to a GetRows is a new protocol data unit (PDU) format. A GetRows response includes the object ID only of the *first* object in each row, followed by the values of all objects requested in that row.

PERFORMANCE

The performance of HNMP may be gauged by how many bits are transferred to perform common operations. A fairly complex station such as that shown schematically in figure 1, is used for computing some example bit counts. In this case, the station is postulated to contain 1 ALE controller, 7 radios, 10 antennas, 6 HF Data Link Protocol (HFDLP) controllers, 1 antenna matrix, and 1 BLACK patch panel. A complete over-the-air load of ALE operating data using HNMP will transfer the following objects:

- 14 scalar values
- 6 Self Address Table entries
- 14 individual and 3 net entries in the Other Address Table
- 30 entries in the Channel Table
- 3 entries in the Channel Set Table

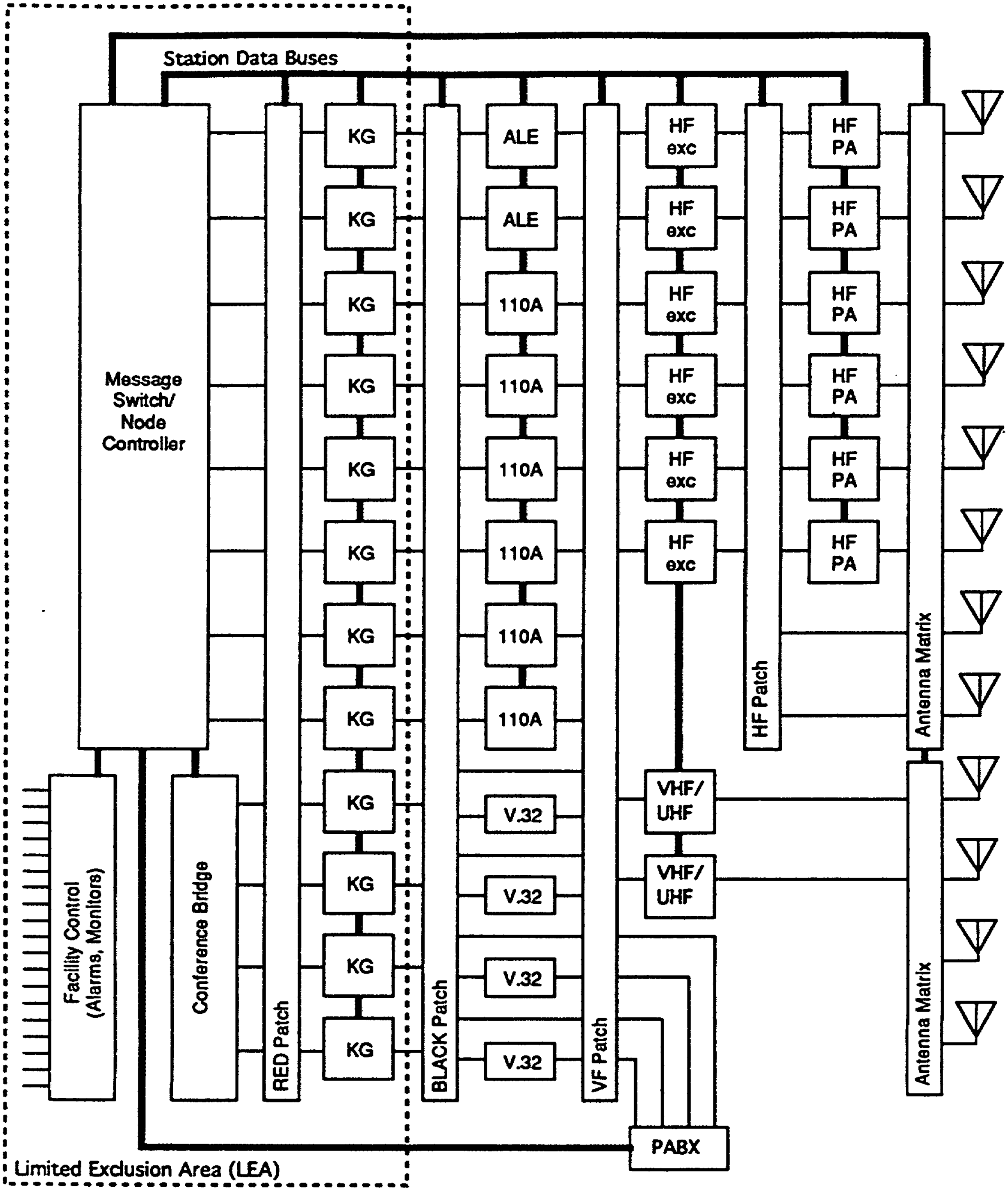

Figure 1. HF Station Example.

Using HNMP, this transfer will require 2,831 octets. Using this as a baseline, the number of octets to load the remaining equipment is estimated as follows:

Radios	15,000
Antennas	500
HFDLP	200
Antenna matrix	500
BLACK patch	500
Total	20,000 (est)

CONCLUSION

Appendix A contains MIBs for network management of automated HF radio networks. This MIB is merely a subset of the management information that will be needed for a full implementation of automated HF radio network management. Additional objects may be defined in equipment-specific MIBs as described in the structure of Management Information [RFC-1442]. Appendix B contains HNMP definitions.

ACKNOWLEDGEMENTS

The HF MIB described here draws from several sources, including the ALE data structures defined in MIL-STD-188-141A and the Interface Control Document for Federal Emergency Management Agency (FEMA) National Radio System Driver Software, suggestions from the HFIA and users, and from The Simple Book by Marshall Rose (for Internet objects).

REFERENCES

The following relevant requests for comment (RFC) are available via anonymous ftp from nic.ddn.mil or nis.nsf.net. They are stored in the rfc directory with file names in the format rfcxxxx.txt. The first three RFCs document SNMP version 1. The remaining RFCs document various aspects of SNMP version 2, which forms the basis for automated HF radio network management.

RFC-1155 Structure and Identification of Management Information

RFC-1157 A Simple Network Management Protocol (SNMP)

RFC-1213 Management Information Base for Network Management of TCP/IP-based Internets: MIB-II

RFC-1441 Introduction to Version 2 of the Internet-standard Network Management Framework

RFC-1442 Structure of Management Information for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1443 Textual Conventions for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1444 Conformance Statements for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1445 Administrative Model for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1446 Security Protocols for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1447 Party MIB for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1448 Protocol Operations for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1449 Transport Mappings for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1450 Management Information Base for Version 2 of the Simple Network Management Protocol (SNMPv2)

RFC-1451 Manager-to-Manager Management Information Base

RFC-1452 Coexistence between Version 1 and Version 2 of the Internet-standard Network Management Framework

Another useful reference is The Simple Book, by Marshall Rose, published by Prentice-Hall. This book provides a thorough introduction to SNMP.

APPENDIX A

ABSTRACT SYNTAX NOTATION (HF-MIB DEFINITIONS)

```
HF-MIB DEFINITIONS ::= BEGIN

IMPORTS
          experimental, OBJECT-TYPE, MODULE-IDENTITY, Counter32, Gauge32, TimeTicks
               FROM SNMPv2-SMI-- RFC 1442

          DisplayString, RowStatus, TimeStamp, TruthValue
               FROM SNMPv2-TC; -- RFC 1443

hf        MODULE-IDENTITY
          LAST-UPDATED "9408310212Z"
          ORGANIZATION "U.S. Army Information Systems Engineering Command"
          CONTACT_INFO
                    "         Eric E. Johnson

                    Postal:   New Mexico State University
                              Dept 3-O, (Electrical Computer Engineering)
                              Las Cruces, NM   88003-0001
                              USA

                     Tel:     +1 505 646 4739
                     Fax:     +1 505 646 1435

                    E-mail:   ejohnson@nmsu.edu"

          DESCRIPTION "The MIB module for MIL/FED-STD automated HF radio networks"
          ::= { 2 43 } -- (encoded as the single octet 123)

admin     OBJECT IDENTIFIER ::= { hf 1 } -- subtree for party context IDs...
security  OBJECT IDENTIFIER ::= { hf 2 } -- subtree for security features,
                                         -- including ECCM and multi-level security
enterprises        OBJECT IDENTIFIER ::= { hf 3 } -- subtree for enterprise-specific MIBs
hfSystem  OBJECT IDENTIFIER ::= { hf 4 } -- generally applicable objects
patch     OBJECT IDENTIFIER ::= { hf 5 } -- interconnection systems such as
                                         -- antenna matrices and patch panels
antenna   OBJECT IDENTIFIER ::= { hf 6 } -- antennas, couplers, etc.
radio     OBJECT IDENTIFIER ::= { hf 7 } -- radios
ale       OBJECT IDENTIFIER ::= { hf 8 } -- automatic link establishment controllers
lp        OBJECT IDENTIFIER ::= { hf 9 } -- linking protection
modem     OBJECT IDENTIFIER ::= { hf 10 } -- modems
hfdlp     OBJECT IDENTIFIER ::= { hf 11 } -- HF data link protocol
ame       OBJECT IDENTIFIER ::= { hf 12 } -- automatic message exchange
hrmp      OBJECT IDENTIFIER ::= { hf 13 } -- relay management protocol
hssp      OBJECT IDENTIFIER ::= { hf 14 } -- station status protocol
hftp      OBJECT IDENTIFIER ::= { hf 15 } -- HF transport protocol
hnmp      OBJECT IDENTIFIER ::= { hf 16 } -- HF network management protocol
```

```
-- the HF system group

hfControlMode OBJECT-TYPE
          SYNTAX INTEGER {
                    other (1)
                    local (2),    -- device is under local control
                    remote (3)    -- remote control enabled
          }
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
                    "locus of control"
          ::= { hfSystem 1 }

hfSelfTestMode OBJECT-TYPE
          SYNTAX INTEGER
          MAX-ACCESS read-write
          STATUS current
          DESCRIPTION
                    "0 indicates device not performing self test; other values correspond to particular self tests;
                    these values and their meanings vary from device to device"
          ::= { hfSystem 2 }

hfLastTestResult OBJECT-TYPE
          SYNTAX INTEGER
          MAX-ACCESS read-write
          STATUS current
          DESCRIPTION
                    "0 indicates self test completed successfully; -1 indicates that no self test has been
                    performed; positive values indicate failures with device-specific meanings; negative values
                    are reserved for standardized fault codes."
          ::= { hfSystem 3 }

hfLastFault OBJECT-TYPE
          SYNTAX INTEGER (0..65535)
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
                    "last fault code returned by device; 0 for no fault"
          ::= { hfSystem 4 }

hfLastMessage OBJECT-TYPE
          SYNTAX DisplayString
          MAX-ACCESS read-only
          STATUS current
          DESCRIPTION
                    "last diagnostic message returned by device; 0-length string if none"
          ::= { hfSystem 5 }
```

```
hfNoChange OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
                "True if no change has occurred to hfLastTestResult, hgLastFault and hfLastMessage since
                each was last read.  False if any has changed."
        ::= { hfSystem 6 }

hfNativeControlPort OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (1..65535))
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "This object implements a transparent pass-through to built-in proprietary control
                interfaces.  Strings written to this object are effectively injected into the local control port
                of the device.  Reading this object returns the status message(s), in order, returned by the
                device in response to the latest write to this object.  All are in the native format of the
                device."
        ::= { hfSystem 7 }


-- the Device Ports and Ranks Tables
-- The ports described in these tables are strictly physical.
-- For "logical ports" use the interfaces group in MIB-II

hfPortRanksTable OBJECT-TYPE
        SYNTAX SEQUENCE OF HfRankEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "Table describing the groups, or ranks, of ports on a device.  A rank may either be a
                logical rank of ports (as in a patch panel), or a group of similar ports (such as the audio
                inputs on a radio)."
        ::= { hfSystem 8 }

hfRankEntry OBJECT-TYPE
        SYNTAX HfRankEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "an entry in the device port ranks table describing one rank of ports"
        INDEX  { hfRankIndex }
        ::= { hfPortRanksTable 1 }
```

```
HfRankEntry ::=
        SEQUENCE {
                hfRankIndex
                        INTEGER,
                hfRankType
                        INTEGER,
                hfRankDescr
                        DisplayString
        }

hfRankIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "rank number; auxiliary variable used to identify one rank of ports in the device port ranks
                table"
        ::= { hfRankEntry 1 }

hfRankType OBJECT-TYPE
        SYNTAX INTEGER {
                other (1),      -- none of the following
                unused (2),     -- an unused rank
                binRed (3),     -- binary ports for classified data
                binBlk (4),     -- binary ports for unclassified data
                vfRed (5),      -- analog ports for classified signals
                vfBlack (6),    -- analog ports for unclas signals
                rfLow (7),      -- radio-frequency ports (up to 300 W)
                rfHigh (8),     -- radio-frequency ports (over 300 W)
        }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
        "type of ports in rank"
        ::= { hfRankEntry 2 }

hfRankDescr OBJECT-TYPE
        SYNTAX DisplayString
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "description of rank of ports; for display to user"
        ::= { hfRankEntry 3 }

hfPortsTable OBJECT-TYPE
        SYNTAX SEQUENCE OF HfPortEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "table of ports in a rank"
        ::= { hfSystem 9 }
```

```
hfPortEntry OBJECT-TYPE
        SYNTAX HfPortEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "an entry in the ports table describing one port"
        INDEX  { hfPortRankIndex hfPortIndex }
        ::=  { hfPortsTable 1 }

HfPortEntry ::=
        SEQUENCE {
                hfPortRankIndex
                        INTEGER,
                hfPortIndex
                        INTEGER,
                hfPortStatus
                        INTEGER,
                hfPortDescr
                        DisplayString
        }

hfPortRankIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "rank number; auxiliary variable used to identify rank number of an entry in the Ports
                Table; corresponds to the rank number in the hfPortRanksTable"
        ::= { hfPortEntry 1 }

hfPortIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "port number; auxiliary variable used to identify an entry in the Ports Table in which port
                in the rank)"
        ::=  { hfPortEntry 2 }

hfPortStatus OBJECT-TYPE
        SYNTAX INTEGER  {
                down (1),    -- inoperative
                avail (2),   -- available for normal operation
                inUse (3),   -- in use for normal operation
                test (4),    -- in some test mode; not available for use
        }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
                "current operational status of port"
        ::=  { hfPortEntry 3 }
```

```
hfPortDescr OBJECT-TYPE
          SYNTAX DisplayString
          MAX-ACCESS read-write
          STATUS current
          DESCRIPTION
                    "name of equipment or circuit attached to this port; for display to user"
          ::= { hfPortEntry 4 }


-- the Channel Table
-- for any equipment that uses channel numbers to refer to operating frequencies
-- and modes, e.g., radios and ALE controllers

hfChannelTable OBJECT-TYPE
          SYNTAX SEQUENCE OF HfChannelEntry
          MAX-ACCESS not-accessible
          STATUS current
          DESCRIPTION
                    "table of channel characteristics"
          ::= { hfSystem 10 }

hfChannelEntry OBJECT-TYPE
          SYNTAX HfChannelEntry
          MAX-ACCESS not-accessible
          STATUS current
          DESCRIPTION
                    "an entry in the channel table"
          INDEX { hfChannelIndex }
          ::= { hfChannelTable 1 }

HfChannelEntry ::=
          SEQUENCE {
                    hfChannelIndex
                              INTEGER,
                    hfChannelType
                              INTEGER,
                    hfChannelRxFreq
                              INTEGER,
                    hfChannelRxMode
                              HfModulation,
                    hfChannelTxFreq
                              INTEGER,
                    hfChannelTxMode
                              HfModulation,
                    hfChannelAntenna
                              INTEGER,
                    hfChannelPower
                              INTEGER,
                    hfChannelStatus
                              RowStatus
          }
```

```
hfChannelIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "channel number; auxiliary variable used to identify an entry in the Channel Table"
        ::= { hfChannelEntry 1 }

hfChannelType OBJECT-TYPE
        SYNTAX INTEGER {
                other (1),      -- none of the following
                unused (2),     -- an unused channel
                duplex (3),     -- a channel in duplex service (both directions simultaneously)
                simplex (4),    -- a channel in simplex service (both directions, but one at
                                   a time)
                listen (5),     -- a channel in receive-only service
        }
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
                "operating mode of channel"
        DEFVAL { simplex }
        ::= { hfChannelEntry 2 }

hfChannelRxFreq OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
                "frequency for this channel"
        DEFVAL { 0 }
        ::= { hfChannelEntry 3 }

hfChannelRxMode OBJECT-TYPE
        SYNTAX HfModulation
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
                "receiving modulation for this channel"
        DEFVAL { usb }
        ::= { hfChannelEntry 4 }
```

```
hfChannelTxFreq OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "transmitting frequency for this channel"
        DEFVAL { 0 }
        ::= { hfChannelEntry 5 }

hfChannelTxMode OBJECT-TYPE
        SYNTAX HfModulation
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "transmitting modulation for this channel"
        DEFVAL { usb }
        ::= { hfChannelEntry 6 }

hfChannelAntenna OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "antenna number (local significance: index into site antenna table)"
        DEFVAL { 1 }
        ::= { hfChannelEntry 7 }

hfChannelPower OBJECT-TYPE
        SYNTAX INTEGER {
            full (1),
            reduced (2)
        }
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "full or reduced transmitter power used on this channel?"
        DEFVAL { 1 }
        ::= { hfChannelEntry 8 }

hfChannelStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and deleting Channel Table entries"
        DEFVAL { active }
        ::= { hfChannelEntry 9 }
```

```
HfModulation ::=
        INTEGER {
            cw (1),
            afsk (2),      -- incl RATT
            am (3),        -- incl AME
            usb (4),
            lsb (5),
            isb2 (6),
            isb4 (7),
            mcw (8),
            fm (9),
            fsk (10),
            psk (11)
        }


-- the Channel Set Table

hfChannelSetTable OBJECT-TYPE
        SYNTAX SEQUENCE OF HfChannelSet
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "contains sets of channels for efficient reference to scan lists, etc."
        ::=  { hfSystem 11 }

hfChannelSet OBJECT-TYPE
        SYNTAX HfChannelSet
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "an entry in the Channel Set Table"
        INDEX { hfChannelSetIndex }
        ::=  { hfChannelSetTable  1 }

HfChannelSet ::=
        SEQUENCE {
            hfChannelSetIndex
                        INTEGER,
            hfChannelSetMembers
                        BIT STRING,
            hfChannelSetStatus
                        RowStatus
        }
```

```
hfChannelSetIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "auxiliary variable to identify an entry in Channel Set Table"
        ::= { hfChannelSet 1 }

hfChannelSetMembers OBJECT-TYPE
        SYNTAX BIT STRING
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "Bit string that indicates which channels are in set. Bit number corresponds to channel
            number. A bit set to 1 indicates that the corresponding channel is in the set, while a bit set
            to 0 indicates that the corresponding bit is not in the set. The bit string need be no longer
            than the highest-numbered channel that is in the set plus one bit. (Bit 0 is always 0, unless
            equipment supports a channel numbered 0.)"
        ::= { hfChannelSet 2 }

hfChannelSetStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and deleting Channel Set Table entries"
        DEFVAL { active }
        ::= { hfChannelSet 3 }


-- the Patch group
-- the Patch Connections Table

patchConnectionsTable OBJECT-TYPE
        SYNTAX SEQUENCE OF PatchConnectionEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "table of connections among patch ports in automated patch panel"
        ::= { patch 1 }

patchConnectionEntry OBJECT-TYPE
        SYNTAX PatchConnectionEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "an entry in the patch connections table"
        INDEX { patchRankA patchPortA patchRankB patchPortB }
        ::= { patchConnectionsTable 1 }
```

```
PatchConnectionEntry ::=
        SEQUENCE {
            patchRankA
                    INTEGER,
            patchPortA
                    INTEGER,
            patchRankB
                    INTEGER,
            patchPortB
                    INTEGER,
            patchConnectionStatus
                    INTEGER
        }

patchRankA OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "rank of first end of a patch connection; auxiliary variable used to identify an entry in
            Patch Connections Table"
        ::=  { patchConnectionEntry 1 }

patchPortA OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "port of first end of a patch connection; auxiliary variable used to identify an entry in
            Patch Connections Table"
        ::=  { patchConnectionEntry 2 }

patchRankB OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "rank of second end of a patch connection; auxiliary variable used to identify an entry in
            Patch Connections Table"
        ::=  { patchConnectionEntry 3 }

patchPortB OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "port of second end of a patch connection; auxiliary variable used to identify an entry in
            Patch Connections Table"
        ::=  { patchConnectionEntry 4 }
```

```
patchConnectionStatus OBJECT-TYPE
        SYNTAX INTEGER {
                free (1),       -- written to release a connection,
                                -- freeing the ports;
                                --  read only in response to freeing SET
                seized (2),     -- written to establish a connection; read when -- established
                reserved (3),   -- written to capture ports without making the
                                -- connection;
                                --  read when both ports have been reserved
        }
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
                "current status of connection; an appropriate error code is returned when a connection
                cannot be established, reserved, or freed as requested, or in response to a get request for a
                non-existent connection"
        DEFVAL  { seized }
        ::=  { patchConnectionEntry 5 }


-- the antenna system group
-- the antenna

tableantennaTable OBJECT-TYPE
        SYNTAX SEQUENCE OF AntennaEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "Table of antennas under the control of the addressed device (antennas are not addressed
                directly)"
        ::=  { antenna 1 }

antennaEntry OBJECT-TYPE
        SYNTAX AntennaEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "An entry in the antenna table"
        INDEX { antennaIndex }
        ::=  { antennaTable 1 }
```

```
AntennaEntry ::=
        SEQUENCE {
                antennaIndex
                                INTEGER,
                antennaType
                                INTEGER,
                antennaPolar
                                INTEGER,
                antennaModel
                                DisplayString,
                antennaMode
                                INTEGER,
                antennaMaxPower
                                INTEGER,
                antennaAzimuth,
                                INTEGER
        }

antennaIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "Antenna number; auxiliary variable used to identify an entry in the Antenna Table"
        ::=  { antennaEntry 1 }

antennaType OBJECT-TYPE
        SYNTAX INTEGER  {
                other (1),      -- none of the following
                whip (2),
                dipole (3),
                longwire (4),
                loop (5),
                omni (6),       -- omnidirectional
                rlp (7),        -- rotatable log-periodic
                beam (8),       -- any other multi-element assembly
                rhombic (9),
                slopingv (10),
                nvis (11)
        }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
                "Type of antenna.  When more than one of the types listed is applicable, use the most
                specific."
        ::=  { antennaEntry 2 }
```

```
antennaPolar OBJECT-TYPE
        SYNTAX INTEGER {
                other (1),        -- none of the following
                horizontal (2),
                vertical (3),
                circular (4)
        }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
                "Polarization of antenna"
        ::= { antennaEntry 3 }

antennaModel OBJECT-TYPE
        SYNTAX DisplayString
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
                "Manufacturer and model of antenna"
        ::= { antennaEntry 4 }

antennaMode OBJECT-TYPE
        SYNTAX INTEGER {
                other (1),        -- none of the following
                RxOnly (2),
                TxOnly (3),
                RxTx (4)
        }
        MAX-ACCESS read only
        STATUS current
        DESCRIPTION
                "Operating mode capability."
        ::= { antennaEntry 5 }

antennaMaxPower OBJECT-TYPE
        SYNTAX INTEGER (-128..127)
        UNITS "dBW"
        MAX-ACCESS read only
        STATUS current
        DESCRIPTION
                "Maximum operating power of antenna.  When rounding computed dBW to integer, round
                down."
        ::= { antennaEntry 6 }
```

```
antennaAzimuth OBJECT-TYPE
        SYNTAX INTEGER (0..359)
        UNITS "degrees"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Current magnetic azimuth of antenna.  Always 0 for omni antennas."
        ::=  { antennaEntry 7 }


-- the radio group

radioChannel OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Index into Channel Table for the radio of its current operating channel.  If its current
            frequencies and modes do not exactly correspond to an entry in that table, equal to -1."
        ::=  { radio 1 }

radioKeyed OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "1 if transmitter is keyed, 0 otherwise.  Writing a 1 keys transmitter."
        ::=  { radio 2 }

radioTxPower OBJECT-TYPE
        SYNTAX INTEGER (-128..127)
        UNITS  "dBW"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Nominal PA output power, as adjusted by power management commands.  For example,
            a 100W radio returns 20 when operating at full rated power.  Writing 10 to radioTxPower
            should cause this radio to reduce its power output by 10 dB to a nominal 10W.  Power
            adjustments will usually be approximations of the output power requested; the actual output
            power resulting from adjustment should be reported in the response to a set.  (-128 dBW
            indicates no power.)"
        ::=  { radio 3 }

radioTxFreq OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Current transmitting frequency."
        ::=  { radio 4 }
```

```
radioTxMode OBJECT-TYPE
        SYNTAX HfModulation
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Current transmitter modulation setting."
        ::= { radio 5 }

radioRxFreq OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Current receiving frequency."
        ::= { radio 6 }

radioRxMode OBJECT-TYPE
        SYNTAX HfModulation
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Current receiver modulation setting."
        ::= { radio 7 }

radioTuned OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "1 if radio and coupler tuned for radioTxFreq, 0 otherwise. Writing a 1 causes tuning (0
            will be read until tuning is completed)."
        ::= { radio 8 }

radioPABypass OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true for bypass; false for normal"
        ::= { radio 9 }

radioCouplerBypass OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true for bypass; false for normal"
        ::= { radio 10 }
```

```
radioActiveAntenna OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Index into antennaTable indicating the antenna currently in use (or ready for use)."
        ::= { radio 11 }

radioPreselectorBypass OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true for bypass; false for normal"
        ::= { radio 12 }

radioFrontEndAtten OBJECT-TYPE
        SYNTAX INTEGER (0..255)
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "attenuation at front end"
        ::= { radio 13 }

radioRFMute OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true if RF is muted, false if unmuted"
        ::= { radio 14 }

radioRFGain OBJECT-TYPE
        SYNTAX INTEGER (-128..127)
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "gain of receiver RF amplifier relative to nominal"
        ::= { radio 15 }

radioVFO OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "frequency of VFO; 0 is off"
        ::= { radio 16 }
```

```
radioNoiseBlanker OBJECT-TYPE
        SYNTAX INTEGER (0..9)
        UNITS "arbitrary"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "noise blanker level; the range of levels supported by the radio shall be mapped into the
            range 0 through 9, with 9 being the highest level; 0 disables noise blanker"
        ::= { radio 17 }

radioNotchFilterMode OBJECT-TYPE
        SYNTAX INTEGER {
            off (1),
            manual (2),
            automatic (3)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "operating mode of notch filter; in automatic mode, notch frequency tracks the interfering
            signal automatically"
        ::= { radio 18 }

radioNotchFilterFrequency OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "center frequency of notch filter; read only when mode is automatic"
        ::= { radio 19 }

radioAGCMode OBJECT-TYPE
        SYNTAX INTEGER {
            off (1),
            fast (2),
            medium (3),
            slow (4),
            external (5),
            coherent (6),
            data (7)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "AGC speed and mode"
        ::= { radio 20 }
```

```
radioAudioClipEnable OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true if audio peak filter is on, false if off"
        ::= { radio 21 }

radioAudioClipLevel OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "level relative to nominal"
        ::= { radio 22 }

radioAudioPassband OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "width of audio passband"
        ::= { radio 23 }

radioPassbandTuning OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "variation of passband center frequency from nominal; 0 means passband tuning is off"
        ::= { radio 24 }

radioBFO OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "frequency of beat frequency oscillator; 0 is off"
        ::= { radio 25 }
```

```
radioSquelch OBJECT-TYPE
        SYNTAX INTEGER (0..9)
        UNITS "arbitrary"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "squelch level; 0 is off"
        ::= { radio 26 }

radioSpeakerMute OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true if speaker is muted, false if unmuted"
        ::= { radio 27 }

radioMicGain OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "gain of microphone input"
        ::= { radio 28 }

radioSpeechProcEnable OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true if speech processor is on, false if off"
        ::= { radio 29 }

radioSpeechProcInputLevel OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "level relative to nominal"
        ::= { radio 30 }

radioSpeechProcOutputLevel OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "level relative to nominal"
        ::= { radio 31 }
```

```
radioAudioGain OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "level relative to nominal"
        ::= { radio 32 }

radioVoxEnable OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "true if VOX is on, false if off"
        ::= { radio 33 }

radioVoxGain OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "gain relative to nominal"
        ::= { radio 34 }

radioVoxAntiTrip OBJECT-TYPE
        SYNTAX INTEGER (0..9)
        UNITS "arbitrary"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "VOX circuit anti-trip setting"
        ::= { radio 35 }

radioVoxDelay OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "ms"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "VOX delay"
        ::= { radio 36 }

radioZeroize OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "set to true to zeroize; reads as true if radio is zeroized"
        ::= { radio 37 }
```

```
radioScanSet OBJECT-TYPE
        SYNTAX SEQUENCE OF INTEGER
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "list of channel set indices in scan set"
        ::= { radio 38 }

radioScanRate OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "channels per second"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "rate at which receiver scans channels"
        ::= { radio 39 }

radioStopScanThreshold OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "level relative to nominal"
        ::= { radio 40 }


-- the radio gauges

radioGauges OBJECT-TYPE
        SYNTAX SEQUENCE OF RadioGaugeEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Table of read-only radio gauges. Organized in no particular order, each is identified by a
            name, and has integer-valued readings in specified units."
        ::= { radio 41 }


radioGaugeEntry OBJECT-TYPE
        SYNTAX RadioGaugeEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An abstract radio gauge"
        INDEX { radioGaugeIndex }
        ::= { radioGauges 1 }
```

```
RadioGaugeEntry ::=
        SEQUENCE {
            radioGaugeIndex
                    INTEGER,
            radioGaugeName
                    DisplayString,
            radioGaugeUnits
                    DisplayString,
            radioGaugeReading
                    Gauge,
            radioGaugeTrapHigh
                    Gauge,
            radioGaugeTrapLow
                    Gauge
        }

radioGaugeIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "gauge number; auxiliary variable used to identify an entry in the table of radio gauges"
        ::= { radioGaugeEntry 1 }

radioGaugeName OBJECT-TYPE
        SYNTAX DisplayString
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Name of the quantity whose value is displayed on the gauge."
        ::= { radioGaugeEntry 2 }

radioGaugeUnits OBJECT-TYPE
        SYNTAX DisplayString
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Units of the value displayed on the gauge.  Should be selected so that integer readings are
            useful."
        ::= { radioGaugeEntry 3 }

radioGaugeReading OBJECT-TYPE
        SYNTAX Gauge
        UNITS "specified in radioGaugeUnits"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Most recent value of the quantity named in radioGaugeName"
        ::= { radioGaugeEntry 4 }
```

```
radioGaugeTrapHigh OBJECT-TYPE
        SYNTAX Gauge
        UNITS "specified in radioGaugeUnits"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "threshold above which a trap will be generated automatically"
        ::= { radioGaugeEntry 5 }

radioGaugeTrapLow OBJECT-TYPE
        SYNTAX Gauge
        UNITS "specified in radioGaugeUnits"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "threshold below which a trap will be generated automatically"
        ::= { radioGaugeEntry 6 }


-- the ALE group

aleScanRate OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "channels per second"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "rate at which ALE receiver scans channels"
        ::= { ale 1 }

aleMaxScanChan OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "maximum number of channels scanned for network"
        ::= { ale 2 }

aleMaxTuneTime OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "100 ms"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "maximum tune time for network"
        ::= { ale 3 }
```

```
aleTurnAroundTime OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "100 ms"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "maximum Tta for network"
        ::= { ale 4 }

aleActivityTimeout OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "seconds"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "wait-for-activity timeout Twa"
        ::= { ale 5 }

aleListenTime OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "seconds"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "listen before transmit time Twt"
        ::= { ale 6 }

aleAcceptAnycall OBJECT-TYPE
        SYNTAX INTEGER {
                respond (1),
                ignore (2)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "will ALE controller respond to anycalls"
        ::= { ale 7 }

aleAcceptAllcall OBJECT-TYPE
        SYNTAX INTEGER {
                accept (1),
                ignore (2)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "will ALE controller detect and stop scan for allcalls "
        ::= { ale 8 }
```

```
aleAcceptAMD OBJECT-TYPE
        SYNTAX INTEGER {
            display (1),
            store (2),
            displayAndStore (3),
            ignore (4)            -- doesn't require return to scan
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "ALE controller action(s) upon receipt of AMD message"
        ::= { ale 9 }

aleAcceptDTM OBJECT-TYPE
        SYNTAX INTEGER {
            accept (1),
            ignore (2)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "ALE controller action upon receipt of data text message"
        ::= { ale 10 }

aleAcceptDBM OBJECT-TYPE
        SYNTAX INTEGER {
            accept (1),
            ignore (2)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "ALE controller action upon receipt of data block message"
        ::= { ale 11 }

aleRequestLQA OBJECT-TYPE
        SYNTAX INTEGER {
            always (1),     -- request LQA in every ALE transmission
            callOnly (2),   -- request LQA only in ALE call
            never (3)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "ALE protocol phases in which ALE controller will request an LQA report"
        ::= { ale 12 }
```

```
aleAutoPowerAdj OBJECT-TYPE
        SYNTAX INTEGER {
            always (1),     -- evaluate every received ALE transmission, but
                            -- request power adjustment only when needed
            callOnly (2),   -- negotiate power only during link
                            -- establishment
            never (3)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "ALE protocol phases in which ALE controller will generate power adjust commands to
            distant station, based upon measurement of received signal strength"
        ::= { ale 13 }

AleAddress ::= OCTET STRING (SIZE (1..15))
-- one to fifteen characters from [A-Z, 0-9]
-- the ALE Self Address Table

aleSelfAddrTable OBJECT-TYPE
        SYNTAX SEQUENCE OF AleSelfAddrEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "table of 'self' addresses for ALE controller, along with ALE information relevant to each
            self address"
        REFERENCE "see MIL-STD-188-141"
        ::= { ale 14 }

aleSelfAddrEntry OBJECT-TYPE
        SYNTAX AleSelfAddrEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "an entry in the ALE Self Address Table"
        INDEX { IMPLIED aleSelfAddr }
        ::= { aleSelfAddrTable 1 }

AleSelfAddrEntry ::=
        SEQUENCE {
            aleSelfAddr
                        AleAddress,
            aleSelfAddrStatus
                        INTEGER,
            aleNetAddr
                        AleAddress,
            aleSlotWaitTime
                        INTEGER,
            aleSelfAddrValidChannels
                        INTEGER
        }
```

```
aleSelfAddr OBJECT-TYPE
        SYNTAX AleAddress
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "ALE self address; one to fifteen characters from [A-Z, 0-9]; auxiliary variable that
            uniquely identifies one entry in the ALE Self Address Table"
        ::= { aleSelfAddrEntry 1 }

aleSelfAddrStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and deleting ALE self address table
            entries"
        DEFVAL { active }
        ::= { aleSelfAddrEntry 2 }

aleNetAddr OBJECT-TYPE
        SYNTAX AleAddress
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "ALE address of net to which this self address belongs"
        DEFVAL { "" }
        ::= { aleSelfAddrEntry 3 }

aleSlotWaitTime OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "ALE word time Tw (130.667 ms)"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "slot wait time for responding to net call"
        ::= { aleSelfAddrEntry 4 }

aleSelfAddrValidChannels OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "index into channel set table (0 means all channels valid)"
        DEFVAL { 0 }
        ::= { aleSelfAddrEntry 5 }
```

```
-- the ALE Other Address Table

aleOtherAddrTable OBJECT-TYPE
        SYNTAX SEQUENCE OF AleOtherAddrEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "ALE addresses of other stations and nets known to this ALE controller"
        REFERENCE "see MIL-STD-188-141"
        ::= { ale 15 }

aleOtherAddrEntry OBJECT-TYPE
        SYNTAX AleOtherAddrEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "an entry in the ALE Other Address Table"
        INDEX { IMPLIED aleOtherAddr }
        ::= { aleOtherAddrTable 1 }

AleOtherAddrEntry ::=
        SEQUENCE {
            aleOtherAddr
                        AleAddress,
            aleOtherAddrStatus
                        INTEGER,
            aleOtherAddrNetMembers
                        OCTET STRING,
            aleOtherAddrValidChannels
                        INTEGER,
            aleOtherAddrAnt
                        INTEGER,
            aleOtherAddrAntAzimuth
                        INTEGER,
            aleOtherAddrPower
                        INTEGER
        }

aleOtherAddr OBJECT-TYPE
        SYNTAX AleAddress
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "ALE address; one to fifteen characters from [A-Z, 0-9]; auxiliary variable that uniquely
            identifies one entry in the ALE Other Address Table"
        ::= { aleOtherAddrEntry 1 }
```

```
aleOtherAddrStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and deleting ALE Other Address Table
            entries"
        DEFVAL  { active }
        ::=  { aleOtherAddrEntry 2 }

aleOtherAddrNetMembers OBJECT-TYPE
        SYNTAX SEQUENCE OF AleAddress
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "List of ALE addresses of net members, in slot order.  Empty list if this other address is
            not a net address.  Unknown net member addresses set to '@' "
        DEFVAL  { } -- empty sequence
        ::=  { aleOtherAddrEntry 3 }

aleOtherAddrValidChannels OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "index into channel set table (0 means all channels valid)"
        DEFVAL  { 0 }
        ::=  { aleOtherAddrEntry 4 }

aleOtherAddrAnt OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "Antenna number (antennaIndex) to use in links with this station or net.  0 means default
            to antenna specified for channel in hfChannelTable"
        DEFVAL  { 0 }
        ::=  { aleOtherAddrEntry 5 }

aleOtherAddrAntAzimuth OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "Azimuth of rotatable antenna to use in links with this station or net.  0 is default."
        DEFVAL  { 0 }
        ::=  { aleOtherAddrEntry 6 }
```

```
aleOtherAddrPower OBJECT-TYPE
        SYNTAX INTEGER {
                default (0),
                full (1),
                reduced (2)
        }
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
                "Power to use in links with this station or net.  0 means default to power specified for
                channel in hfChannelTable"
        DEFVAL  { 0 }
        ::=  { aleOtherAddrEntry 7 }


-- the LQA matrix

aleLqaMatrix OBJECT-TYPE
        SYNTAX SEQUENCE OF AleLqaEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "table of link quality measurements"
        ::=  { ale 16 }

aleLqaEntry  OBJECT-TYPE
        SYNTAX AleLqaEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "an entry in the ALE Other Address Table"
        INDEX { IMPLIED aleLqaAddr aleLqaChannel }
        ::= { aleLqaMatrix 1 }

AleLqaEntry ::=
        SEQUENCE {
                aleLqaAddr
                                AleAddress,
                aleLqaChannel
                                INTEGER,
                aleLqaStatus
                                INTEGER,
                aleLqaAge
                                INTEGER,
                aleLqaMultipath
                                INTEGER,
                aleLqaSINAD
                                INTEGER,
                aleLqaBER
                                INTEGER
        }
```

```
aleLqaAddr OBJECT-TYPE
        SYNTAX AleAddress
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "ALE address; one to fifteen characters from [A-Z, 0-9]; auxiliary variable that identifies
                (along with channel number) one entry in the ALE LQA Matrix"
        ::= { aleLqaEntry 1 }

aleLqaChannel OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
                "Channel number of LQA measurement; auxiliary variable that identifies (along with
                aleLqaAddr) one entry in the ALE LQA Matrix"
        ::= { aleLqaEntry 2 }

aleLqaStatus OBJECT-TYPE
        SYNTAX  RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
                "The status column used for creating, modifying, and deleting LQA Matrix entries"
        DEFVAL { active }
        ::= { aleLqaEntry 3 }

aleLqaAge     OBJECT-TYPE
        SYNTAX INTEGER {
                lqaFifteen (0),         -- 0-15 minutes
                lqaThirty (1),          -- 15-30 minutes
                lqaSixty (2),           -- 30-60 minutes
                lqaTwoHr (3),           -- 1-2 hours
                lqaFourHr (4),          -- 2-4 hours
                lqaToday (5),           -- 4-23 hours
                lqaYesterday (6),       -- 23-25 hours
                lqaTooOld (7)           -- over 25 hours or unknown
        }
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
                "Age of LQA measurement"
        ::= { aleLqaEntry 4 }
```

```
aleLqaMultipath OBJECT-TYPE
          SYNTAX INTEGER (0..7)
          UNITS "ms"
          MAX-ACCESS read-create
          STATUS current
          DESCRIPTION
                "multipath measurement; 7 means unknown"
          ::= { aleLqaEntry 5 }

aleLqaSINAD   OBJECT-TYPE
          SYNTAX INTEGER (0..31)
          UNITS "dB"
          MAX-ACCESS read-create
          STATUS current
          DESCRIPTION
                "SINAD measurement; 31 means unknown"
          ::= { aleLqaEntry 6 }

aleLqaBER   OBJECT-TYPE
          SYNTAX INTEGER (0..31)
          MAX-ACCESS read-create
          STATUS current
          DESCRIPTION
                "pseudo-BER measurement; 31 means unknown"
          ::= { aleLqaEntry 7 }


-- the ALE controls

aleScanSet OBJECT-TYPE
          SYNTAX SEQUENCE OF INTEGER
          MAX-ACCESS read-write
          STATUS current
          DESCRIPTION
                "list of channel set indices in scan set"
          ::= { ale 16 }

aleConnectionTable OBJECT-TYPE
          SYNTAX SEQUENCE OF AleConnectionEntry
          MAX-ACCESS not-accessible
          STATUS current
          DESCRIPTION
                "table of currently-linked stations"
          ::= { ale 17 }
```

```
aleConnectionEntry OBJECT-TYPE
        SYNTAX AleConnectionEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "an entry in the ALE Connection Table"
        INDEX  { IMPLIED aleConnectedAddr }
        ::=  { aleConnectionTable 1 }

AleConnectionEntry ::=
        SEQUENCE {
            aleConnectedAddr
                        AleAddress,
            aleConnectionStatus
                        INTEGER
        }

aleConnectedAddr OBJECT-TYPE
        SYNTAX AleAddress
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "ALE address of station or net to which connected; auxiliary variable that uniquely
            identifies one entry in the ALE Connection Table"
        ::=  { aleConnectionEntry 1 }

aleConnectionStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and deleting ALE Connection Table
            entries.  Management stations may initiate link establishment by setting
            aleConnectionStatus to createAndGo.  During link establishment, the connection status will
            be notInService, changing to active when the link is established.  Management stations may
            initiate link termination by setting aleConnectionStatus to destroy."
        DEFVAL  { notInService }
        ::=  { aleConnectionEntry 2 }
```

```
-- the LP (linking protection) group

lpLevelsAvail OBJECT-TYPE
        SYNTAX BIT STRING {
            unprotected (0),    -- no linking protection
            al1 (1),            -- unclassified application level AL-1
            al2 (2),            -- unclassified enhanced application level AL-2
            al3 (3),            -- unclassified but sensitive application level AL-3
            al4 (4),            -- classified application level AL-4
            other (5)           -- any AL not identified in MIL-STD-188-141
        }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Reports available linking protection (LP) application levels.  Because AL-1 is the defined
            interoperability level, the al1 bit may be 0 only if all bits other than bit 0 are also set to 0,
            indicating no LP capability."
        REFERENCE "see MIL-STD-188-141, Linking protection application levels"
        ::= { lp 1 }


-- the modem group

modemStatus OBJECT-TYPE
        SYNTAX INTEGER {
            other (1),          -- none of the following
            available (2),      -- "on hook"
            connecting (3),     -- "off hook" but no received carrier
            carrier (4),        -- "off hook" and receiving carrier
            dataSync (5),       -- "off hook," receiving carrier, and
                                -- achieved data synchronization
            fault (6)           -- failure detected
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "modem status; only the following values are valid in a set operation:  available (2) forces
            the modem on-hook or resets a fault, and connecting (3) initiates a
            (re)connection attempt"
        ::= { hf modem 1 }
```

```
modemMode OBJECT-TYPE
        SYNTAX INTEGER {
            other (1),          -- none of the following
            hfSerialTone (2),
            hf16Tone (3),
            hf39Tone (4),
            fsk170 (5),         -- 170 Hz shift
            fsk850 (6),         -- 850 Hz shift
            stanag4285 (7),
            bell103 (8),        -- 300 bps
            bell212a (9),       -- 1200 bps
            v21 (10),           -- 300 bps
            v22 (11),           -- 1200 bps
            v22bis (12),        -- 2400 bps
            v32 (13),           -- 4800/9600 bps
            v32bis (14)         -- 7200/9600/12000/14400 bps
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "modem operating mode; a set operation that specifies an unavailable mode shall not
            change the operating mode"
        ::= { hf modem 2 }

modemAvailableModes OBJECT-TYPE
        SYNTAX BIT STRING {
            other (1),          -- none of the following
            hfSerialTone (2),
            hf16Tone (3),
            hf39Tone (4),
            fsk170 (5),         -- 170 Hz shift
            fsk850 (6),         -- 850 Hz shift
            stanag4285 (7)
            bell103 (8),        -- 300 bps
            bell212a (9),       -- 1200 bps
            v21 (10),           -- 300 bps
            v22 (11),           -- 1200 bps
            v22bis (12),        -- 2400 bps
            v32 (13),           -- 4800/9600 bps
            v32bis (14)         -- 7200/9600/12000/14400 bps
        }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "available operating modes"
        ::= { hf modem 3 }
```

```
modemMaxDataRate OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "bps"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "maximum data rate supported by modem"
        ::= { hf modem 4 }

modemTxDataRate OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "bps"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "data rate for data sent by modem; set operation causes data rate change at next logical
            opportunity"
        ::= { hf modem 5 }

modemTxInterleaver OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "100 ms"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "interleaver length used in sending data; 0 means no interleaver; a set operation that
            specifies an unavailable length should result in use of the nearest available length to that
            specified"
        ::= { hf modem 6 }

modemRxDataRate OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "bps"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "rate of data currently (or most recently) received by modem"
        ::= { hf modem 7 }

modemRxInterleaver OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "100 ms"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "interleaver length used for data currently (or most recently) received by modem"
        ::= { hf modem 8 }
```

```
modemRxSNR OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "dB"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "signal-to-noise ratio measured for data currently (or most recently) received by modem"
        ::= { hf modem 9 }

modemRxFreqOffset OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "Hz"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "measured data carrier offset for data currently (or most recently) received by modem"
        ::= { hf modem 10 }

modemLoopbackMode OBJECT-TYPE
        SYNTAX INTEGER {
            none (1),     -- no loopback
            digital (2),  -- transmit data connected to receive data
            analog (3)    -- transmit analog signal connected to
                          -- receive analog input
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "modem loopback mode; a set operation that specifies an unavailable mode shall effect no
            change"
        ::= { hf modem 11 }

modemDuplexMode OBJECT-TYPE
        SYNTAX INTEGER {
            other (1),    -- none of the following
            simplex (2),  -- send and receive alternately
            duplex (3),   -- send and receive simultaneously
                          -- ("full" duplex)
            sendOnly (4),
            rcvOnly (5)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "modem duplex mode; a set operation that specifies an unavailable mode shall effect no
            change"
        ::= { hf modem 12 }
```

```
modemARQProtocol OBJECT-TYPE
        SYNTAX INTEGER {
            none (1),      -- no ARQ protocol
            other (2),     -- none of the following
            hfdlp (3),
            v42 (4),
            lapm (5),
            mnp (6),
            mnp10 (7)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "modem ARQ protocol; a set operation that specifies an unavailable mode shall effect no
            change"
        ::= { hf modem 13 }

modemCompressionProtocol OBJECT-TYPE
        SYNTAX INTEGER {
            none (1),      -- no compression
            other (2),     -- none of the following
            mnp (3),
            v42bis (4)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "modem compression protocol; a set operation that specifies an unavailable mode shall
            effect no change"
        ::= { hf modem 14 }


-- the HF data link protocol group

hfdlpProtocolVersion OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "version of protocol in use by terminal"
        ::= { hfdlp 1 }
```

```
hfdlpControlMode OBJECT-TYPE
        SYNTAX INTEGER {
                varFrameARQ (1),     -- variable-length control frames with ARQ
                broadcast (2),       -- fixed-length control frames with no ARQ
                circuitARQ (3),      -- variable-length control frames with ARQ
                                     -- and "keep-alive"
                fixedFrameARQ (4)    -- fixed-length control frames with ARQ
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "control mode currently (or most recenlty) in use on link; set operation determines
                preference, but other terminal in a link can override varFrameARQ (1) or circuitARQ (3)
                to force fixedFrameARQ (4)"
        ::= { hfdlp 2 }

hfdlpNegotiationMode OBJECT-TYPE
        SYNTAX INTEGER {
                normal (1),          -- negotiate changes only
                everySeries (2)      -- negotiate between every data series
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "negotiation mode currently (or most recently) in use on link; set operation determines
                preference, but other terminal in a link can override normal (1) to force everySeries (2)"
        ::= { hfdlp 3 }

hfdlpSelfAddress OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (2..18))
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "address of this terminal"
        ::= { hfdlp 4 }

hfdlpOtherAddress OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE (0..18))
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "address of other terminal in link; zero-length string if no link; all 1s if broadcast"
        ::= { hfdlp 5 }
```

```
hfdlpLinkState OBJECT-TYPE
        SYNTAX INTEGER {
            idle (1),
            calling (2),
            callAcknowledge (3),
            sending (4),        -- transmit terminal in link-up state
            receiving (5),      -- receive terminal in link-up state
            circuitIdle (6)     -- link-up state, but no traffic in progress
                                -- (ARQ Circuit Mode only)
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "link establishment state of HFDLP terminal; only the following values are valid in a set
            operation:
                    idle (1) forces terminal to drop link
                    calling (2) initiates a (re)connection attempt
                    sending (4) initiates Immediate mode message transfer"
        ::= { hfdlp 6 }

hfdlpMaxRetries OBJECT-TYPE
        SYNTAX INTEGER (0..7)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "maximum number of times transmit terminal will resend control frames; 0 means no
            retransmissions (set ignored by receive terminal)"
        ::= { hfdlp 7 }

hfdlpRetryCountdown OBJECT-TYPE
        SYNTAX INTEGER (0..7)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "remaining number of times terminal will send current control frame"
        ::= { hfdlp 8 }

hfdlpLinkTimeout OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "100 ms"
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "link timeout value in use by a transmit terminal or receive terminal"
        ::= { hfdlp 9 }
```

```
hfdlpFrameLength OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "data bytes per data frame in use by transmit terminal (set ignored by receive terminal)"
        ::= { hfdlp 10 }

hfdlpSeriesLength OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "frames per data series in use by transmit terminal (set ignored by receive terminal)"
        ::= { hfdlp 11 }


-- the AME group

ameForwarding OBJECT-TYPE
        SYNTAX INTEGER {
            relay (1),      -- entity forwards messages
            terminal (2)    -- entity does not forward messages
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Enables or disables message relay in networking controller"
        ::= { ame 1 }

ameAdaptiveRouting OBJECT-TYPE
        SYNTAX INTEGER {
            adaptive (1),   -- entity automatically updates Routing
                            -- Table from local data, HRMP, or HSSP
            static (2)      -- entity doesn't automatically update Routing Table
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "Enables or disables adaptive routing in networking controller.  (Always reads as static if
            no Routing Table.)"
        ::= { ame 2 }
```

```
ameAlternateMedia OBJECT-TYPE
        SYNTAX INTEGER {
              hfOnly (1),   -- entity routes messages only via HF links
              allMedia (2)  -- entity routes messages via any available links
        }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
              "Enables or disables multi media routing in networking controller. (Always reads as
              hfOnly if no Routing Table.)"
        ::=  { ame 3 }

ameRetryCount OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
              "Maximum number of delivery attempts before a message is discarded"
        ::=  { ame 4 }

ameRetryInterval OBJECT-TYPE
        SYNTAX INTEGER
        UNITS "seconds"
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
              "Initial retry interval for message delivery; subsequent intervals are larger"
        ::=  { ame 5 }

ameInReceives OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
              "Messages received by AME entity"
        ::=  { ame 6 }

ameInForwMsgs OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
              "Messages forwarded by AME entity"
        ::=  { ame 7 }
```

```
ameInUnknPorts OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Messages received by AME entity, but discarded due to unknown AME port numbers"
        ::= { ame 8 }

ameInDelivers OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Messages received by AME entity and delivered to higher-layer protocol"
        ::= { ame 9 }

ameOutRequests OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Messages from higher-layer protocol passed to AME entity for delivery."
        ::= { ame 10 }

ameOutDiscards OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Messages from higher-layer protocol discarded by AME entity after maximum retries"
        ::= { ame 11 }


-- the AME Routing Table

ameRoutingTable OBJECT-TYPE
        SYNTAX SEQUENCE OF AmeRouteEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The AME Routing Table"
        REFERENCE "see MIL-STD-187-721"
        ::= { ame 12 }
```

```
ameRouteEntry OBJECT-TYPE
        SYNTAX AmeRouteEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the AME Routing Table"
        INDEX { IMPLIED ameRouteDest ameRouteRank }
        ::= { ameRoutingTable 1 }

AmeRouteEntry ::=
        SEQUENCE {
            ameRouteDest
                    AleAddress,
            ameRouteRank
                    INTEGER,
            ameRouteIfIndex
                    INTEGER,
            ameRouteNextHop
                    AleAddress,
            ameRouteHops
                    INTEGER,
            ameRouteStatus
                    RowStatus
        }

ameRouteDest OBJECT-TYPE
        SYNTAX AleAddress
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Address of station to which message is to be routed"
        ::= { ameRouteEntry 1 }

ameRouteRank OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "Order of this route among all listed routes to the destination (1 is highest ranking).
            Routes should be ranked in order of preference"
        DEFVAL { 1 }
        ::= { ameRouteEntry 2 }

ameRouteIfIndex OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "interface (link layer controller) to use for this route"
        DEFVAL { 1 }
        ::= { ameRouteEntry 3 }
```

```
ameRouteNextHop OBJECT-TYPE
        SYNTAX AleAddress
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "address of relay (or destination if a direct route)"
        ::= { ameRouteEntry 4 }

ameRouteHops OBJECT-TYPE
        SYNTAX INTEGER
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "number of hops (links) in this route to destination"
        DEFVAL { 1 }
        ::= { ameRouteEntry 5 }

ameRouteStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and deleting AME Routing Table entries"
        DEFVAL { active }
        ::= { ameRouteEntry 6 }

END
```

APPENDIX B

ABSTRACT SYNTAX NOTATION (HNMP DEFINITIONS)

```
HNMP DEFINITIONS ::= BEGIN

IMPORTS
        ObjectName, ObjectSyntax, Integer32, MODULE-IDENTITY
            FROM SNMPv2-SMI; -- RFC 1442

hnmp    MODULE-IDENTITY
        LAST-UPDATED "9408021914Z"
        ORGANIZATION "U.S. Army Information Systems Engineering Command"
        CONTACT_INFO
            "           Eric E. Johnson

            Postal:     New Mexico State University
                        Dept 3-O, (Electrical Computer Engineering)
                        Las Cruces, NM   88003-0001
                        USA

              Tel:      +1 505 646 4739
              Fax:      +1 505 646 1435

            E-mail:     ejohnson@nmsu.edu"

        DESCRIPTION "The HF Network Management Protocol for MIL/FED-STD automated HF
                     radio networks"
        ::= { hf 15 } -- normally encoded as { 2 43 15 }

        HfObjID ::=
          [PRIVATE 0]
            IMPLICIT OBJECT IDENTIFIER

        HfObjectName::=
          CHOICE {
            long-form               -- uses full path to the root
                    ObjectName,
            short-form              -- uses truncated path starting with HF MIB flag { 2 43 } encoded as
                                       123
                    HfObjID
        }

        HfObjectSyntax::=
          CHOICE {
            smi-object-value        -- universal and application types from SMI
                    ObjectSyntax,
            hfObjID-value           -- truncated object ID starting with HF MIB flag { 2 43 } encoded as
                                       123
                    HfObjID
        }
```

```
-- protocol data units

PDUs::=
   CHOICE {
     get-request
       GetRequest-PDU,

     get-next-request
       GetNextRequest-PDU,

     get-bulk-request
       GetBulkRequest-PDU,

     get-rows-request
       GetRowsRequest-PDU,

     response
       Response-PDU,

     get-rows-response
       GetRowsResponse-PDU,

     set-request
       SetRequest-PDU,

     inform-request
       InformRequest-PDU,

     snmpV2-trap
       SNMPv2-Trap-PDU
}

--PDUs
GetRequest-PDU::=
   [0]
     IMPLICIT PDU

GetNextRequest-PDU::=
   [1]
     IMPLICIT PDU

Response-PDU::=
   [2]
     IMPLICIT PDU

SetRequest-PDU::=
   [3]
     IMPLICIT PDU

-- [4] is obsolete
```

```
GetBulkRequest-PDU::=
  [5]
    IMPLICIT BulkPDU

InformRequest-PDU::=
  [6]
    IMPLICIT PDU

SNMPv2-Trap-PDU::=
  [7]
    IMPLICIT PDU

GetRowsRequest-PDU::=
  [28]
    IMPLICIT BulkPDU

GetRowsResponse-PDU::=
  [29]
    IMPLICIT RowsPDU

max-bindings
  INTEGER::=2147483647

PDU::=
  SEQUENCE {
    request-id
      Integer32,

    error-status               -- sometimes ignored
      INTEGER {
        noError(0),
        tooBig(1),
        noSuchName(2),         -- for proxy compatibility
        badValue(3),           -- for proxy compatibility
        readOnly(4),           -- for proxy compatibility
        genErr(5),
        noAccess(6),
        wrongType(7),
        wrongLength(8),
        wrongEncoding(9),
        wrongValue(10),
        noCreation(11),
        inconsistentValue(12),
        resourceUnavailable(13),
        commitFailed(14),
        undoFailed(15),
        authorizationError(16),
        notWritable(17),
        inconsistentName(18)
      },
```

```
        err-index               -- sometimes ignored
          INTEGER (0..max-bindings),

        variable-bindings       -- values are sometimes ignored
          VarBindList
      }

    BulkPDU::=                  -- MUST be identical in
      SEQUENCE {                -- structure to PDU
        request-id
          Integer32,

        non-repeaters
          INTEGER (0..max-bindings),

        max-repetitions
          INTEGER (0..max-bindings),

        variable-bindings       -- values are ignored
          VarBindList
    }

    RowsPDU::=                  -- MUST be identical in
      SEQUENCE {                -- structure to PDU
        request-id
          Integer32,

        non-repeaters
          INTEGER (0..max-bindings),

        max-repetions
          INTEGER (0..max-bindings),

        non-repeater-bindings
          VarBindList,

        row-bindings
          RowBindList
      }
```

```
-- variable binding

VarBind::=
  SEQUENCE {
    name
      HfObjectName,

    CHOICE {
      value
        HfObjectSyntax,
      unSpecified          -- inretrieval requests
            NULL,
                           -- exceptions in responses
      noSuchObject[0]
            IMPLICIT NULL,

      noSuchInstance[1]
            IMPLICIT NULL,

      endOfMibView[2]
            IMPLICIT NULL
    }
  }

-- variable-binding list

VarBindList::=
  SEQUENCE (SIZE (0..max-bindings)) OF
    VarBind
```

```
-- row-binding

RowBind::=
  SEQUENCE {
    name                  -- object name of first object only
      HfObjectName,

    SEQUENCE OF           -- followed by values of all objects request in row
      CHOICE {            -- containing first object
        value
          HfObjectSyntax,
                          -- exceptions in responses
        noSuchObject[0]
            IMPLICIT NULL,

        noSuchInstance[1]
            IMPLICIT NULL,

        endOfMibView[2]
            IMPLICIT NULL,

        wrongRow[3]
            IMPLICIT NULL
      }
    }


-- row-binding list
RowBindList::=
  SEQUENCE OF
    RowBind

END
```

CONCLUDING MATERIAL

Custodians:
Army - SC
Navy - EC
Air Force - 90

Review activities:
Army - CR
Navy - MC
DoD - DC, NS, DI

User activities:
Army - AC, PT
Navy - NC, TD, OM, CG
Air Force - 02,13,21
DoD - DH, ECAC, MP
DOT - FAA, OST

Civil agency coordinating activities:
NCS

Preparing activity:
Army - SC

(Project TCSS-7213)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-STD-187-721C	2. DOCUMENT DATE *(YYMMDD)* 941130

3. DOCUMENT TITLE
Interface and Performance Standard for Automated Control Applique for HF Radio

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b. ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d. TELEPHONE *(Include Area Code)* (1) Commercial (2) AUTOVON *(If applicable)*	7. DATE SUBMITTED *(YYMMDD)*

8. PREPARING ACTIVITY

a. NAME	b. TELEPHONE *(Include Area Code)*
Department of the Army U.S. Army Information Systems Engineering Command	(1) Commercial (602) 538-3188 (2) AUTOVON 879-3188
c. ADDRESS *(Include Zip Code)* ATTN: ASQB-OST Fort Huachuca, Arizona 85613-5300	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340