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DEPARTMENT OF DEFENSE INTERFACE STANDARD

INTEROPERABILITY AND PERFORMANCE STANDARD
FOR ADVANCED ADAPTIVE HF RADIO



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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: AMSEL-IE-CO, 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.
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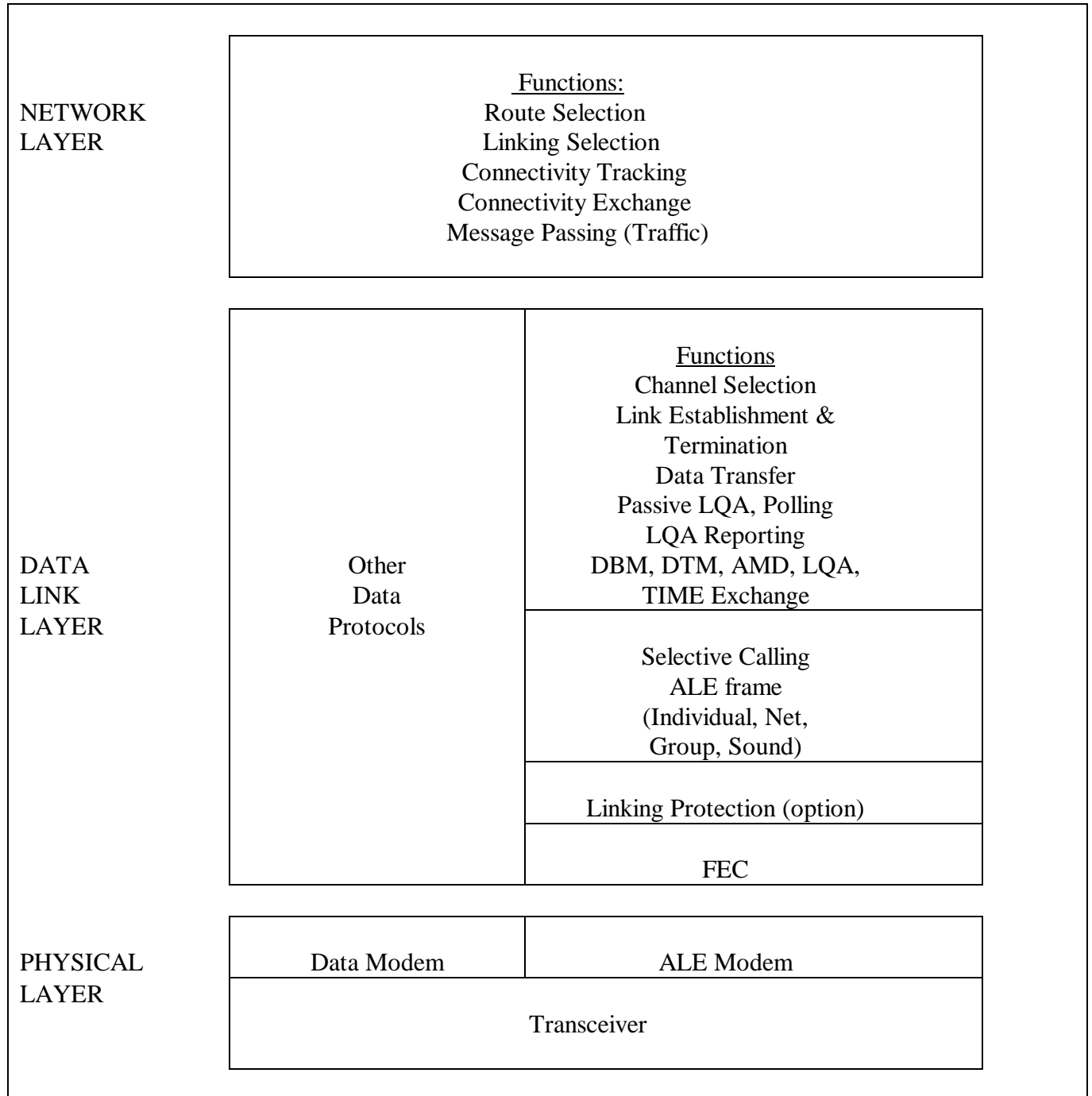
6. The treatment of the basic HF radio and the adaptive technologies for the HF radio contained in MIL-STD-188-141 provides the technical foundation upon which this document rests. The current baseline second generation automatic link establishment (ALE) system was one of the adaptive high frequency (HF) radio features developed through a Massachusetts Institute of Technology Research & Engineering (MITRE) effort in 1986.
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. 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 unmanned (lights out) operation of HF standards.
9. The technical parameters of this standard have not been verified by testing or implementation. Careful engineering, desktop 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 Standardization Activity (see address below) of planned implementations, the status of those implementations, and any problems encountered in applying this standard.

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Functional hierarchy of an automated HF station.

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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. The advanced technology contained in this standard 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.

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 systems and 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 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 paragraph 6.1.2.

2. APPLICABLE DOCUMENTS

2.1 General.

The documents listed in this section are specified in sections 3,4, and 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3, 4, and 5 of this standard, whether or not they are listed.

2.2 Government documents.

2.2.1 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.
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DEPARTMENT OF DEFENSE

MIL-STD-188-110	Interoperability and Performance Standards for HF Data Modems.
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MIL-STD-188-141	Interoperability and Performance Standards for Medium and High Frequency Radio Equipment.
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MIL-STD-188-148	(S) Interoperability Standard for Anti-Jam (AJ) Communications in the High Frequency Band (2-30MHz) (u)
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(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Document Order Desk, 700 Robbins Avenue, Building #4, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings, and publications.

2.3 Non-Government publications.

2.4 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 the current edition of FED-STD-1037. In addition, the following definitions are applicable for the purposes of this standard.

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.

Multiple media - Transmission media using more than one type of transmission path (e.g. optical fiber, radio, and copper wire) to deliver information.

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.

Abn	Airborne
ACK	acknowledgment
ADC	available data capacity
AI	articulation index
ALE	automatic link establishment
ALM	automatic link maintenance
ALQA	automatic link quality analysis
AME	automatic message exchange
ARQ	automatic repeat-request
ASCII	American Standard Code for Information Interchange
AVQ	achievable voice quality
BCD	binary coded decimal
BER	bit error ratio
b/s	bits per second
<u>CMD</u>	ALE preamble word <u>COMMAND</u>
<u>CQM</u>	channel quality measure
<u>DATA</u>	ALE preamble word <u>DATA</u>

dB	decibel
dBm	decibel referenced to one milliwatt
DBM	data block message
DO	design objective
DTM	data text message
EFI	error-free interval
FEC	forward error correction
GPS	Global Positioning System
HF	high frequency
HFDLP	HF data link protocol
HFNC	HF networking controller
HMTF	HF mail transfer protocol
hr	hour
Hz	hertz
ICD	interface control document
IONCAP	program of link quality predictions
LAT	latitude
LP	linking protection
LPM	link performance measure
LQA	link quality analysis
LON	longitude
LSB	least significant bit
min	minutes
MP	multipath
ms	milliseconds
MSB	most significant bit
NAK	negative acknowledgment
NCS	net control station
No Op	no operational
PBER	pseudo bit error ratio
PDU	protocol data unit
ppm	parts per million
PSK	phase shift key
s	second
SD	spectral distortion

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

UTC universal time, coordinated

3.3 Timing symbols.

T_{rw} redundant word time

T_{sc} scanning call phase

T_w wait time

3.4 ALQA mathematical expressions.

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

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

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

L_m length of message body (ADC)

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

N_{oi} noise spectral density in the i-th frequency band

R effective message data rate (ADC)

S_i signal spectral density in the i-th frequency band

T_b beginning time of message transfer (ADC)

T_f time when message transfer finishes (ADC)

U station utilization (ADC)

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 that 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.

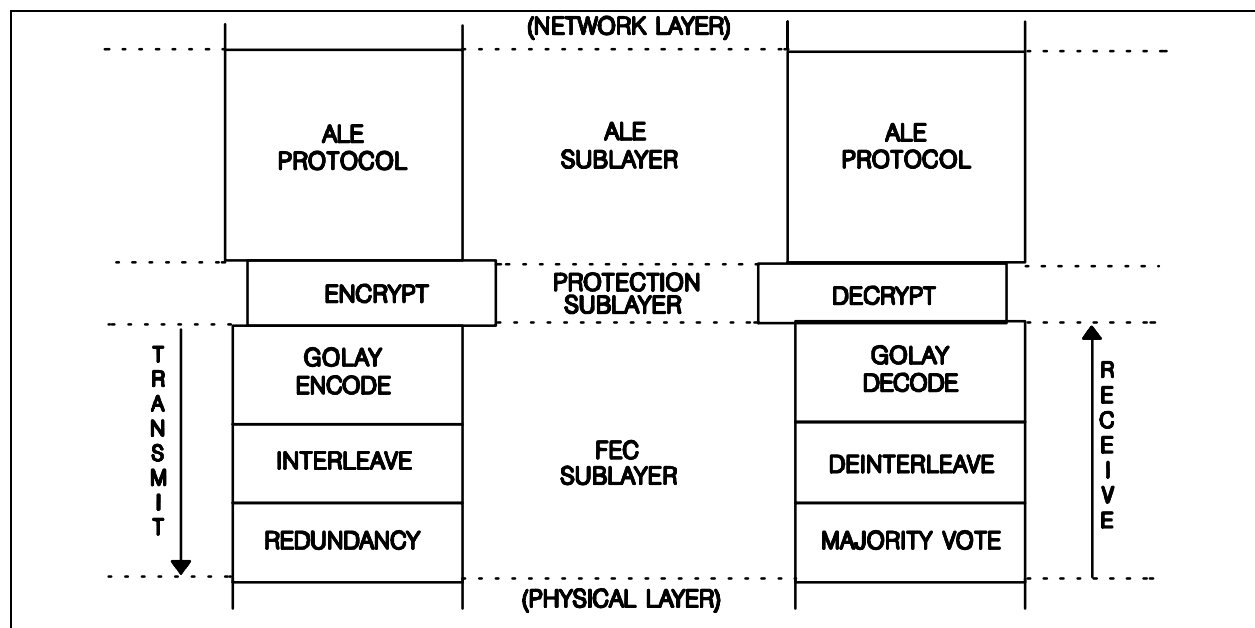


FIGURE 1. Conceptual model of data link layer protocols in MIL-STD-188-141.

4.2 Linking protection.

See MIL-STD-188-141.

4.3 Time of day (TOD) synchronization.

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 that 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 XVI, 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 $h_X(i; j+1, k)$, and the oldest histogram $h_X(i; N_k, k)$ shall be discarded. Epoch 4 is a special case; epoch 4 counters shall simply accumulate all samples, with no averaging over individual integrating periods.

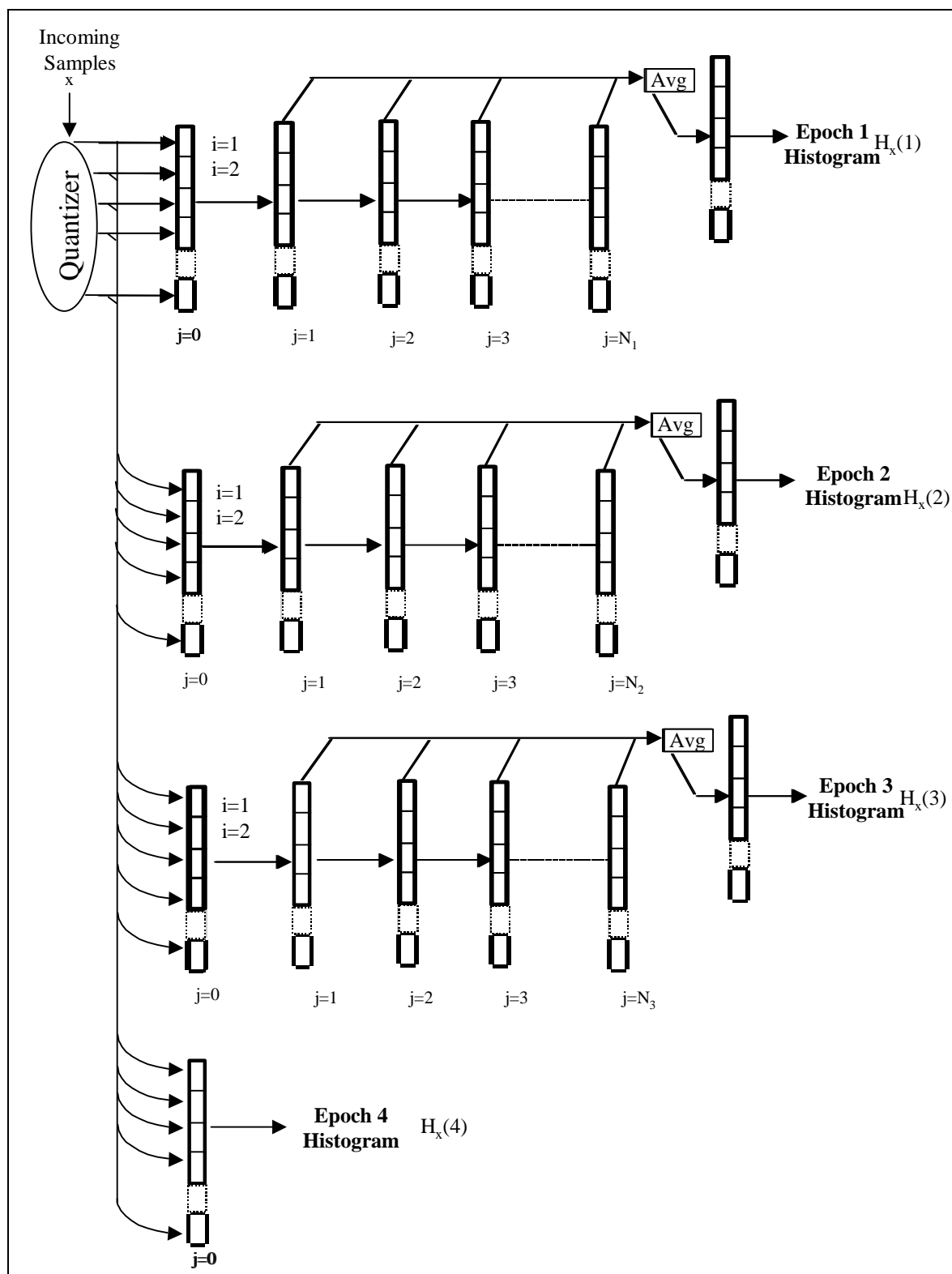


FIGURE 2. Histogram generation.

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 $H_x[i; k]$):

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

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.

See MIL-STD-188-141.

4.7 Interface to link controllers.

See MIL-STD-188-141.

4.8 Network management.

See MIL-STD-188-141.

4.9 Multi-media networks.

See MIL-STD-188-141.

4.10 New ALE or orderwire functions.

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

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TABLE I. 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	*A.5.6.6.2
	d	1100100	Data Port Selection	5.6.4.4
	n	1101110	Modem Negotiation	*A.5.6.6.1
	q	1110001	Digital Squelch	5.6.4.6
	z	1111010	Digital LINCOMPEX Zeroize	5.6.4.5
n	1101110		Noise Report	*A.5.4.4
p	1110000		Power Control	*A.5.6.3
r	1110010		LQA Report	*A.5.4.3
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	1101100	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
	w	1110111	Set Slot Width	5.6.6.15
	x	1111000	Do Not Respond	*A.5.6.8
	y	1111001	Year and Date	5.6.6.16
	z	1111010	Zulu Time	5.6.6.17
v	1110110	c 1100011	Capabilities	*A.5.6.7.2
		s 1110011	Version	*A.5.6.7.1
~	1111110		Time Exchange	*A.5.6.4.3

* MIL-STD-181-141

4.11 Automatic link maintenance.

Automated HF systems that implement automatic link maintenance (ALM) shall monitor link quality after link establishment and negotiate changes in operating frequency and power as described in 5.11. Changes in data rate and interleaver shall be negotiated by the HFDLP as described in FED-STD-1052.

4.11.1 Link quality monitoring.

Quality of an established link shall be monitored by the subsystem using the link and reported to the link maintenance controller. Alternate channels shall be evaluated using transmissions on unused traffic channels in the unused direction while a link is in progress.

4.11.2 Frequency negotiation.

When a link is in use for voice traffic, a single third-generation ALE (see 4.12) Response PDU containing a Preferred Channel command shall be sent at the end of each transmission and after every 10 seconds of uninterrupted voice transmission. The HFDLP Automatic Link Maintenance protocol shall be used to negotiate alternate frequencies when HFDLP is in use (see 5.11).

If either station detects imminent link failure, it shall initiate a frequency change using either the HFDLP, when it is in use, or by sending a repeated third-generation ALE Commence Traffic PDU that names the new channel. When the stations have completed a three-way handshake containing Commence Traffic or the equivalent HFDLP commands, they shall change to the new frequencies.

If the link fails without negotiation of a frequency change, the system that detects the failure shall automatically initiate link establishment on the most recently named alternate channel from the other station.

4.11.3 Automatic power control.

Third-generation ALE systems shall automatically adjust transmitter power in response to power control commands sent in the unused link direction on the associated calling channel.

4.12 Advanced automatic link establishment.

Advanced automatic link establishment, also known as third-generation automatic link establishment (ALE), provides functionality similar to second-generation ALE as described in MIL-STD-188-141 Appendix A, but with improved ability to link in stressed channels, to link more quickly, and to operate efficiently in large, data-oriented networks. Third-generation ALE is optional, but if implemented shall comply with MIL-STD-188-141, Appendix C, Third Generation HF Automation..

4.13 System parameters by address.

Not yet standardized. (This optional feature will extend the station table to include recommended antennas, antenna azimuths, frequencies, modems, and coding for use in communicating with each listed station.)

4.14 HF e-mail.

Messages sent using HF skywave links shall use the following protocols to ensure interoperability, performance, and high efficiency. Use of other protocols (e.g., for surfacewave applications) requires a gateway for conversion to and from this suite. Interface to the Internet also requires a gateway for conversion to and from this suite.

The HF Mail Transfer Protocol (HMTP) shall be used at the Application Layer.

The Automatic Message Exchange (AME) protocol in accordance with MIL-STD-188-141 Appendix D shall be used at the Network Layer.

The HF Data Link Protocol (HFDLP) in accordance with MIL-STD-188-110 Appendix B shall be used at the Data Link Layer.

The Physical Layer shall consist of serial-tone HF data modems in accordance with MIL-STD-188-110 and HF radios in accordance with MIL-STD-188-141.

See MIL-STD-188-141 for details.

4.15 Automatic location feature.

Automatic location reporting is an optional feature. If provided, it shall comply with this section and section 5.15.

4.15.1 Automatic reporting.

If implemented in a second-generation ALE system, the automatic location feature shall embed a Location Report CMD (see 5.15) in the message section of each ALE transmission. Location reporting for third-generation ALE systems is not yet standardized. The specific version of the CMD sent determines the precision of the location report; this selection shall be programmable at the network management interface.

4.15.2 Disable capability.

The operator shall have the capability to disable automatic reporting, and to manually send a location report while automatic reporting is disabled.

4.15.3 Secure transmission.

Location reports constitute sensitive information. Procuring agencies shall determine the degree of security required for location reports. Use of Linking Protection in accordance with MIL-STD-188-141 Appendix B provides a range of cryptographic protection from Type IV to Type I algorithms.

5. DETAILED REQUIREMENTS

5.1 Linking protection.

See MIL-STD-181-141.

5.2 Time exchange protocols.

See MIL-STD-188-141.

5.3 Channel and frequency designators.

See MIL-STD-188-141.

5.4 Link quality functions.

The central data structure for the link quality functions is the LQA matrix in MIL-STD-188-141, the figure on connectivity and LQA memory.

5.4.1 LQA matrix.

This is an array of link quality records, each containing bi-directional measurements for (at least) BER, SINAD, and multipath (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 II.

TABLE II. 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.

See MIL-STD-188-141.

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 3).
- 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 TWAS 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.

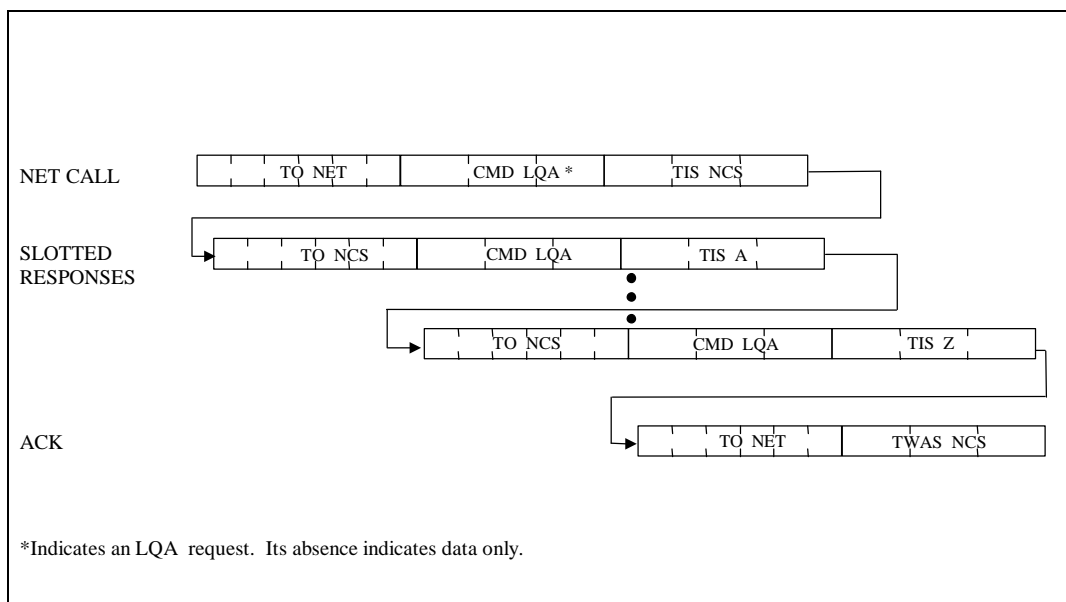


FIGURE 3. Hub net poll (T_{sc} not shown).

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 4). 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 TWAS 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 non-responding net members (including the hub) shall be filled with “no report” words.

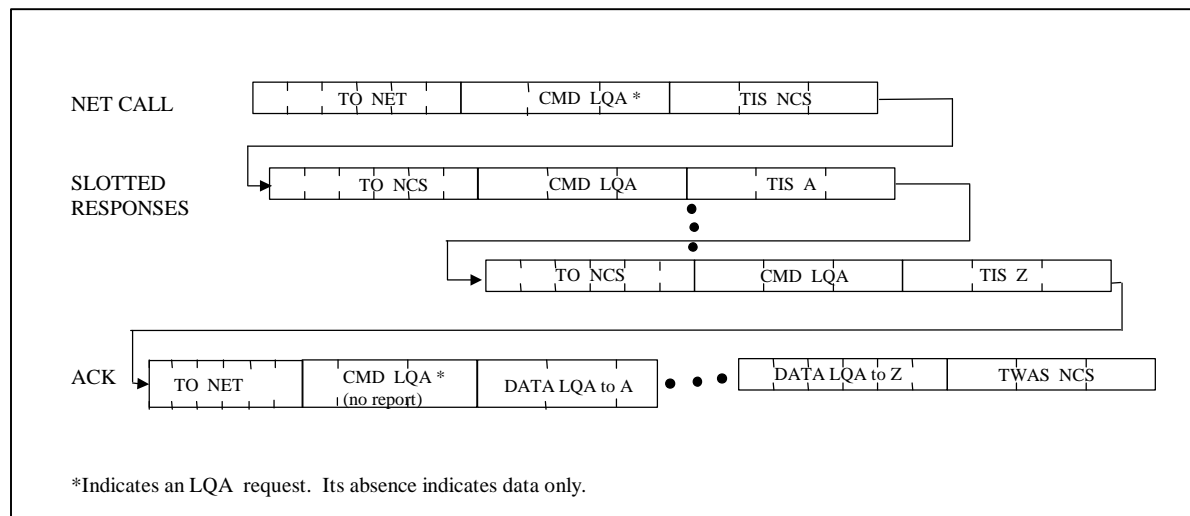


FIGURE 4. Full net poll (T_{sc} not shown).

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 5).

(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
<u>CMD</u>	Channels (ASCII ‘c’)	Type	Tune	Mode	Control
110	1100011	00			

FIGURE 5. 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 III. It indicates the time that must be allowed for tuning before each non-scanning call.

TABLE III. 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 IV. 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 IV. 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 6. 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 V). In either case, the message carrying the reports shall immediately follow the LQA report command word.

3	7	2	5	2	5
<u>CMD</u>	LQA Report (ASCII 'r')	Type	Control	*	Chan
110	1110010	00		00	

* Reserved block (set to 00)

FIGURE 6. LQA report CMD format.

TABLE V. 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 7). 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 MIL-STD-188-141, section entitled “Channel Designation or Frequency designation.”

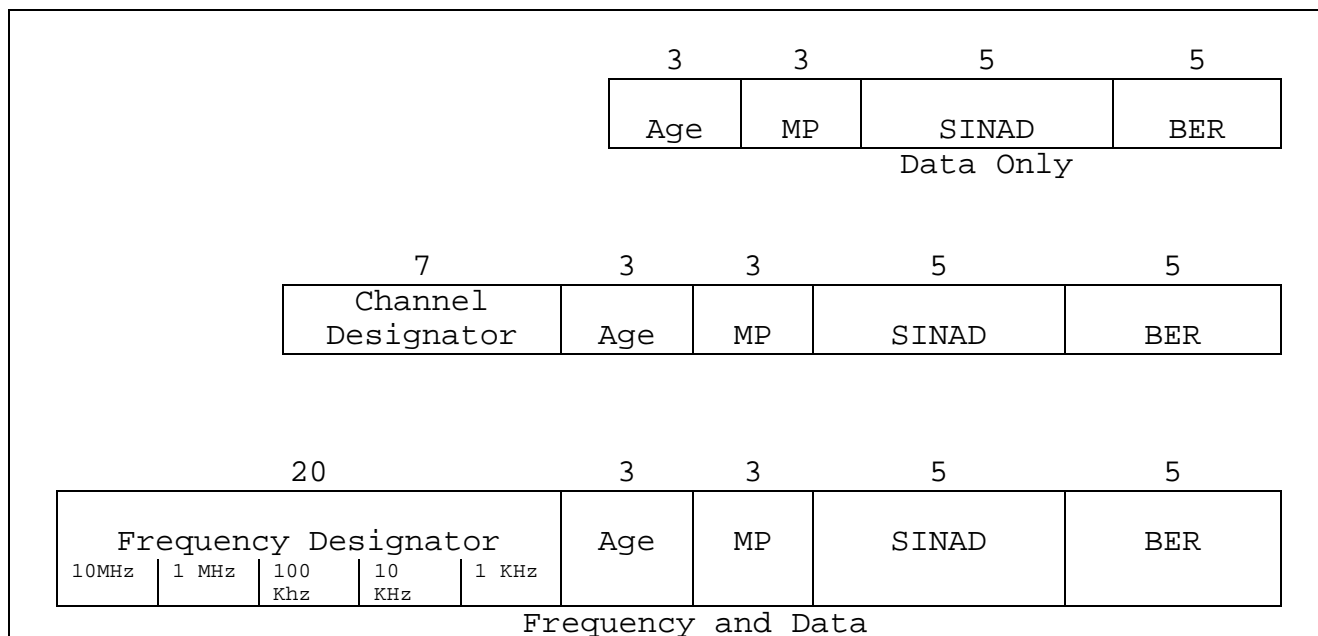


FIGURE 7. LQA report formats.

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 (1111) 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 VI.

TABLE VI. 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 8. The bits of the control field are used to request the format of LQA reports, and shall be assigned in accordance with table V. The Age field specifies the maximum age acceptable for the reports and shall be encoded in accordance with table VI. 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
<u>CMD</u>	LQA Report (ASCII 'r')	Type	Control	*	Age
110	1110010	10		0000	
* Reserved block (set to 0000)					

FIGURE 8. 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 VII. (The weights F_i shown in table VII 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 VII. 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 $1 \text{ dB} \leq E_i \leq 12 \text{ dB}$, get W_i from table VIII.
- (3) For $12 \text{ dB} < E_i \leq 36 \text{ dB}$, $W_i = (E_i - 6)/30$.
- (4) For $E_i > 36 \text{ dB}$, $W_i = 1$.

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 VII 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 VIII. E_i to W_i conversion (1 dB $\leq E_i \leq 12$ 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 9). Each (e.g., SINAD and PBER) measurement pair falls within one of the regions on figure 9; the number of that region is the spectral distortion measurement for that received ALE word. Spectral distortion measurements shall be histogrammed in accordance with 4.5.3.
- b. Points along the lines that separate the regions shown on figure 9 are tabulated in table IX; 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 X, 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.

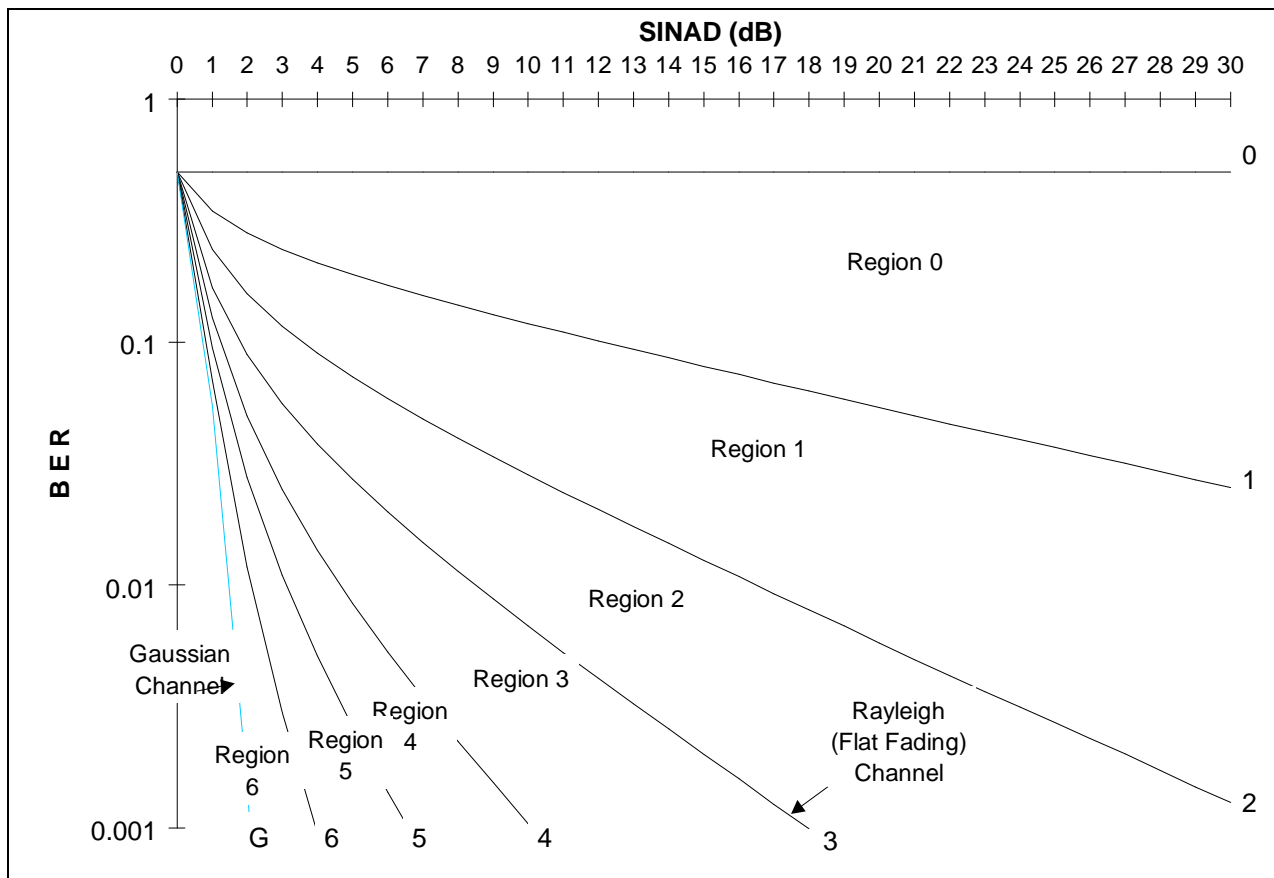


FIGURE 9. Spectral distortion partition of BER versus SINAD sample space.

TABLE IX. 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				

- (3) Use the SINAD code to select a row in table X.
- (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 XI 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:

$$2P_e = \frac{\text{Total errors}}{\text{Total words}} \qquad P_b = \frac{\text{Burst errors}}{\text{Total errors}}$$
$$\text{EFI} = \frac{(1/P_e) - 1}{1 - P_b}.$$

TABLE X. 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 - 12	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 XI. 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 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.

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 the 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. (If possible, also compute available data capacity samples when messages are sent by other data link controllers.) See table XII for the applicable symbology. Available data capacity samples require the measurements for the symbols listed in table XII for each message sent.

TABLE XII. 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 acknowledgment. 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,

$$R = \frac{2100}{100} = 21 \text{ b / s}$$

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

$$x = 21(1 - 0.40) = 12.6 \text{ b / s}$$

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 10 through 13 and 15) 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 XIII). (Note that the Epoch field in a report need not have the same value as in the request.)

TABLE XIII. 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 XIV. 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 XIV. 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 <u>CMD</u>

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 10. The Control and Epoch fields shall be encoded as described above. Each channel quality measure selector bit (see table XV) 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
<u>CMD</u>	1100000 (“”:ALQA)	10	Control	Epoch	CQM 1-5

FIGURE 10. ALQA channel quality measure request CMD format.

TABLE XV. Channel quality measure selector bit assignments.

Selector Bit	Channel Quality Measure (CQM)
CQM5 (MSB)	SINAD
CQM4	$P_c = 1 - \text{PBER}$
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 11) encoded as in table XVI. 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 XVI.

3	2	4	4	4	3	4
<u>DATA</u>	00	SINAD	$P_c = 10 \text{ PBER}$	AI	SD	0000

FIGURE 11. ALQA channel quality measure threshold word.

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

Code	SINAD (dB)	$P_C = 1 - \text{PBER}$	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 12. 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 XVI. (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
<u>CMD</u>	1100000 ("":ALQA)	11	Control	Epoch	D	LPM Threshold

FIGURE 12. ALQA link performance measure request CMD format.

5.5.3.4 Channel quality measure reports.

The channel quality measure report CMD (figure 13) 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
<u>CMD</u>	1100000 (“^”:ALQA)	00	Control	Epoch	Channels

FIGURE 13. Channel quality measure report CMD format.

Channel quality measure reports shall be formatted as illustrated on figure 14, 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 XVI 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.

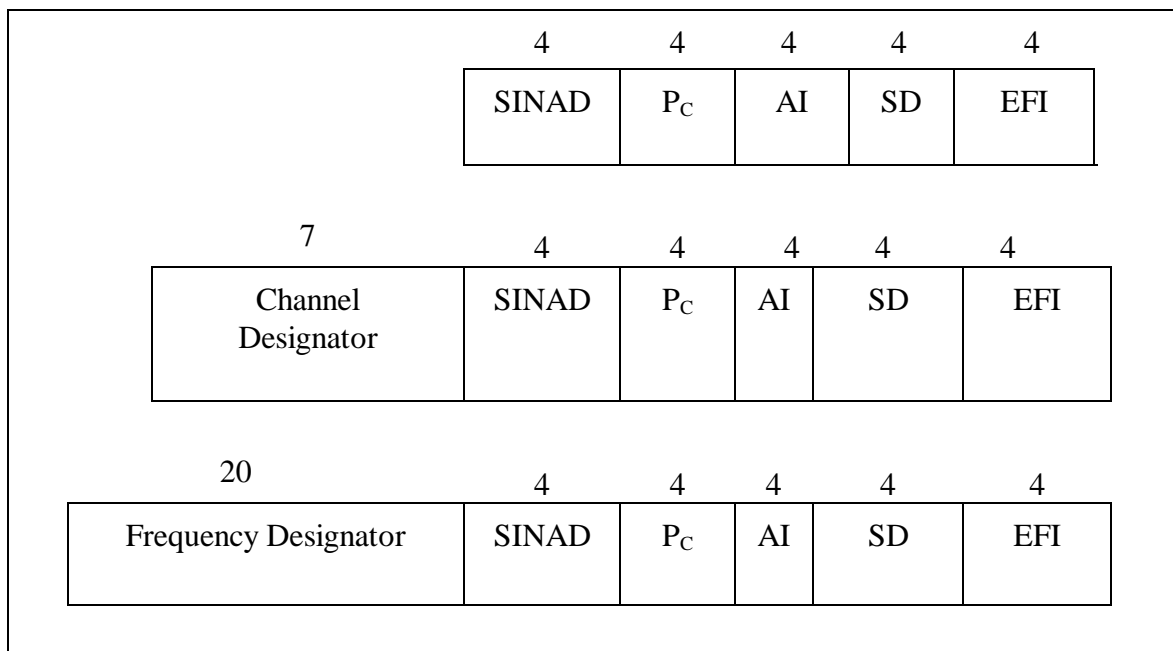


FIGURE 14. Channel quality measure report formats.

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 15. 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 XVI.

3	7	2	5	2	1	4
<u>CMD</u>	1100000 ("": ALQA)	01	Control	Epoch	D	LPM Report

FIGURE 15. 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.

See MIL-STD-188-141.

5.6.2 Capabilities function.

See MIL-STD-188-141.

5.6.3 Frequency select CMD.

See MIL-STD-188-141.

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.

5.6.4.1 Modem negotiation and handoff.

See MIL-STD-188-141.

5.6.4.2 Crypto negotiation and handoff.

See MIL-STD-188-141.

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 16. The bits of the analog port field in the CMD are assigned as indicated in table XVII. 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.

NOTES:

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

3	7	7	7
<u>CMD</u>	1101101 ("m": mode control)	1100001 ("a": analog port select)	Analog Port Bits

FIGURE 16. Analog port selection CMD format.

TABLE XVII. 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 17). Other port numbers from 3 through 15 have station-specific meanings.

3	7	7	3	4
<u>CMD</u>	Mode Control (ASCII “m”)	Data Port Select (ASCII “d”)	*	Port No.
110	1101101	1100100	000	

* Reserved block (set to 000)

FIGURE 17. 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 18). The subcommand position shall be set to 1111111 to initiate zeroization.

3	7	7	7
CMD	1101101 (“m” : mode control)	1111010 (“z” : LINCOMPEX zeroize)	Subcommands

FIGURE 18. Digital LINCOMPEX zeroization CMD format.

5.6.4.6 Digital squelch.

The digital squelch command format, figure 19, 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
<u>CMD</u>	1101101 (“m”: mode control)	1110001 (“q”: digital squelch)	(Subcommand)

FIGURE 19. Digital squelch CMD format.

5.6.5 Power control.

See MIL-STD-188-141.

5.6.6 Scheduling functions.

Table XVIII lists the groups of ALE scheduling functions that are defined in the following paragraphs:

TABLE XVIII. Groups of ALE scheduling functions.

Group	Scheduling functions	Second character	Date/Time option	Cross reference
Future Calls	Contact Later	l (1101100)	Yes	5.6.6.6
	Meet Me	m (1101101)		5.6.6.7
	Quiet Contact	q (1110001)		5.6.6.11
Wait on channel	Halt and Wait	h (1101000)	No	5.6.6.5
	Respond and Wait	r (1110010)		5.6.6.12
	Tune and Wait	t (1110100)		5.6.6.14
	Do Not Respond	x (1111000)		A.5.6.8 *
Congestion Management	Station Busy	b (1100010)	No	5.6.6.2
	Channel Busy	c (0011100)		5.6.6.3
	Set Dwell Time	d (1100100)		5.6.6.4
Slot Width	Adjust Slot Width	a (1100001)	No	5.6.6.1
	Set Slot Width	w (1110111)		5.6.6.15
Periodic Functions	Schedule Periodic Function	p (1110000)	Yes	5.6.6.10
	Set Sounding Interval	s (1110011)		5.6.6.13
Poll Operator	Poll Operator (default NAK)	n (1101110)	Yes	5.6.6.8
	Request Operator			5.6.6.9
	ACK	o (1101111)		
Date and Time	Year and Date	y (1111001)	(Implicit)	5.6.6.16
	Zulu Time	z (1111010)		5.6.6.17

* MIL-STD-188-141

a. Each of these functions employs a scheduling CMD word with the generic format shown on figure 20. 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 XIX. 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).

3	7	7	7
<u>CMD</u>	1110100 (‘t’: scheduling)	Second Character	Time Code or Special

FIGURE 20. Generic scheduling CMD.

TABLE XIX. Time codes for scheduling.

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

b. In some cases noted in table XVIII (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 21. 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 with the desired hour (0-23), and the Minute field with 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	4	5	1	5	6
<u>DATA</u>	Month	Day	z	Hour	Minute

FIGURE 21. 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 W₄₋₁₀ 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 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 TWAS and return to scan. Otherwise (either no operator response by time “T”, or a request for negative acknowledgment), the ALE controller shall respond with a transmission terminating in TIS (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 TWAS and return to scan. If the operator requests a negative acknowledgment, the ALE controller shall respond with a transmission terminating in TIS 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 indicted 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 CMDs. 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 22 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 in accordance with figure 20) report the year, date, and time. Other values in the third character position are reserved, and shall not be used until standardized.

NOTE: Implementors of this function shall ensure that year 00 is interpreted as greater than year 99 so no difficulties occur when a CMD sent in 1999 schedules an event in 2000.

3	7	7	7
<u>CMD</u>	1110100 ("t": scheduling)	1111001 ("y": year and date)	Year (00-99)

FIGURE 22. 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 on figure 23 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 in accordance with figure 20) 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
<u>CMD</u>	1110100 ("t": scheduling)	1111001 ("z": time)	Half Second Year (0-119)

FIGURE 23. Zulu time CMD.

5.6.6.18 Do not respond.

See MIL-STD-188-141.

5.7 Networking functions.

See MIL-STD-188-141.

5.8 Network management.

See MIL-STD-188-141.

5.9 Multimedia operation.

See MIL-STD-188-141.

5.10 HFNC interface to local equipment (station data bus).

See MIL-STD-188-141.

5.11 Automatic link maintenance protocol.

The HF Data Link Protocol (HFDLP) of MIL-STD-188-110 shall be extended as follows to support ALM.

5.11.1 Control frame CMDs for link maintenance.

Automatic link maintenance CMDs shall be embedded in HFDLP control frames in the Extended function bits. An ALM CMD shall be indicated by a User ID code of 3FFE in hexadecimal (11 1111 1111 1110 binary). ALM CMDs shall be embedded in the 50 Function Bits as shown on figure 24.

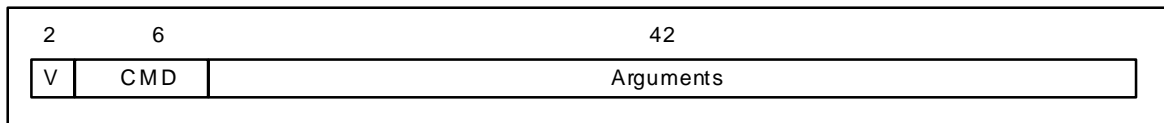


FIGURE 24. ALM CMD format in HFDLP control frame function bits.

The V bits shall indicate the version of the HFDLP ALM CMD set in use. The current version is 00. The CMD field shall contain one of the CMDs listed below. The Arguments field shall contain arguments to the CMDs as indicated in the appropriate CMD description paragraph below.

The CMDs defined are in table XX for version 0 of the HFDLP ALM protocol:

TABLE XX. HFDLP ALM commands.

CMD Code	CMD Name	Arguments
000000	No Op	(none)
000001	Preferred Channels	One or more 7-bit channel numbers
000010	Assign Frequency	Flags, channel number, frequency
000011	Change Frequency	Frequency
000100	Adjust Power	Flags, adjustment
all others	(reserved until standardized)	

Channel numbers in the HFDLP ALM protocol are 7 bits long. When used with second-generation ALE, the 7 bits shall be interpreted as a channel number with a valid range of 1 to 100.

When used with third-generation ALE, the 7 bits shall be interpreted as follows: the two most-significant bits shall select a channel list, and the five least-significant bits shall select a channel within that list. When the channel list bits are 00, they shall be interpreted as selecting the current channel list; otherwise, they shall select channel list 1, 2 or 3 (see 4.12.1.2.2).

5.11.1.1 HFDLP ALM No Operational (No Op) CMD.

The No Op CMD shall be sent when no other CMD is appropriate. No arguments are needed. The argument bits shall all be set to 0.

5.11.1.2 HFDLP ALM Preferred Channels CMD.

The Preferred Channels CMD shall be sent to indicate alternative traffic channels for use when changing frequencies from the current channel. One or more 5-bit channel numbers shall be sent as arguments to this CMD (see figure 25). The channel number in the most-significant bits of the Arguments field is the most preferred alternative channel, with other channels listed in descending order of preference. When fewer than six channels are specified, the least-preferred channel number shall be repeated as required to fill the arguments field.

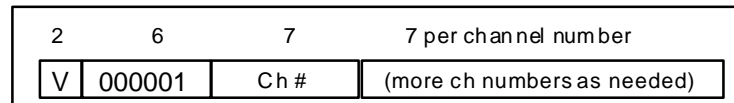


FIGURE 25. HFDLP ALM preferred channels CMD.

5.11.1.3 HFDLP ALM assign frequency CMD.

The Assign Frequency CMD shall be sent to assign a frequency to a channel number as shown on figure 26.

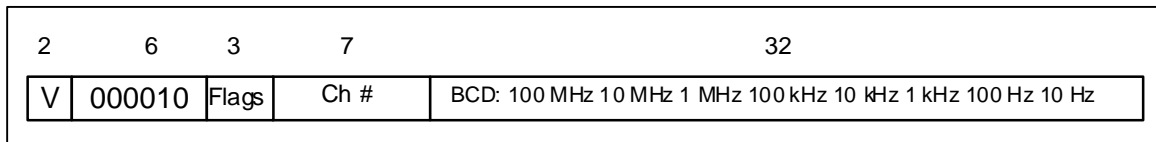


FIGURE 26. HFDLP ALM assign frequency CMD.

The Flags field shall indicate whether the specified frequency is absolute or relative to the frequency currently in use to carry traffic to the station sending the CMD (see table XXI).

TABLE XXI. Flags in HFDLP ALM frequency CMDs.

Flags	Meaning of Frequency Field
000	(reserved)
001	Absolute frequency
010	Negative offset from current frequency
011	Positive offset from current frequency
1xx	(reserved)

The frequency (or frequency offset) shall be represented in binary coded decimal (BCD), 4 bits per digit, with digits for 100, 10, and 1 MHz; 100, 10, and 1 kHz, and 100 and 10 Hz.

5.11.1.4 HFDLP ALM change frequency CMD.

The Change Frequency CMD shall be sent to indicate a new operating frequency as shown on figure 27.

2	6	3	7	32
V	000011	000	Ch #	...000...
2	6	3	7	32
V	000011	Flags	0000000	BCD: 100 MHz 10 MHz 1 MHz 100 kHz 10 kHz 1 kHz 100 Hz 10 Hz

FIGURE 27. HFDLP ALM change frequency CMD.

When the Flags field is set to 000, the Channel Number field shall indicate the new channel for traffic. When the Flags field is non-zero, the Channel Number field shall be all 0s, and the Flags and Frequency fields shall be used as in the Assign Frequency CMD to indicate the new traffic frequency.

5.11.1.5 HFDLP ALM adjust power CMD.

The Adjust Power CMD shall be sent to request a change in output power from the other station on a link as shown on figure 28. The request specifies either an absolute output power or an adjustment relative to the current power level as defined in table XXII.

2	6	3	6	33
V	000100	Flags	Power	...000...

FIGURE 28. HFDLP ALM adjust power CMD.

TABLE XXII. Flags in HFDLP ALM adjust power CMD.

Flags	Meaning of Power Field
000	Absolute Power in dBW (> 1W)
001	Absolute Power in -dBW (< 1W)
010	Power increase in dB
011	Power decrease in dB
1xx	(reserved)

5.11.2 Data frame CMDs for link maintenance.

ALM CMDs shall be embedded in a data frame of an HFDLP data series by setting the Reserved bit to 1 in the Reverse Channel Control Frame Recommendation of a Data Frame header. The ALM CMD shall be left-justified in the first seven bytes of the data frame as shown on figure 29. The remaining bits of the data frame shall be set to 0.

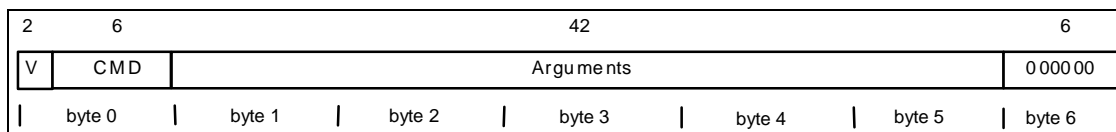


FIGURE 29. HFDLP ALM CMD embedding in data frame.

The CMDs sent in HFDLP data frames shall be identical to those sent in control frames.

5.11.3 Initiation of ALM operation.

Before HFDLP terminals begin ALM operation, they shall ascertain that both are ALM capable. If an ALM CMD has not been received from the other terminal, no ALM CMD other than a No Op shall be sent. The response to an ALM No Op may be any ALM CMD, including a No Op.

5.11.4 Alternate frequency negotiation.

After ALM operation has been established (see 5.11.3), the best alternate frequency (or frequencies) for transmissions to a station shall be reported in every HFDLP data series and in every data ACK that is not used for another ALM CMD. These alternate frequencies should be provided to the ALE controller for guidance in reestablishing the link should it fail, and for future use for link establishment.

If either terminal detects imminent link failure, it shall initiate a frequency change by sending a Change Frequency CMD at the first opportunity. The other terminal shall respond with a Change Frequency CMD indicating its preferred new frequency. If the first terminal receives this response, it shall acknowledge the frequency change by repeating its Change Frequency CMD and shall depart to the new frequency. Upon receipt of the acknowledgment (or the expiration of a timeout awaiting the acknowledgment), the second terminal shall also depart to the new frequency. The second terminal shall initiate HFDLP link establishment.

5.11.5 Automatic power control.

HFDLP ALM Adjust Power CMDs may be sent after the HFDLP terminals have negotiated ALM operation as described above. When an Adjust Power CMD is received, the terminal shall pass the request to the station device that can implement the power change.

5.12 Advanced third-generation automatic link establishment.

See MIL-STD-188-141.

5.13 System parameters by address.

Not yet standardized.

5.13.1 Multiple frequency set operation.

Not yet standardized.

5.13.2 Antenna selection.

Not yet standardized.

5.13.3 Power selected by net authorization.

Not yet standardized.

5.14 HF mail transfer protocol (HMTP).

See MIL-STD-188-141.

5.15 Automatic location report CMD.

When location is reported by a second-generation ALE system, it shall use one of the following location report CMD formats.

5.15.1 Coarse location.

Position of the transmitter can be reported to within a 15° grid square using a single ALE word. When this precision is adequate the location CMD shall be formatted as shown on figure 30.

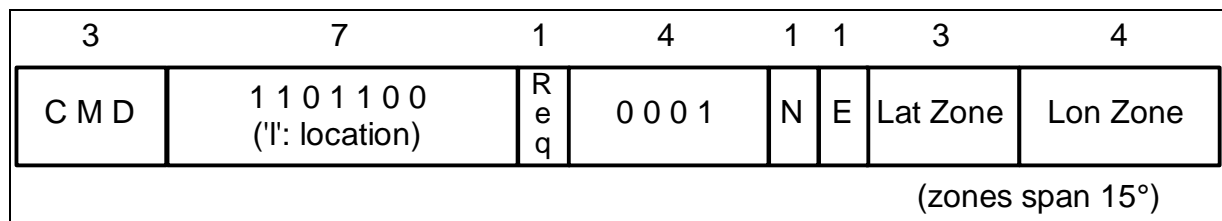


FIGURE 30. Coarse location CMD.

The Req bit shall be set to 1 to request a location report in response, or to 0 if no report is requested. The N bit shall be set to 1 if the position is in the northern hemisphere, or to 0 if in the southern hemisphere. The E bit shall be set to 1 if the location is in the eastern hemisphere, or to 0 if in the western hemisphere. The Lat Zone shall be set to the latitude divided by 15, rounded to an integer, in a range of 0 through 6. Lat Zone shall be set to 7 (111) to indicate unknown latitude. The Lon Zone shall be set to the longitude divided by 15, rounded to an integer, in a range of 0 through 12. Lon Zone shall be set to 15 to indicate unknown latitude; other values are reserved.

5.15.2 One-minute location.

When position is to be reported to a precision finer than 15 degrees but greater than or equal to one minute, the One-minute location CMD format shown on figure 31 shall be used.

3			7				1	4		1	1	7		
C M D		1 1 0 1 1 0 0 (!': location)					R e q	0 0 1 0		A b n	N	Lat Degrees		
D A T A		E	Lon Degrees					Lon Minutes				Lat Minutes		
3		1	8				6				6			

FIGURE 31. One-Minute location CMD.

The Req, N, and E flags shall be used as described for the Coarse Location CMD. The Abn flag shall be set to 1 if the transmitter is airborne, or to 0 otherwise. The Lat and Lon Degrees and Minutes fields shall be set to all 1s if no value is available for that field. Lat Degrees shall be set to the latitude in degrees, in a range of 0 through 90, rounded to the nearest integer if the Lat Minutes field is all 1s, truncated to an integer otherwise. Likewise, the Lon Degrees field shall be set to the longitude in degrees, in a range of 0 through 180, rounded to the nearest integer if the Lon Minutes field is all 1s, truncated to an integer otherwise. The Lon Minutes and Lat Minutes fields shall be rounded to the nearest integers.

5.15.3 Precise location.

Precise location in two or three dimensions has not yet been standardized.

5.16 System parameters by address.

Not yet standardized.

5.16.1 Multiple frequency set operation.

Not yet standardized.

5.16.2 Antenna selection.

Not yet standardized.

5.16.3 Power selected by net authorization.

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. 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 network. Procuring activities should identify clear requirements 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 availability 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 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 transmission 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 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.

6.2 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

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

Link quality functions

LQA

Multimedia

Networking controller

Polling protocols

SINAD

SNMP

Spectral distortion

Time protocols

MIL-STD-187-721D

Custodians:

Army – CR1
Navy – EC
Air Force – 02

Preparing Activity:

Army – CR1

Review Activities:

Army – AC
Navy – MC
DOD – DC, NS, DI

(Project TCSS-0078)

Civil Agency Coordinating Activities:

NCS
NTIA – ITS