NOTICE OF CHANGE

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MIL-STD-188-141A
NOTICE 1
17 June 1992

MILITARY STANDARD
INTEROPERABILITY AND PERFORMANCE
STANDARDS FOR MEDIUM AND HIGH
FREQUENCY RADIO EQUIPMENT

TO ALL HOLDERS OF MIL-STD-188-141A:

1. THE FOLLOWING PAGES OF MIL-STD-188-141A HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

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2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-STD-188-141A will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check list. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the military standard is completely revised or canceled. Paragraphs and tables that have been changed are identified by a vertical bar in the margin.

Custodians:
Army--SC
Navy--EC
Air Force--90

Preparing activity:
Army--SC

Review activities:
Army--CR
Navy--MC, SH
DoD--DC, NS, JT

(Project SLHC-1412)

AMSC N/A

SLHC/TCTS

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APPENDIXES PAGE

APPENDIX A

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APPENDIXES PAGE

FIGURES

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3. DEFINITIONS.

3.1 Terms. Definitions of terms used in this document shall be as specified in the current edition of FED-STD-1037. In addition, the following definitions are applicable for the purposes of this standard.

Automatic link establishment (ALE). The method of automatic station contact initiation as described in appendix A of this standard.

Automatic sounding. Sounding is the ability to empirically test selected channels (and propagation paths) by providing a very brief beacon-like identifying broadcast which may be utilized by other stations to evaluate connectivity, propagation, and availability, and to select known working channels for possible later use for communications or calling. Such soundings are primarily intended to increase the efficiency of the ALE function, thereby increasing system throughput. Sounding information shall be used for reducing the set of assigned channels to be used for a particular ALE connectivity attempt.

High-performance HF data modem. High-speed (capable of at least 1200 bps) or robust data modems which incorporate sophisticated techniques for correcting or reducing the number of raw (over-the-air induced) errors.

Link compressor and expander (Lincompex). A speech processing system consisting of a compressor and expander linked by a control channel separate from the audio (speech) channel.

Linking protection (LP). Linking protection is the protection of the linking function of automatic link establishment from manipulation and unintentional interference.

Link quality analysis (LQA). The overall process by which relative measurements of signal quality are performed. This signal quality is characterized by such parameter assessments as BER, SINAD, and MP. Such assessments are stored and/or exchanged between stations for ALE decision use.

Multipath (MP). The propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths, especially when this results in signal distortion due to differential time delay.

Phase noise (dBc/Hz). The amount of single-sided phase noise, contained in a one-hertz bandwidth, produced by a carrier (signal generation) source, and referenced in decibels below the full (unsuppressed) carrier output power.

Signal plus noise plus distortion to noise plus distortion ratio (SINAD). The ratio expressed in decibels (dB) consisting of (a) the recovered

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audio power (original modulating audio signal plus noise plus distortion) from a modulated radio frequency carrier, and (b) any residual audio power (noise plus distortion) remaining after the original modulating audio signal is removed.

Third-order intercept point. The third-order intercept point is a standard measure of how well a receiver performs in the presence of strong nearby signals. The receiver third-order intercept point is an extrapolated convergence (not directly measurable) of a desired output intermodulation distortion products.

NOTE: Testing is conducted using two frequencies, f1 and f2, which fall within the first intermediate frequency mixer passband. (In general, the test frequencies will be about 20-30 Khz apart.)

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

ABCA	American, British, Canadian, and Australian (Armies)
ACK	acknowledgement
AGC	automatic gain control
AJ	anti-jam
AL-0	Unprotected application level
AL-1	Unclassified application
ALC	automatic level control
ALE	automatic link establishment
AMD	automatic message display
ANSI	American National Standards Institute
ARQ	automatic repeat request
ASCII	American Standard Code for Information Interchange
BER	bit error ratio
CCEP	Commercial COMSEC Endorsement Program
CCIR	International Radio Consultative Committee
COMSEC	Communications Security
CMD	ALE preamble word COMMAND
CRC	cyclic redundancy check
DATA	ALE preamble word DATA
dBc	decibels referenced to full-rated PEP carrier power
DBM	data block message
DCE	data circuit-terminating equipment
DCS	Defense Communications System

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DISA	Defense Information Systems Agency
DISAC	Defense Information Systems Agency Circular
DO	design objective
DoD	Department of Defense
DODISS	Department of Defense Index of Specifications and Standards
DTE	data terminal equipment
DTM	data text message
EDC	error detection and correction
FCS	frame check sequence
FDM	frequency-division multiplexing
FEC	forward error correction
FIPS	Federal Information Processing Standards
FSK	frequency-shift keying
HF	high frequency
IAW	in accordance with
ICD	interface control document
ICW	interrupted continuous wave
IMD	intermodulation distortion
ISB	independent sideband (transmission)
ISDN	Integrated Services Digital Network
ISO	International Organization for Standardization
ITU	International Telecommunications Union
JCS	Joint Chiefs of Staff
LP	linking protection
LPCM	linking protection control module

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LQA	link quality analysis
LSB	(1) lower side band (radio) (2) least significant bit (data)
ms	millisecond
MSB	most significant bit
NAK	nonacknowledgement (request for repeat)
NATO	North Atlantic Treaty Organization
NBFM	narrowband frequency modulation
NMCS	National Military Command System
NSA	National Security Agency
OSI	Open Systems Interconnection
PEP	peak envelope power
PI	protection interval
ppm	parts per million
PTT	push to talk
QSTAG	Quadripartite Standardization Agreement
REP	ALE preamble word REPEAT
RTTY	radio teletypewriter
SINAD	signal plus noise plus distortion to noise plus distortion ratio
SNR	signal-to-noise ratio
SSB	single sideband
STANAG	Standardization Agreement (NATO)
TBD	to be developed
TOD	time of day
uncl	unclassified

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USAISEC	U. S. Army Information Systems Engineering Command
UUT	unit under test
USB	upper sideband
UUF	user unique function
VFCT	voice frequency carrier telegraph
VSWR	voltage standing wave ratio

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4. GENERAL REQUIREMENTS.

4.1 General. By convention, frequency band allocation for the MF Band is from 0.3 megahertz (MHz) to 3 MHz and the HF band is from 3 MHz to 30 MHz. However, for military purposes, equipment designed for HF band use has historically been designed with frequency coverage extending into the MF band. For new HF equipment, HF band standard parameters shall apply to any portion of the MF band included as extended coverage. Currently there are no known military requirements below 1.5 MHz. Consequently, this portion of the MF band is not standardized.

Equipment parameters will be categorized using functional use groups for radio assemblages/sets. Historically, these groups have been fixed (long-haul) installations and tactical sets. The tactical sets are subgrouped further into vehicle transportable and manpack versions. Although these distinctions still exist in principle, the former lines of distinction have become somewhat blurred. The mobility of current military forces dictates that a significant number of long-haul requirements will be met with transportable systems, and in some cases, such systems are implemented with design components shared with manpack radios. When such "tactical" equipment is used to meet a long-haul requirement, the equipment shall meet long-haul minimum performance standards. Accordingly, within this standard, tactical use groups may contain dual-value parameters. One parameter reflects usage wherein the frequency-determining elements are temperature controlled. The other usage is deployment related, wherein the frequency-determining elements are not temperature controlled (the usual condition for manpack equipment in tactical operations).

4.2 Equipment operation modes.

4.2.1 Baseline mode. Frequency control of all new HF equipment shall be capable of being stabilized by an external standard. Should multiple-frequency (channel) storage be incorporated, it shall be of the programmable-memory type and be capable of storing/initializing the operational mode (see 4.2.1.1 and 4.2.1.2 below, and 40.2 of appendix A) associated with each particular channel.

4.2.1.1 Single-channel. All new single-channel HF equipment shall provide, as a minimum, the capability for the following one-at-a-time selectable operational modes:

a. One nominal 3-kHz channel upper sideband (USB) or lower sideband (LSB) (selectable).

b. One (rate-dependent bandwidth) interrupted continuous wave (ICW) channel.

c. A narrowband frequency modulation (NBFM) channel capability should be included as a design objective (DO).

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4.2.1.2 Multichannel. All new multichannel HF equipment shall provide, as a minimum, the capability for single-channel operation as set forth in 4.2.1.1 above and the following one-at-a-time selectable operational modes:

a. Two nominal 3-kHz channels in the USB or LSB (two independent channels in the same sideband--sideband selectable).

b. One nominal 6-kHz channel in the USB or LSB (selectable).

c. Two nominal 3-kHz channels in the USB and two in the LSB (four independent 3-kHz channels--two in each sideband).

d. One nominal 6-kHz channel in the USB and one in the LSB (two independent 6-kHz channels--one in each sideband).

e. One nominal 3-kHz channel in the USB and one in the LSB (two independent 3-kHz channels--one in each sideband)

4.2.2 Automatic link establishment (ALE) mode. Should an ALE capability be included, it shall be of the channel-scanning type and shall provide for contact initiation by either or both manual and automated control. See 4.5 for the list of features required to support this operational mode.

4.2.3 Anti-jam (AJ) mode. If AJ is to be implemented, the AJ capabilities and features for HF radios shall be in accordance with MIL-STD-188-148.

4.2.4 Linking protection (LP). If LP is to be implemented, the LP capabilities and features for HF radios shall be in accordance with appendix B.

4.3 Interface parameters.

4.3.1 Electrical characteristics of digital interfaces. As a minimum, any incorporated interfaces for serial binary data shall be in accordance with the provisions of MIL-STD-188-114. Such interfaces shall also include provisions for request-to-send and clear-to-send signaling. The capability to accept additional standard interfaces is not precluded.

4.3.2 Electrical characteristics of analog interfaces. See 5.3.6 and 5.4.5.

4.3.3 Modulation and data signaling rates. The modulation rate (expressed in baud (Bd)) or the data signaling rate (expressed in bits per second (bps)) at interface points A and A' on figure 1 shall include those contained in the HF modem portion of MIL-STD-188-110.

4.4 North Atlantic Treaty Organization (NATO) and Quadripartite interoperability requirements.

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4.4.1 Single-channel communications systems. For interoperation with NATO member nations, land, air, and maritime, single-channel HF radio equipment shall comply with the applicable requirements of the current edition of STANAG 4203.

Page 14a added.

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5. DETAILED REQUIREMENTS.

5.1 General.

5.1.1 Introduction. This section provides detailed performance standards for MF and HF radio equipment. These performance standards shall apply over the appropriate frequency range from 2.0 MHz to 29.9999 MHz (DO: 1.5 MHz to 29.9999 MHz).

5.1.2 Signal and noise relationships. The signal and noise relationships are expressed as signal plus noise plus distortion to noise plus distortion ratio (SINAD), unless otherwise identified. Unless otherwise specified, when the ratio is stated, the noise bandwidth is 3 kHz.

5.2 Common equipment characteristics.

These characteristics shall apply to each transmitter and to each receiver unless otherwise specified.

5.2.1 Displayed frequency. The displayed frequency shall be that of the carrier, whether suppressed or not.

5.2.2 Frequency coverage. The radio equipment shall be capable of operation over the frequency range of 2.0 MHz to 29.9999 MHz in a maximum of 100-Hz frequency increments (DO: 10-Hz) for single-channel equipment, and 10-Hz frequency increments (DO: 1-Hz) for multichannel equipment.

5.2.3 Frequency accuracy. The accuracy of the radio carrier frequency, including tolerance and long-term stability but not any variation due to doppler shift, shall be within ±30 Hz for manpack equipment and within ±10 Hz for all others, measured during a period of not less than 30 days.

5.2.4 Phase stability. The phase stability shall be such that the probability that the phase difference will exceed 5 degrees over any two successive 10 millisecond (ms) periods (13.33-ms periods may also be used) shall be less than one percent. Measurements shall be performed over a sufficient number of adjacent periods to establish the specified probability with a confidence of at least 95 percent.

5.2.5 Phase noise. The synthesizer and mixer phase-noise spectrum at the transmitter output shall not exceed those limits as depicted on figures 2 and 3 under continuous carrier single-tone output conditions. Figure 2 depicts the limits of phase noise for fixed-site and transportable long-haul radio transmitters. Figure 3 depicts the limits for tactical radio transmitters. See 4.1 for application statements on dual parameters.

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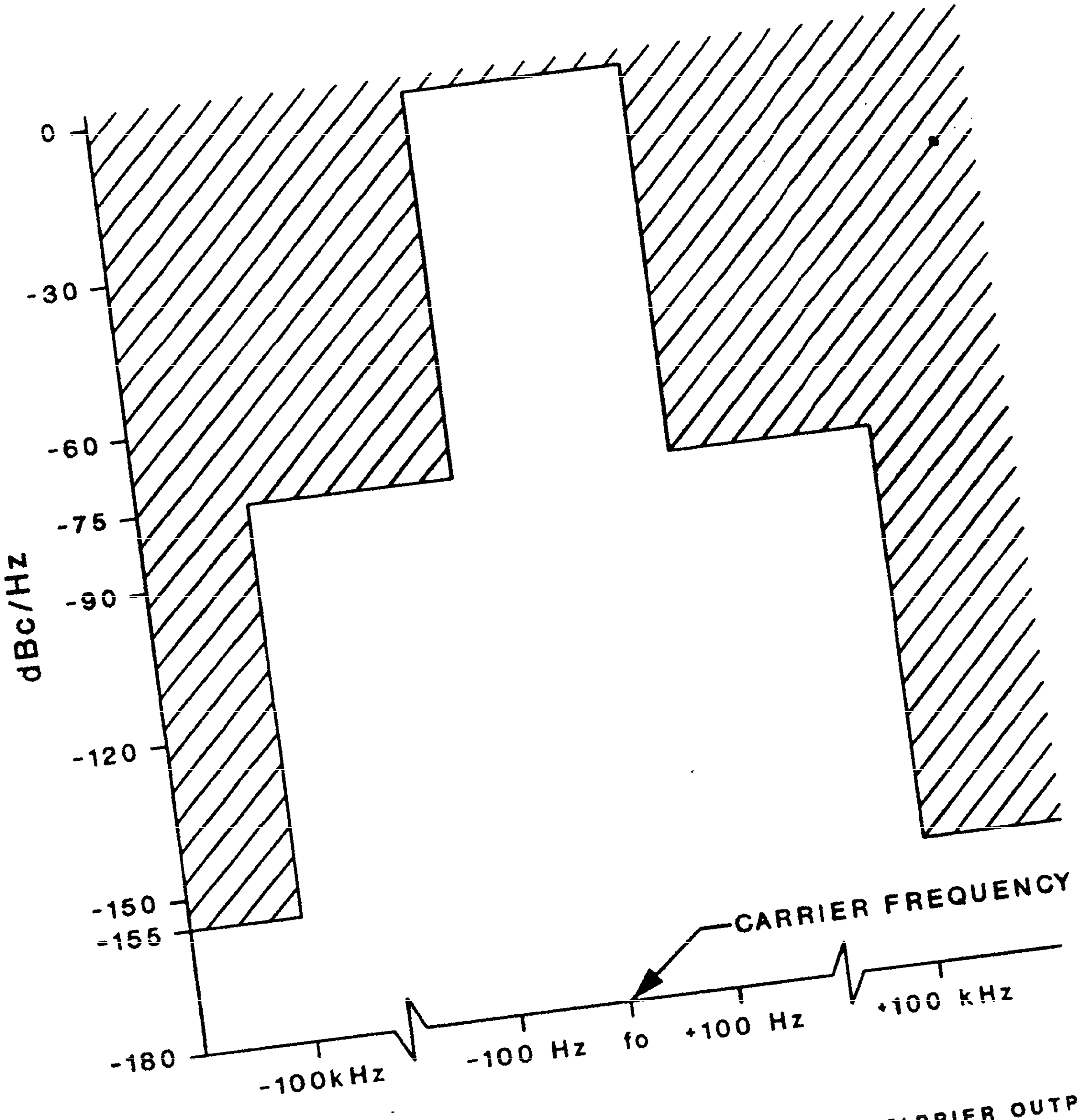

NOTE:

dBc = DECIBELS REFERENCED TO A FULL-RATED PEP CARRIER OUTPUT

FIGURE 2. Phase noise limit mask for fixed site and transportable long-haul radio transmitters with temperature-controlled frequency-determining elements.

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5.4.5.2 Output impedance and power. The receiver output impedance shall be a nominal 600 ohms, balanced with respect to ground, and designed to drive a minimum of six paralleled 600-ohm loads without decrease in output power greater than 2.5 dB relative to a single matched-load output. Electrical symmetry shall be sufficient to suppress longitudinal currents at least 40 dB below reference signal level. The receiver output signal power for operation with a headset or handset shall be adjustable at least over the range from -30 dBm to 0 dBm. For operation with a speaker, the output level shall be adjustable at least over the range from 0 dBm to +30 dBm. As a DO, an additional interface which can accommodate speakers ranging from 4 to 16 ohms impedance should be provided.

5.5 Automatic link establishment (ALE). If ALE is to be implemented, it shall be in accordance with appendix A. The ALE requirements include selective calling and handshake, link quality analysis and channel selection, scanning, and sounding. These requirements are organized in appendix A as follows:

a. Requirements for ALE implementation are given in sections 10 through 40.

b. Detailed requirements on ALE waveform, signal structure protocols, and orderwire messages are contained in sections 50 through 90.

5.6 Linking protection (LP). If linking protection is required to be implemented, it shall be in accordance with appendix B. These requirements are organized in appendix B as follows:

a. General requirements for LP implementation are given in sections 10 through 30.

b. Detailed requirements on how to implement LP are given in section 40.

c. The unclassified application level (AL-1) is the lowest level of LP and is mandatory for all protected radios implementing LP.

d. AL-1 is the only level of LP presently covered in appendix B. The higher levels of LP, application levels 2 through 4, will be added to appendix B as development and testing are completed under MIL-STD-187-721 Planning Standard.

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6. NOTES.

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

6.1 Intended use. This standard contains requirements to ensure interoperability of new long-haul and tactical radio equipment in the medium frequency (MF) band and in the high frequency (HF) band.

6.2 Issue of DODISS. When this standard is used in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Subject term (key word) listing.

Adaptive communications
AJ mode
ALE
ALE mode
Automatic link establishment (ALE)
Automatic sounding
Baseline mode
Deep interleaving
Forward error correction
Golay coding
Interface control document
Leading redundant word
Lincompex
Linking protection
Linking protection control module
Link quality analysis (LQA)
LQA
Orderwire data messages
Protection interval
Radio frequency scanning
Selective calling
Slotted responses
Star net and group
Triple redundant word
Word phase

6.4 International standardization agreements. Certain provisions of this standard in 4.2, 4.4, 5.2, 5.3, and 5.4 are the subject of international standardization agreements, STANAGs 4203 and 5035, and QSTAG 733. When change notice, revision, or cancellation of this standard is proposed that will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels, including departmental standardization offices, to change the agreement or make other appropriate accommodations.

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6.5 Changes from previous issue. The margins of this standard are marked with vertical lines to indicate where changes (additions, modifications, corrections, deletions) from the previous issue were made. This was done as a convenience only and the Government assumes no liability whatsoever for any inaccuracies in these notations. Bidders and contractors are cautioned to evaluate the requirements of this document based on the entire content irrespective of the marginal notations and the relationship to the last previous issue.

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AUTOMATIC LINK ESTABLISHMENT SYSTEM

10. GENERAL.

10.1 Scope. This appendix provides details of the prescribed waveform, signal structures, protocols, and performance for the automatic link establishment (ALE) system.

10.2 Applicability. This appendix is a mandatory part of MIL-STD-188-141A whenever ALE is a requirement to be implemented into the HF radio system. The functional capability described herein includes automatic signaling, selective calling, automatic answering, and radio frequency (rf) scanning with link quality analysis (LQA). The capability for manual operation of the radio in order to conduct communications with existing, older generation, nonautomated manual radios, shall not be impaired by implementation of these automated features.

20. APPLICABLE DOCUMENTS.

20.1 Government documents. The following document forms a part of this appendix to the extent specified:

STANDARDS

FEDERAL

Federal Information Processing Standards

FIPS PUB 1-1	Publications Code: for information interchange

(Copies of Federal Information Processing Standards (FIPS) are available to Department of Defense activities from the Commanding Officer, Naval Publications and Forms Center, Standardization Document Order Desk, 700 Robbins Avenue, Building #4, Section D, Philadelphia, PA 19111-5094. Others must request copies of FIPS from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161-2171.)

20.2 Non-Government publications. The following documents form a part of this appendix to the extent specified:

INTERNATIONAL STANDARDIZATION DOCUMENTS

International Telecommunications Union (ITU), Radio Regulations

CCIR Recommendation 520	Use of High Frequency Ionospheric Channel Simulators

(Application for copies should be addressed to the General Secretariat, International Telecommunications Union, Place des Nations, CH-1211 Geneva 20, Switzerland.)

Supersedes page 37 of 15 September 1988.

International Organization for Standardization (ISO)

International Standard 7498-1984	Open Systems Interconnection (OSI) Reference Model

(Application for copies should be addressed to the Central Secretariat, International Organization for Standardization (ISO) 1, Rue de Varembe, CH-1211, Geneva, 20, Switzerland.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

30. DEFINITIONS.

30.1 Standard definitions and acronyms. See Section 3.

30.2 Definitions of timing symbols. The abbreviations and acronyms used for timing symbols are contained in annex A to this appendix.

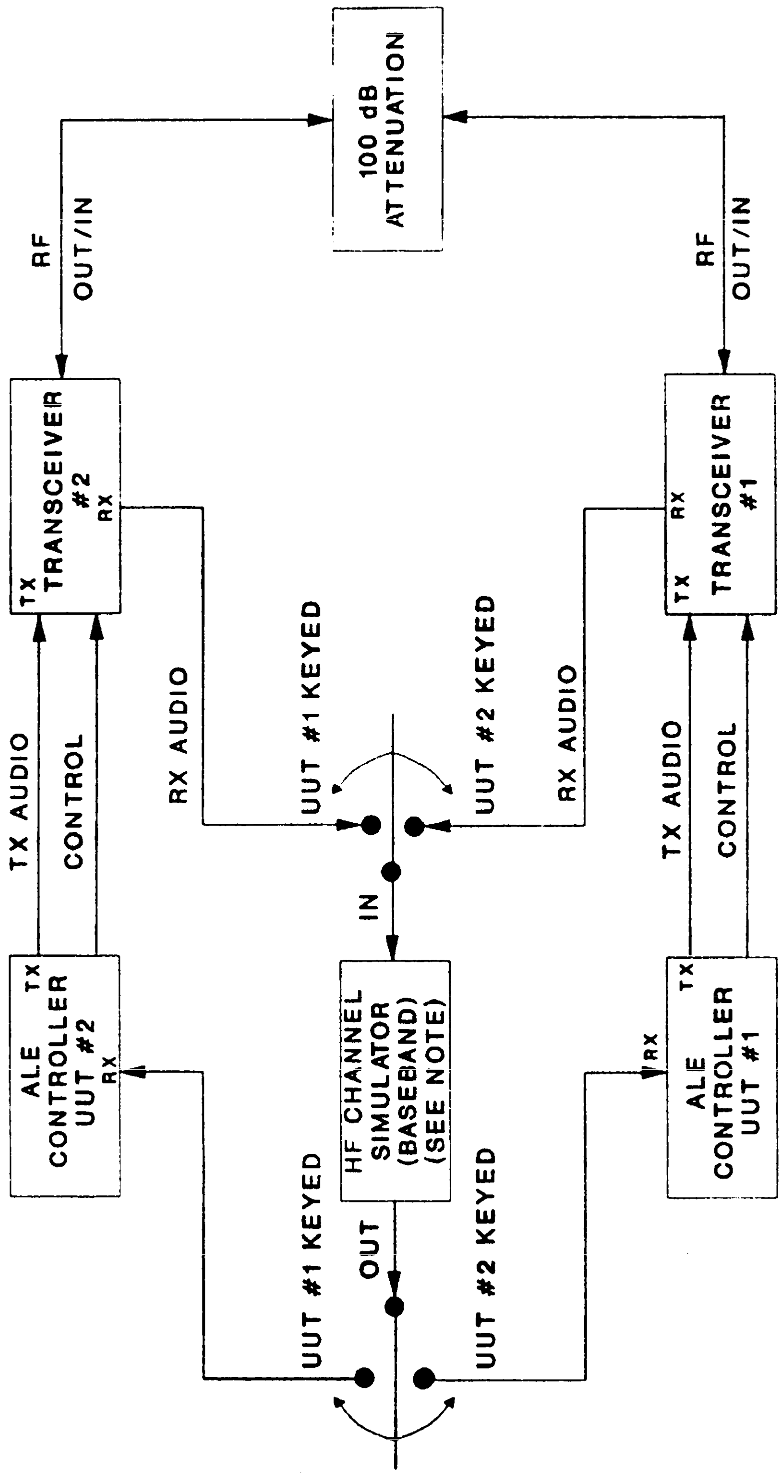
40. GENERAL REQUIREMENTS.

40.1 Systems test performance. Stations designed to this standard shall demonstrate an overall system performance equal to or exceeding the following requirements. Linking attempts made with a test setup configured as shown on figure A-1, using the specified ALE signal created in accordance with this appendix, shall produce a probability of linking as shown in table A-I.

TABLE A-I. Probability of linking.

	Signal-to-noise ratio (db)		
Probability of linking (P1)	Gaussian noise channel	CCIR good channel	CCIR poor channel
≥25%	-2.5	+0.5	+1.0
≥50%	-1.5	+2.5	+3.0
≥85%	-0.5	+5.5	+6.0
≥95%	0.0	+8.5	+11.0

Supersedes page 38 of 15 September 1988.



NOTE:

THE SIMULATOR INCLUDES EITHER INTERNAL OR EXTERNAL CAPABILITY TO ADJUST/MONITOR SIGNAL/NOISE/DOPPLER-OFFSET SETTINGS AND SHALL INCORPORATE APPROPRIATE FILTERING TO LIMIT THE AUDIO PASSBAND TO 300 - 3050 Hz.

FIGURE A-1. System performance measurements test setup.

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The receive audio input to the ALE controller shall be used to simulate the three channel conditions. The CCIR good channel shall be characterized as having 0.5 ms multipath delay and a fading (two sigma) bandwidth of 0.1 Hz. The CCIR poor channel, normally characterized as consisting of a circuit having 2.0 ms multipath delay with a fading (two sigma) bandwidth of 1.0 Hz, shall be modified to have 2.2 ms multipath delay and a fading (two sigma) bandwidth of 1.0 Hz. Doppler shifts of -60 Hz shall produce no more than a 1.0 dB performance degradation from the requirements of table A-I for the CCIR good and poor channels.

NOTE: This modification is necessary due to the fact that the constant 2-ms multipath delay (an unrealistic fixed condition) of the CCIR poor channel results in a constant nulling of certain tones of the ALE tone library. Other tone libraries would also have some particular multipath value which would result in continuous tone cancellation during simulator testing.

Each of the signal-to-noise ratio (SNR) values shall be measured in a nominal 3-kHz bandwidth. Performance tests of this capability shall be conducted in accordance with CCIR Recommendation 520 "Use of High Frequency Ionospheric Channel Simulators", employing the C.C. Watterson Model. This test shall use the individual scanning calling protocol described in 70.4.3. The time for performance of each link attempt shall be measured from the initiation of the calling transmission until the successful establishment of the link. Performance testing shall include the following additional criteria:

a. The protocol used shall be the individual scanning calling protocol with only TO and THIS IS preambles.

b. Addresses used shall be alphanumeric, one word (3 characters) in length from the 38-character basic ASCII subset.

c. Units under test (UUTs) shall be scanning 10 channels at 2 channels per second.

d. Call initiation shall be performed with the UUT transmitter stopped and tuned to the calling frequency.

e. Maximum time from call initiation (measured from the start of UUT rf transmission -- not from activation of the ALE protocol) to link establishment shall not exceed 14.000 seconds, plus simulator delay time. The call shall not exceed 23 Trw, the response 3 Trw, and the acknowledgement 3 Trw.

NOTE: Performance at the higher scan rates shall also meet the foregoing requirements and shall produce the same probability of linking as shown in table A-I.

40.2 Channel memory. The equipment shall be capable of storing, retrieving, and employing at least 100 different sets of information concerning channel data to include receive and transmit frequencies with associated mode information. See table A-II. The channel data storage shall be nonvolatile.

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TABLE A-II. Channel memory example.

Channel	Frequency (MHz) TX	Frequency (MHz) RX	Mode TX	Mode RX	T/R	SCAN	SCTY	(3) Next Sound	Sound Interval	* SAN	* ANT	* PWR	* USE	Example comments
C-1	17,777.7	17,777.7	USB	USB	T/R	Y	C	14 min	40 min	2	1	LO	V	Typical simplex channel, low power, voice, clear
C-2	22,222.2	22,222.2	USB	USB	R	Y	C	--	--	2	1	LO	V	Same, but receive only at this time
C-3	10,333.0	10,333.0	USB	LSB	T/R	Y	CS	1 min	60 min	2	2	HI	V	Half-duplex, uses another antenna, high power, clear and secure
C-4	13,111.0	13,999.0	LSB	LSB	T/R	Y	CS	22 min	60 min	5	1	HI	V,D	Typical voice or data, half-duplex, high power, clear and secure
C-5	9,900.0	9.900.0	USB	LSB	T/R	N	S	--	--	5	2	LO	D	Typical simplex, non-scan, data only, secure
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
C-100	0.0	5,000.0	--	AM	R	N	C	--	--	-	1	-	V,D	Receive only, non-scan, clear

NOTE:
1. (*) Optional storage of antenna selection(s) "ANT"; power output "PWR"; and usage "USE".
2. Y-yes, N-no, C-clear, S-secure, V-voice, D-data.
3. "Next sound" indicates time until next sounding on channel and is periodically decremented until "zero" value triggers sounding. It is reset to "sound interval" value by any identifiable transmission (sound or call).
4. Values shown for example only.

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The mode information shall include:

- o sounding data
- o group/net association
- o modulation type (associated with frequency)
- o transmit/receive modes
- o filter width (DO)
- o AGC setting (DO)
- o input/output antenna port selection (DO)
- o input/output information port selection (DO)
- o noise blanker setting (DO)
- o transmit power level (DO)
- o traffic or channel use (voice, data, etc.) (DO)
- o security (DO)
- o sounding self address(es) SAn....(DO)

Any channel (a) shall be capable of being recalled manually or under the direction of any associated automated controller, and (b) shall be capable of having its information altered after recall without affecting the original stored information settings.

40.3 Scanning. The radio shall be capable of repeatedly scanning selected channels stored in memory (in the radio or controller) under either manual control or under the direction of any associated automated controller. The scanned channels should be selectable by groups (such as 10 groups of 10 channels) and also individually within the groups, to enable flexibility in channel and network scan management. The design shall incorporate selectable scan rates of 2 channels per second (chps) and 5 chps (DO: 2,5, and 10 chps). Performance shall meet the requirements of 40.1. The radio shall stop scanning and wait on the most recent channel during the advent of any of the following selectable events:

- o Automatic controller input of stop scan (the normal mode of operation)
- o Manual input of stop scan
- o Activation of push-to-talk (PTT) line (DO)
- o Activation of external stop-scan line (DO)

40.4 Self address memory. The radio shall be capable of storing, retrieving, and employing at least twenty different sets of information concerning self addressing. The self address information storage shall be nonvolatile. These sets of information include **self (its own personal) address(es), valid channels which are associated for use, and net addressing. Net addressing information shall include (for each "net member" self address, as necessary) the net address and the present slot wait time (in multiples of Tw). See table A-III. The slot wait time values are Tswt(SN) from the formula in 70.6.2. Stations called by their net call address shall respond with their associated self (net member) address with the specified delay (Tswt(SN)). For example, the call is "GUY", thus the response is "BEN". Stations called individually by one of their self addresses (even if a net member address) shall respond immediately, and with that address, as specified in the** individual scanning calling protocol. Stations called by one of their self addresses (even if a net member

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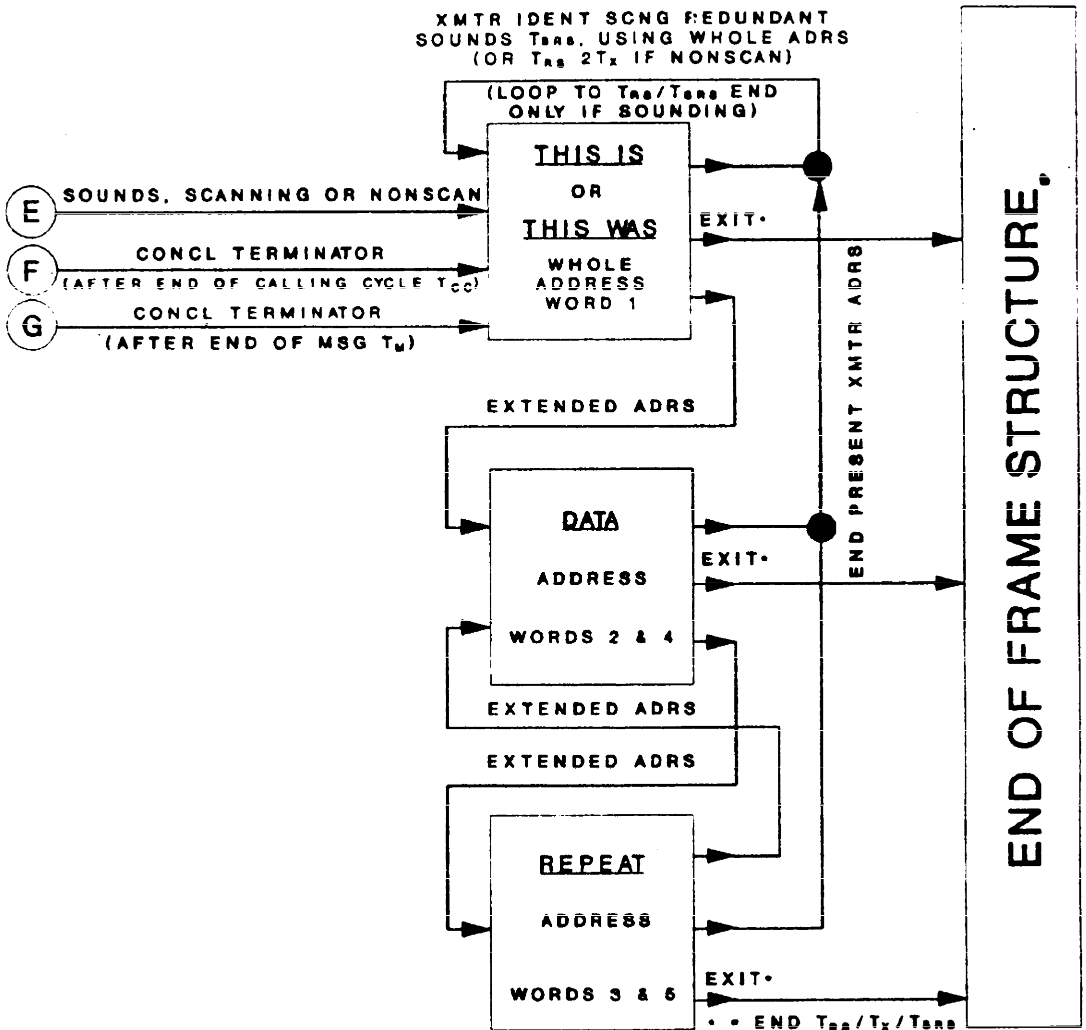

FRAME TERMINATION

- IF NONSOUND $T_X = T_A$ XMTR
- IF NONSCANNING SOUND $T_{RS} = 2T_A$ XMTR
- IF SCANNING SOUND $T_{SRS} = n \times T_A$ XMTR $\geq T_S + T_{RS}$

CONCLUSION SECTION (TRAILER)

FIGURE A-5c. Valid word sequences -- Continued: (conclusion section).

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TABLE A-VI. Limits to calls.

Calls	Limit
Address size (5 words) (Ta max)	1960 ms
Call time (12 words) (Tc max of the call)	4704 ms
Scan period (Ts max)	50 s
Message section basic time (Tm max basic) (unless modified by AMD extension, or by COMMAND such as DTM or DBM)	11.76 s
Message section, time limit of AMD (90 characters) (Tm max AMD)	11.76
Message section time, DTM (1053 characters) (Tm max DTM)	2.29 min (entire data block)
Message section time, DBM (37377 characters) (Tm max DBM)	23.26 min (entire deeply interleaved block)

If an orderwire protocol such as AMD, DTM, or DBM is used to extend the basic message section, it shall start no later than the start of the 30th word (11.368s). Such extension of the message section shall be determined by the length of the extending orderwire protocol, and the message section shall terminate at the end of the orderwire without additional extension. The conclusion shall start at the end of the message section.

60.2.4.2 Basic 38 ASCII subset. The basic 38 ASCII subset shall include all capital alphabetics (A-Z) and all digits (0-9), plus designated utility and wildcard symbols "@" and "?", as shown on figure A-6. The basic 38 subset shall be used for all basic addressing functions as described in 60.5. To be a valid basic address, the word shall contain a routing preamble (such as TO...), plus three alphanumeric characters (A-Z, 0-9) from the basic 38 subset in any combination. In addition, the "@" and "?" symbols shall be used for special functions only as described in 60.5.4. Digital discrimination of the basic 38 subset shall not be limited to examination of only the three MSBs (b_7 through b_5), as a total of 48 digital bit combinations would be possible (including ten invalid symbols which would be improperly accepted).

60.2.4.3 Expanded 64 ASCII subset. The expanded 64 ASCII subset shall include all capital alphabetics (A-Z), all digits (0-9), the utility symbols "@" and "?", plus 26 other commonly used symbols. See figure A-7. The expanded 64 subset shall be used for all basic orderwire message functions, as described in section 80, plus special functions as may be standardized.

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For orderwire message use, the subset members shall be enclosed within a sequence of DATA (and REPEAT) words and shall be preceded by an associated COMMAND (such as data text message). This COMMAND designates the usage of the information which follows, and shall also be preceded by a valid and appropriate calling cycle using the basic 38 subset addressing. Digital discrimination of the expanded 64 subset may be accomplished by examination of the two MSBs (b_7 and b_6), as all of the members within the "01" and "10" MSBs are acceptable. No parity bits are transmitted, because the integrity of the information is protected by the basic ALE FEC and redundancy and may be ensured by optional use of the COMMAND CRC (cyclic redundancy check), as described in section 80.

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60.3.3 Interleaving and deinterleaving. The basic word bits W1 (MSB) through W24 (LSB), and resultant Golay FEC bits G1 through G24 (with G13 through G24 inverted), shall be interleaved, before transmission using the pattern shown on figure A-13. The 48 interleaved bits plus a 49th stuff bit S49, (value = 0) shall constitute a transmitted word and they shall be transmitted A1, B1, A2, B2... A24, B24, S49 using 16-1/3 symbols (tones) per word (Tw) as described in 50.3. At the receiver, and after 2/3 voting (see 60.3.4), the first 48 received bits of the majority word (including remaining errors) shall be deinterleaved as shown on figure A-13 and then Golay FEC decoded to produce a correct(ed) 24-bit basic word (or an uncorrected error flag). The 49th stuff bit (S49) is ignored.

60.3.4 Redundant words. Each of the transmitted 49-bit (or 16-1/3 symbol) (Tw) words shall be sent redundantly (times 3) to reduce the effects of fading, interference, and noise. An individual (or net) routing word (TO...), used for calling a scanning (multichannel) station (or net), shall be sent redundantly as long as required in the scan call (Tsc) to ensure receipt, as described in 70.4. However, when the call is a non-net call to multiple scanning stations (a group call, using THRU and REPEAT alternately), the first individual routing word (THRU) and all the subsequent individual routing words (REPEAT, THRU, REPEAT,...) shall be sent three adjacent times (Trw). These triple words for the individual stations shall be rotated in group sequence as described in 70.6. See figure A-14. At bit time intervals (approximately Tw/49), the receiver shall examine the present bit and past bit stream and perform a 2/3 majority vote, on a bit-by-bit basis, over a span of three words. See tables A-VII and A-VIII. The resultant 48 (ignoring the 49th bit) most recent majority bits constitute the latest majority word and shall be delivered to the deinterleaver and FEC decoder. In addition, the number of unanimous votes of the 48 possible votes associated with this majority word are temporarily retained for use as described in 60.4.

60.4 Word framing and synchronization.

60.4.1 General. The ALE system is inherently asynchronous and does not require any additional forms of system synchronization, although it is compatible with such techniques. However, the imbedded timing and structure of the system provide specific synchronous benefits in linking, orderwire, and anti-interference functions, as described herein.

60.4.2 Framing. All ALE transmissions, commonly referred to herein as "calls," are based on the tones, timing, bit, and word structures described in sections 50 and 60.2. All calls shall be composed of a "frame," which shall be constructed of contiguous redundant words in valid sequence(s) as described on figure A-5, as limited in table A-VI, and in formats as described in section 70. There are three basic frame sections: calling cycle, message, and conclusion. See 60.4.2.4 for basic frame structure examples.

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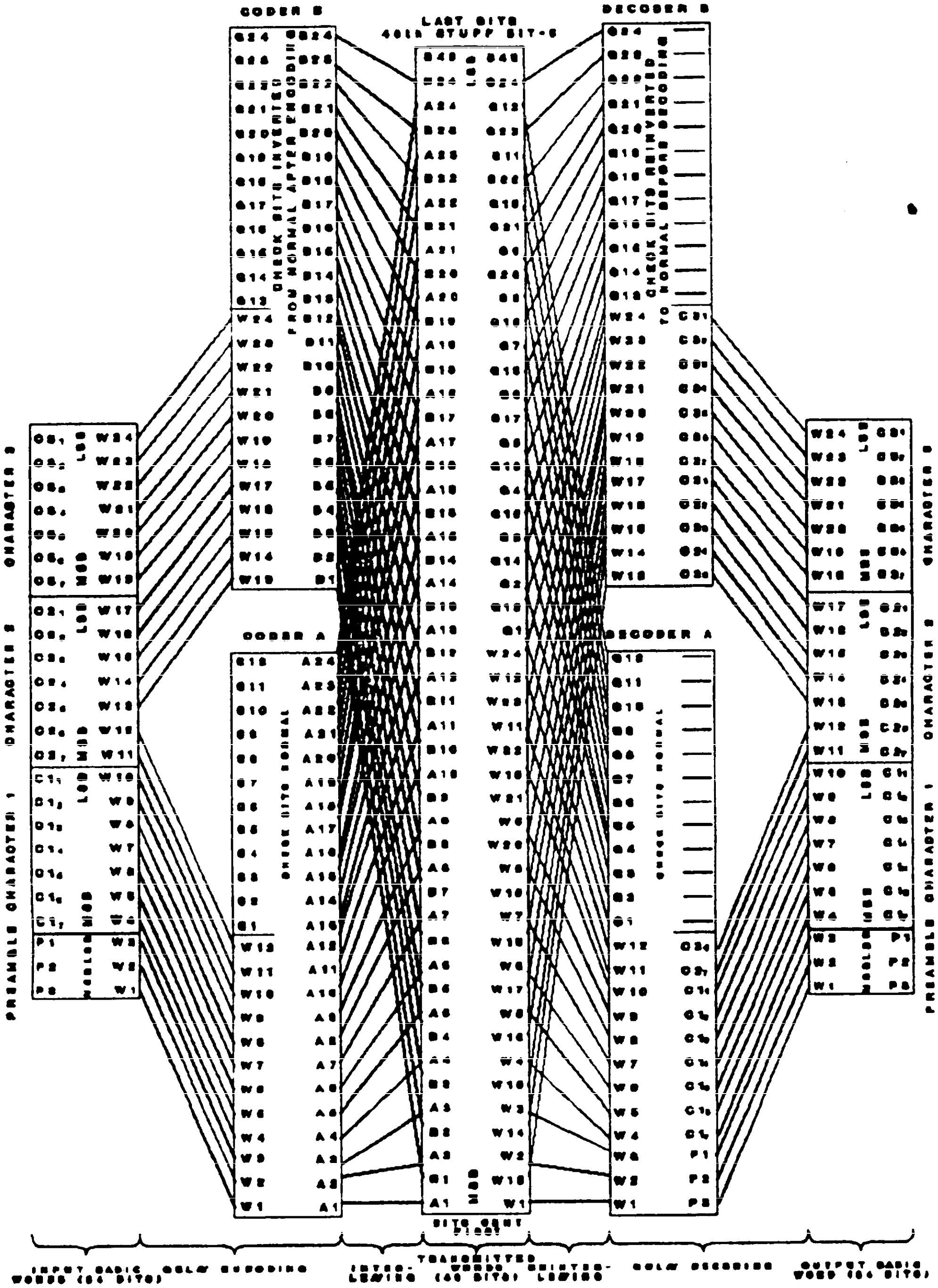

FIGURE A-13. Word bit coding and interleaving.

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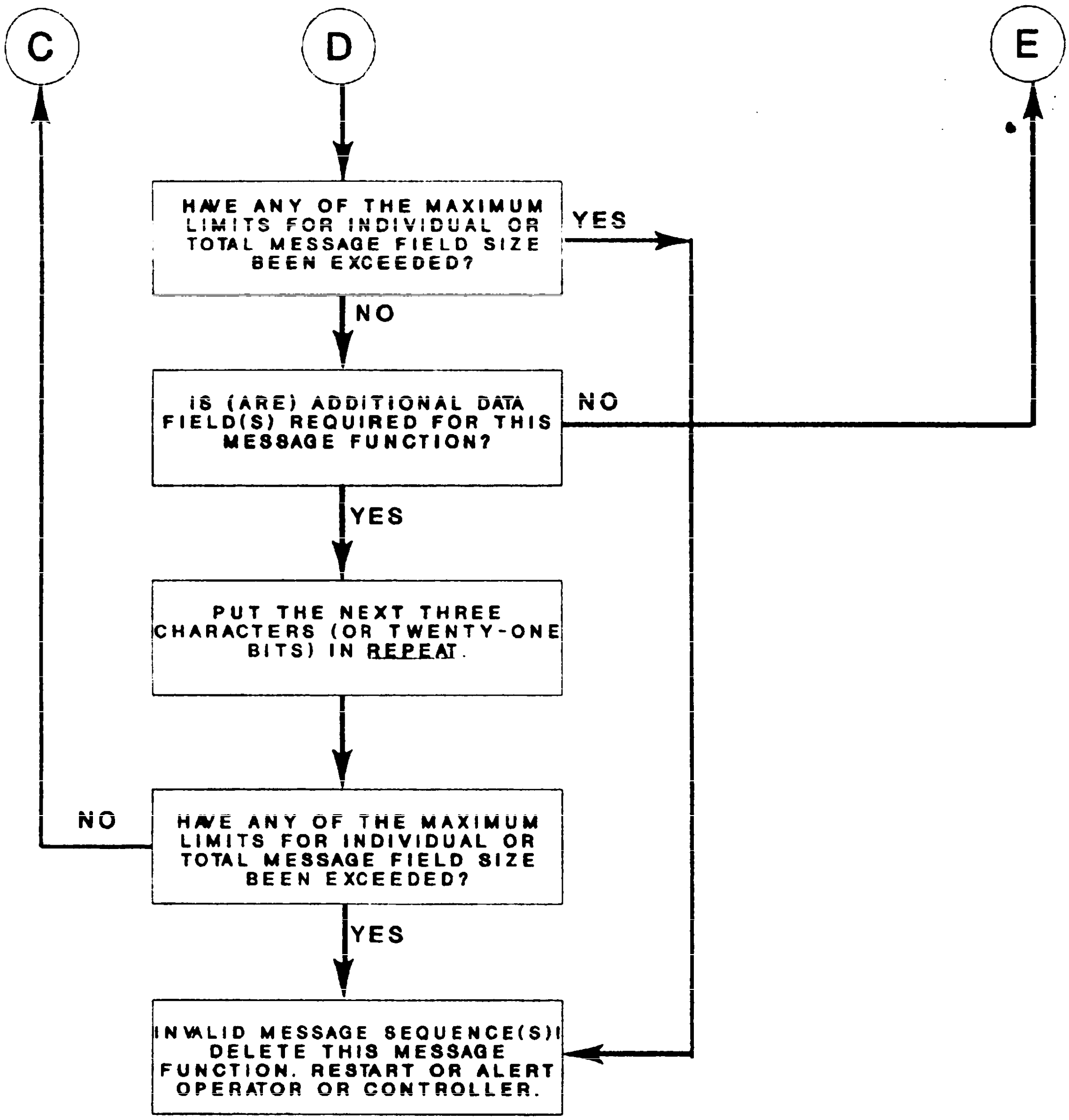

FIGURE A-16. Message sequences -- Continued.

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60.4.2.3 Conclusion. The third section of all calls is termed a "conclusion." It shall be composed of either THIS IS or THIS WAS (but not both) (and possibly DATA and REPEAT) words, from the end of the message (or calling cycle sections, if no message) until the end of the call. See figure A-17. Sounds, an exception, shall start immediately with THIS IS (or THIS WAS) words as described in 70.5. REPEAT shall not immediately follow THIS IS or THIS WAS. Both conclusions and sounds contain the whole address of the transmitting station.

60.4.2.4 Basic frame structure examples. Contained in figure A-18 are basic examples (does not include the optional message section) of frame construction. Included are single-word and multiple-word examples of either single or multiple called station address(es) for nonscan (single-channel) and scanning (multiple-channel) use in individual, net, or group calls.

60.4.3 Synchronization.

60.4.3.1 Transmit modulator. The ALE transmit modulator accepts digital data from the encoder and provides modulated baseband audio to the transmitter. The signal modulation is strictly timed as described in 50.3 and 50.4. After the start of each transmission by a station, the ALE transmit modulator shall maintain a constant phase relationship, within the specified timing accuracy, among all transmitted triple redundant words, at all times, until the final frame in the transmission is terminated. Specifically,

$$T_{(\text{later triple redundant word})} - T_{(\text{early triple redundant word})} = n \times Trw$$

where T( ) is the event time of a given triple redundant word within any frame, Trw is the period of three words (392 ms), and n is any integer.

NOTE: Word phase tracking will only be implemented within a transmission and not between transmissions.

The internal word phase reference of the transmit modulator shall be independent of the receiver (which tracks incoming signals) and shall be self timed (within its required accuracy. See 50.4.)

NOTE: In some applications, a single transmission may contain several frames.

60.4.3.2 Receive demodulator. The receive demodulator accepts baseband audio from the receiver, acquires, tracks, and demodulates ALE signals, and provides the recovered digital data to the decoders. See figure A-14. In data block message (DBM) mode, the receive demodulator shall also be capable of reading single data bits for deep deinterleaving and decoding.

60.4.3.3 Synchronization criteria. The decoder accepts digital data from the receive demodulator and performs deinterleaving, decoding, FEC, and data checking. During initial and continuing synchronization, all of the following criteria shall be used to discriminate and read every ALE word:

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TABLE A-X. Use of "@" utility symbol.

Pattern	Function	Guidance
TO A B C	"Standard" three-character address structure "ABC"	Any position in address and sequences
TO A B @	"Stuff-1" reduced-address field; adds two characters "A,B"	Only last word in address; anywhere in sequences
TO A @ @	"Stuff-2" reduced address field; adds one character "A"	Only last word in address; anywhere in sequences
TO @ ? @	"Allcall" global address; all stop and listen (unless inhibited), none respond	Exclusive member of calling cycle; single TO only
TO @ A @ REPEAT @ b @ (option)	"Selective allcall": global address; all with same last character "A" (or "B") stop and listen (unless inhibited), none respond	Alone, or with additional different allcall selections, for "group selective allcall"; only in calling cycle; must use TO, REPEAT alternately never DATA, if more than one*
TO @ @ ?	"Anycall" global address; all stop and respond in PRN slots (unless inhibited), using own addresses	Exclusive member of calling cycle; single TO only
TO @ @ A REPEAT @ @ B (option)	"Selective anycall": all with same last character(s) "A" (or "B") stop and respond in PRN slots (unless inhibited), using own addresses	Alone, or with additional different anycall selections, for "group selective anycall"; only in calling cycle; must use TO, REPEAT alternately (never DATA), if more than one*
TO @ A B REPEAT @ C D (option)	"Double selective anycall" all with same last characters "AB" (or "CD") stop and respond in PRN slots (unless inhibited) using own addresses	Alone, or with additional different anycall selections for "group double selective anycall"; only in calling cycle, must use TO, REPEAT alternately (never DATA), if more than one*
TO @ @ @	"Null" address; all ignore, test and maintenance use, or extra "buffer" slot	Any position in address sequence (omit from Tsc if group call) except never in conclusion (terminator), or REPEAT, only, if following TO

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TABLE A-X. Use of "@" utility symbol -- Continued.

NOTES:

1. All patterns not shown here are reserved and shall be considered invalid until standardized.
2. "@" indicates special utility character (1000000); "?" wildcard (0111111).
3. "A", "B", "C", or "D" indicates any alphanumeric member of basic 38 subset other than "@", or "?", that is "A-Z" and "0-9".
4. * THRU, REPEAT in Tsc if group call.

60.5.4.3 Allcalls. An "allcall" is a general broadcast which does not request responses and does not designate any specific address. This essential function is required for emergencies ("HELP!"), sounding-type data exchanges, and propagation and connectivity tracking. See table A-X. If an ALE station requires an allcall type function, it shall use the following allcall protocols. The allcall special address structures shall be the exclusive members of the calling cycle (both Tsc and Tlc, of Tcc) in the initial call, shall not be used in any other address field or part of the handshake, and shall use the TO words. The global allcall special address shall be "TO @?@", with standard redundancy. It shall employ only the TO preamble and shall not be followed by REPEAT or DATA. Upon receipt of the allcall, (and unless inhibited or otherwise directed by the operator or controller), all receiving allcalled stations shall temporarily stop their scan (for a preset limited time, Tcc max). If the message section or terminator section does not arrive within Tcc max, the station shall automatically resume scanning. If a quick-ID (indicated by a FROM after the calling cycle) arrives, the pause for the message section shall be extended for no more than five words (5 Trw), and if a COMMAND does not arrive, the station shall resume scanning. If a message arrives (indicated by receipt of a COMMAND), the station shall pause (for a preset limited time, Tm max) to read the message. If the terminator section does not arrive within Tm max, the station shall automatically resume scanning. If a terminator arrives (indicated by receipt of a THIS IS or THIS WAS), the station shall pause (for a preset limited time, Tx max) to read the caller's (transmitter's) address. If the end of the signal does not arrive within Tx max, the station shall automatically resume scanning. If the allcall is successfully received with a THIS IS, the called station shall stop scanning, alert the operator, and unmute its speaker (to receive a message). If there is no activity for a preset time (Twa), the station shall automatically mute its speaker and return to scan. To minimize possible adverse effects resulting from overuse or abuse of all calls, stations shall have the capability to disable receipt of the allcall. Normally the allcall should be enabled. If the allcall is successfully received with a THIS WAS, the called station shall automatically resume scanning and will not respond (unless otherwise directed by the operator or controller). If multichannel calling is used, at the end of the allcall transmission on a channel, the caller shall use call acceptance (THIS IS, with a pause) or call rejection (THIS WAS) protocols identical to the sounding (scanning) protocols in 70.5. If an allcalled or receiving station desires to attempt to link (within the pause after THIS IS), it shall use the optional handshake protocol in 70.5.4. In all handshakes (other than the calling cycle of the initial allcall), the allcall address shall not be used.

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As an additional procedure, the calling station shall have the optional capability to organize (or divide) the available but unspecified receiving stations into logical subsets, using the selective allcall protocol. The selective allcall is identical in structure, function, and protocol to the allcall except that it specifies the last single character of the addresses of the desired subgroup of receiving stations (1/36 of all). By replacing the "?" with an alphanumeric, the selective allcall special address pattern shall be "TO @A@" in Tsc and Tlc (or possibly "THRU @A@" and "REPEAT @B@" in Tsc, and then TO and REPEAT in Tlc if more than one subset is also desired), and rotated if necessary. "A" (and "B", if applicable) in this notation represents any alphanumeric of the basic 38 subset characters (except "@" or "?"). "A" and "B" may represent the same or different character from the subset, and specifically indicate which character(s) must be last in a station's address in order to stop scan and listen. As an example of proper usage, a selective allcall to all stations ending in "P", "Q", and "R",)3/36 of all) would be structured "THRU @P@", "REPEAT @Q@", "THRU @R@", "REPEAT @P@", until appropriately long for the Tsc scan call (and finish with TO, REPEAT, TO... in Tlc). As in the global allcall, the scanning and optional procedure are the same as for the sounding scanning protocol.

60.5.4.4 Anycalls. An ALE station may call, and receive responses from, essentially unspecified stations, and it thereby can identify new stations and connectivities. An "anycall" is a general broadcast which requests responses without designating any specific addressee(s). It is required for emergencies, reconstitution of systems, and creation of new networks. See table A-X. If an ALE station requires an anycall type function, it shall use the following anycall protocols. The anycall special address structures shall be the exclusive members of the calling cycle in the initial call, shall not be used in any other address field or part of the handshake, and shall use the TO the entire Tcc. The global anycall special address pattern shall be "TO @@?", and repeated if necessary for scanning. Upon receipt of the anycall (and unless inhibited or otherwise directed by the operator or controller), all receiving anycalled stations shall temporarily stop their scan, and examine the call identically to the procedure for allcalls in 60.5.4.3, including the Tcc max, Tm max, and Tx max limits. If the anycall is successfully received, the station shall automatically perform a slotted response identical to that for a star net (scanning) call protocol (70.6.2), but as modified below.

There shall be seventeen standardized slots (slot 0 plus sixteen) each 20 Tw (2613.33... ms) wide, for a total duration of approximately 44 seconds. As is described in 70.6, the primary general variation to slot size is with LQA. If the calling station requests LQA in the message (:), the responses shall expand by 3 Tw to include the LQA (▼), and the slots shall automatically expand by 3 Tw to 23 Tw (3005.33... ms), for a total of approximately 51 seconds. In either anycall case, each responding station shall individually select a slot (of one through sixteen, but not zero unless emergency), essentially pseudorandomly (PRN), to transmit its response in. In this protocol, collisions are expected and tolerated, and the caller attempts to read the best response in each slot. Responses shall be standard star net (or individual call) responses consisting of TO (with the address of the caller) and THIS IS (with the address of the responder), with the LQA

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included if requested, and shall not use the anycall special address. The caller should use a short one-word self address and shall not use more than two words. The responders shall use a self address no longer than five words minus twice the caller address length. (For example, if the caller address is two words, the responder cannot exceed one word.) Upon receipt of the slotted responses, the calling station shall transmit the acknowledgement (ACK) to any selected combination (individual or group call) of stations which responded and were read. The responders which receive acknowledgements shall alert, unmute their speakers, and shall pause for traffic, (or quit immediately), as indicated by the caller's ACK conclusion THIS IS (or THIS WAS, respectively). The caller shall not use the anycall special address in the ACK. The caller may pause for additional interoperation and traffic (THIS IS) with the responders; or may immediately resume scanning calling on the next channel (THIS WAS); or try again, as appropriate to the caller's original purpose. Any responding stations that are not included in the ACK shall immediately depart and resume scan. If the anycall is successfully received with a THIS IS, the called station shall stop scan, alert the operator and unmute its speaker (to receive a message). If there is no activity for a preset time (Twa), the station shall automatically mute its speaker and return to scan. To minimize possible adverse effects resulting from overuse or abuse of anycalls, stations shall have the capability to disable receipt of the anycall. Normally the anycall should be enabled.

If too many responses are received, or if the caller must organize the available but unspecified responders into logical subsets, the selective anycall protocol shall be used. The selective anycall is a selective general broadcast which is identical in structure, function, and protocol to the global anycall, except that it specifies the last single character of the addresses of the desired subset of receiving stations (1/36 of all). By replacing the "?" with an alphanumeric, the global anycall becomes a selective anycall whose special address pattern shall be "TO @@A" in Tcc. If a group call (multiple selective anycall), the THRU @@A and REPEAT @@B... are used alternately in the scan call (Tsc), and then TO @@A and REPEAT @@B... in the leading call (Tlc), and rotated if necessary. "A" (and "B", if applicable) in this notation represents any alphanumeric of the basic 38 subset characters (except "@" or "?"). "A" and "B" may represent the same or different characters from the subset, and specifically indicate which character(s) must be last in a station's address in order to initiate a response. As an example of proper usage, a selective anycall to all stations ending in "P", "Q", and "R" (3/36 of all) would be structured "TO @@P", "REPEAT @@Q", "TO @@R", "REPEAT @@P", until appropriately long for the calling cycle.

NOTE: If a narrower acceptance and response criteria is required, the double selective anycall should be used. The double selective anycall is an operator selected general broadcast which is identical to the selective anycall described above, except that its special address (using "@AB" format) specifies the last two characters that the desired subset of receiving stations must have to initiate a response. See table A-X.

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60.6 Link quality analysis (LQA).

60.6.1 General. LQA concerns the automatic measurement of the quality of the ALE signal on the link(s) between station(s). The resultant LQA data is used to score the channels and to support selection of a "best" (or an acceptable) channel for calling and communication. See 60.7. LQA shall also be used for continual monitoring of the link(s) quality during communications which use ALE signaling. The stored values shall be available to be transmitted upon request, or as the network manager shall direct. Unless specifically and otherwise directed by the operator or controller, all ALE stations shall automatically insert the COMMAND LQA word (▼) in the message section of their signals and handshakes when requested by the handshaking station(s), when prearranged in a network, or when specified by the protocol. See 80.2. If an ALE station requires, and is capable of using LQA information (polling-capable), it may request the data from another station by setting the control bit KA1 to "1" in the COMMAND LQA word. If an ALE station which is sending a COMMAND LQA in response to a request is incapable of using such information itself (not polling-capable), it shall set the control bit KA1 to "0". It will be a network management decision to determine if the LQA is to be active or passive. For human factor considerations, LQA scores which may be presented to the operator should have higher (number) scores for better channels.

60.6.2 Basic bit error ratio (BER). The ALE system essentially performs a "pass/fail" LQA test on every received signal by its critical examination of proper coding, structure, and format. Within its integral demodulation and decoding functions is an inherent basic BER measurement capability. The purpose of the basic BER/LQA measurement described herein is to obtain an additional assessment of link quality which provides more resolution than available with the absolute "pass/fail" approach. The BER/LQA function uses data obtained in the process of decoding the received words used in the automatic linking process.

Analysis of the BER on rf channels, with respect to poor channels and the 8-ary modulation, plus the design and use of both redundancy and Golay FEC, shows that an excellent and proportional measure of BER may be obtained by counting the number of nonunanimous (2/3) votes (out of 48) in the majority vote decoder. The BER values should be represented internally by a number which shall range from 0(000000) to 48(110000). The BER/LQA measurement is based on each redundant triplet (3 Tw) word which is received and properly decoded as a valid majority word. Therefore, in an ALE transmission, the best BER/LQA value should appear when the majority vote decoder is properly aligned with the incoming signal; that is, all three-word inputs are occupied with identical (except for errors) redundant words.

The BER may vary during an ALE transmission, and a linearly averaged BER/LQA, which includes all the measurements on good words which were properly aligned, shall be used. If a badly received word is unreadable and is rejected, it shall be assigned the worst BER/LQA value 48(110000) and averaged.

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All ALE stations shall automatically perform the basic BER/LQA algorithm on all received ALE signals based on majority decoder voting. The individual word internal BER/LQA values shall be directly derived from the number of nonunanimous (2/3) majority votes for a particular triple redundant word, properly aligned. The value for an entire received signal shall be the linear average of the internal BER/LQA values of the valid received words, shall include a worst-case 48(110000) value for rejected words, and shall be for an entire and uninterrupted signal. For transmission in the COMMAND LQA word, the internal average value shall be converted to five-bit values as shown in table A-XII. The five-bit values, BE5 (MSB) through BE1 (LSB), shall be the binary representation of the average number of counted (or averaged) nonunanimous (2/3) votes.

60.6.3 Signal plus noise plus distortion to noise plus distortion ratio (SINAD). The optional signal to noise and distortion measurement employed within the LQA shall be a SINAD measurement ((S+N+D)/(N+D)) averaged over the duration of the received ALE signal. If implemented, the SINAD values shall be measured on all ALE signals and shall be inserted into all LQA words in the same manner as the BER. It shall be communicated in 4-bit values as shown in 80.2.2.

60.6.4 Multipath (MP). MP measurements are reserved until standardized.

60.7 Channel selection.

60.7.1 General. Channel selection concerns the automatic identification of a (recently) best (or acceptable) channel for initiating calls or broadcasts to one or several stations. The selection is based on the information stored within the LQA memory (such as BER, SINAD, and MP) and this information is used to speed connectivity and to optimize the choice of quality channels. The ranking and selection method should depend on the quality of information available, the type(s) of link(s) required (1-or 2-way, voice or data), and the quantity of stations involved. The manufacturer should select method(s) for optimum performance.

When initiating scanning (multichannel) calling attempts, the sequence of channels to be tried shall be derived from information in the LQA memory with the channel(s) with the "best score(s)" being tried first (unless otherwise directed by the operator or controller) until all the LQA scored channels are tried. However, if such information is unavailable (or it has been exhausted and other valid channels remain available and untried) the station shall start (or continue) on the highest frequency (untried valid) channel, and if unsuccessful shall continue with the next highest (untried valid) channel, until successful or until all the remaining (untried valid) channels have been tried.

60.7.2 Single-station channel selection. The station shall be capable of selecting the (recent) best channel to initiate a call to, or seek a single station, based on the values in the LQA memory. Figure A-19 represents a simple LQA memory example. For each address/channel call, the received LQA (upper section) and reported LQA values (lower section) are stored. Bilateral (handshake) scores in this example are the sum of the two LQA values.

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TABLE A-XII. Basic bit-error-ratio (BER) values.

Average 2/3 votes counted	LQA transmission bits MSB BE5	BE4	BE3	BE2	LSB BE1	Approx. BER
0	0	0	0	0	0	0.0
1	0	0	0	0	1	0.006993
2	0	0	0	1	0	0.01409
3	0	0	0	1	1	0.02129
4	0	0	1	0	0	0.02860
5	0	0	1	0	1	0.03602
6	0	0	1	1	0	0.04356
7	0	0	1	1	1	0.05124
8	0	1	0	0	0	0.05904
9	0	1	0	0	1	0.06699
10	0	1	0	1	0	0.07508
11	0	1	0	1	1	0.08333
12	0	1	1	0	0	0.09175
13	0	1	1	0	1	0.1003
14	0	1	1	1	0	0.1091
15	0	1	1	1	1	0.1181
16	1	0	0	0	0	0.1273
17	1	0	0	0	1	0.1368
18	1	0	0	1	0	0.1464
19	1	0	0	1	1	0.1564
20	1	0	1	0	0	0.1667
21	1	0	1	0	1	0.1773
22	1	0	1	1	0	0.1882
23	1	0	1	1	1	0.1995
24	1	1	0	0	0	0.2113
25	1	1	0	0	1	0.2236
26	1	1	0	1	0	0.2365
27	1	1	0	1	1	0.2500
28	1	1	1	0	1	0.2643
29	1	1	1	0	1	0.2795
30 (or more)	1	1	1	1	0	0.3 (or more)
--	1	1	1	1	1	no value available

NOTES:

1. BER calculated statistically from probability of number of nonunanimous (2/3) votes of 48.
2. The 2/3 votes count is the average of 2/3 votes of 48 over the words in the received signal.

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ADDRESSES (OTHER STATIONS)		CHANNELS						
		C1	C2	C3	C4	C5	C6	
A	FROM	10	4	1	0	6	15	
	TO	14	8	2	x	7	11	
B	FROM	9	5	1	3	2	6	
	TO	x	7	4	3	5	12	
C	FROM	30	22	13	8	3	18	
	TO	x	-	17	6	2	-	
D	FROM	1	2	5	12	20	-	
	TO	-	4	7	15	21	-	
E	FROM	-	2	6	7	10	-	
	TO	x	14	6	9	12	x	

LQA SCORES

NOTES:

1. UPPER VALUE IS LQA MEASUREMENT ON RECEIVED SIGNAL FROM OTHER STATION.

2. LOWER VALUE IS LQA MEASUREMENT ON TRANSMITTED SIGNAL TO OTHER STATION AS RECEIVED AND REPORTED BACK.

3. EXAMPLE SHOWS RANGE OF 0 TO 30 FOR LQA "SCORES", WITH SMALLER VALUE BEING BETTER.

   - LQA = "0" IS EXCELLENT, RANGING DOWN TO "30" WHICH IS VERY POOR
   - LQA = "X" INDICATES NONE AVAILABLE AFTER HANDSHAKE ATTEMPT.
   - LQA = "-" INDICATES NONE AVAILABLE BUT HANDSHAKE NOT TRIED.

FIGURE A-19. LQA memory example.

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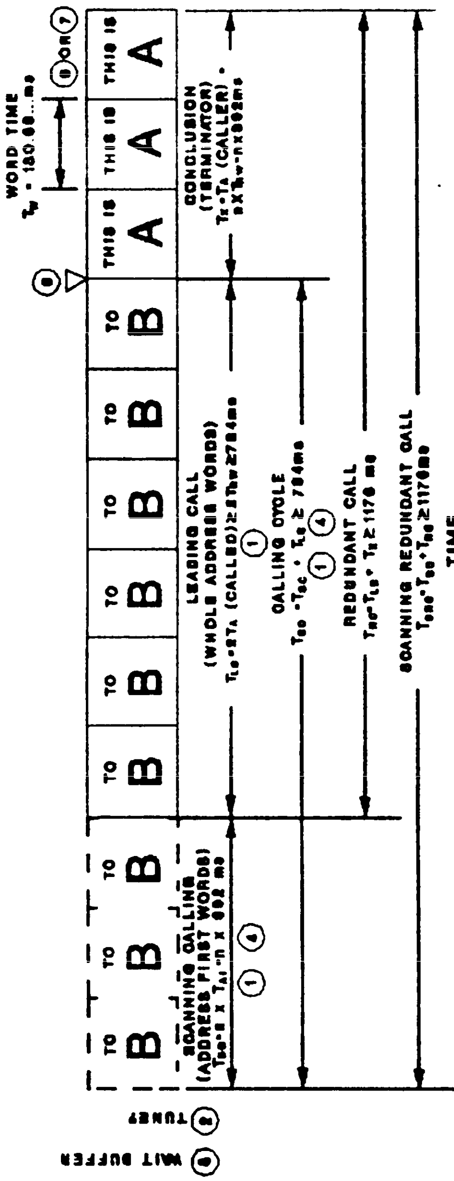

NOTES:

1. SINGLE-CHANNEL (AND MULTIPLE-CHANNEL) EXAMPLES SHOWN WITH ONE-WORD ADDRESSES.
2. TUNING REQUIRED INITIALLY (T_T).
3. WAIT (LISTEN) TIME (T_{WT}).
4. CALLING CYCLE (T_{CC}) DEPENDS ON SCAN PERIOD (T_S).
   - T_{SC}-USE ADDRESS FIRST WORD(S) ONLY (OPTIONAL IF NON-SCAN)
   - T_{LC}-USE WHOLE ADDRESS(ES) ONLY.
5. ∇ OPTIONAL INSERTION OF COMMANDS AND INFORMATION (VLQA). EACH WORD ADDS T_{RW}.
6. THIS WAS TERMINATES PROTOCOL, SUPPRESSES ALERTS.
7. THIS IS NORMALLY COMPELLED BY CALL RECEIPT. (A PAUSES FOR A RESPONSE FROM B).

FIGURE A-2D. Basic call structure.

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70.4.2 Single channel. The fundamental capability to automatically link on a channel is provided by the individual calling protocol. This protocol establishes and positively confirms bilateral connectivity between stations on a channel. ALE stations shall employ this protocol for single-channel linking, polling, and networking, and for basic automated ALE interoperation on a channel after scanning linking. All ALE stations, when operational and not otherwise committed, shall continually listen for calls; that is, they are "always available." See figure A-21. The protocol consists of three parts: an individual call, a response, and an acknowledgement. At the left, in this one-channel example (1), the caller A should already be properly tuned to the channel (2). The wait buffer (3) provides a listen-before-transmit pause, to avoid "disturbing active channels." It has an optional length (Twt) because, in the single channel case, the history of channel activity (and present occupancy) is generally known. Similarly, there is generally no need for an extended calling cycle (4), although it may provide increased probability of signal detection and call receipt. If a fixed station is trying to contact a scanning station, or does not know if the called station is scanning, it should use the totally compatible individual scanning calling protocol. Normally, both A and B are on channel and available; that is, their speakers are muted, they are "always listening", and they "will respond when called." Starting with the individual call, station A shall call station B by transmitting a calling cycle containing B's address ("TO B"), followed by a conclusion (terminator) containing his own ("THIS IS A") (7). A then shall wait a preset reply time (Twr, a buffer which includes anticipated propagation each way and B's turnaround time) to start to receive B's response (9). Upon receipt of A's call and recognition of both his and A's address, B shall tune up (if needed) (2), send the response, and wait his own reply time Twr. Upon receipt of B's response (starting within the reply wait Twr), and recognition of both his and B's addresses, A shall sent the acknowledgement, enter the linked state (with B), unmute his speaker, and alert his operator. Upon receipt of the acknowledgement (starting within B's reply time Twr), B shall also enter the linked state (with A), B shall also alert his own operator and unmute his speaker. During the linked state (A-B) the operators may then pick up their microphones and exchange conventional PTT voice communication, radio teletypewriter (RTTY), ICW, or anything else required. If the expected reply from B does not start to arrive within the preset wait for reply time (Twr) or wait for reply and tune time (Twrt), the handshake shall be terminated, A does not enter the linked state, and A's operator or controller shall be notified. If the expected acknowledgement from A does not start to arrive within the preset wait for reply time (Twr), the handshake shall be terminated, B does not enter the linked state, and B's operator or controller will be notified. However, the linking attempt may be re-initiated by the operator or controller at any time. In rare cases when the acknowledgement to B is lost, A will be in the linked state (without B) but shall return to scan or "available" after the wait for activity timer (Twa) expires.

If implemented, termination of the linked state (after successful linking handshake(s)) shall be accomplished, by the user of a (non-scanning) basic call using THIS WAS, from any station to any other linked station(s) which is (are)

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to be terminated. For example, "TO B, TO B, THIS WAS A" (when sent by A) shall terminate the link (and linked state) between stations A and B. B shall immediately mute and return to "available", unless it still retains a linked state with any other stations on the channel. Likewise, A shall also immediately mute and return to "available", unless it also still retains a linked state with any other stations on the channel. To terminate multiple stations (and linked states) simultaneously, these stations shall use the Net, Group, or series of individual call protocols, with THIS WAS as described in sections 70.6.2 and 70.6.3.

When they are through, they may reset the stations (mute the speakers), therefore restoring them to ALE "available." This manual or automatic reset shall cause a termination (THIS WAS) transmission, as specified above.

If an operator or controller does not key the PTT or use the station within a preset time limit for activity (Twa), the station shall automatically mute, terminate the linked state with that/those stations, and return to "available". The wait for activity timer is mandatory, but it shall be capable of being disabled by the operator or net manager. This timed reset is not required to cause a termination (THIS WAS) transmission, as specified above, however; as a recommended (default) operator or net manager selected option, a termination should be sent to reset the other linked station(s) and immediately free them for being "available".

Termination during a handshake or protocol by the use of THIS WAS (or a timer) shall cause the receiving (or timed) station to end the handshake or protocol, terminate the linked state (with that station), remute, and immediately return to "available" unless it still retains a linked state with another station.

There are several specific variations to the protocol. If an automated message (or COMMAND sequence) is to be sent in any of the signals, it shall be inserted at the (∇) delta location (5), and the signal frame will be appropriately lengthened. The message can provide many options, such as the insertion of LQA information at (▼), and it may significantly affect the protocol and timing, as described in section 80. Normally, A's use of "THIS IS" in the call compels B's response, and the substitution of a "THIS WAS"

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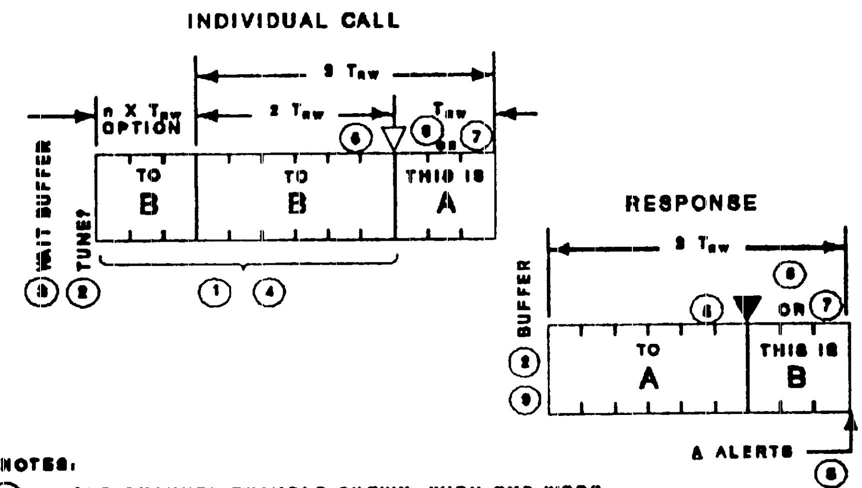

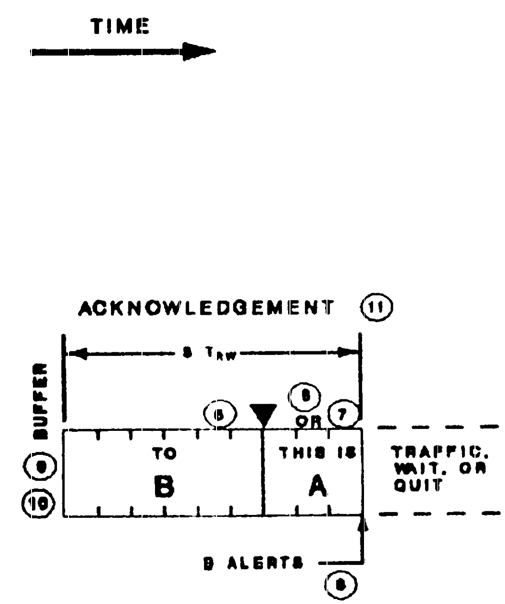

NOTES:

(1) SINGLE-CHANNEL EXAMPLE SHOWN, WITH ONE WORD ADDRESSES.

(2) TUNING REQUIRED INITIALLY (T_T).

(3) WAIT (LISTEN) TIME (T_{WT}).

(4) CALLING CYCLE (T_{CC}) DEPENDS ON SCAN PERIOD (T_S)
- T_{SC} - USE ADDRESS FIRST WORD(S) ONLY (OPTIONAL IF NONSCAN).
- T_{LC} - USE WHOLE ADDRESS(ES) ONLY.

(5) ▽ OPTIONAL INSERTION OF COMMAND AND INFORMATION (▼LQA). EACH WORD ADDS T_{RW}.

(6) THIS WAS TERMINATES PROTOCOL, SUPPRESSES ALERTS.

(7) THIS IS NORMALLY COMPELLED BY CALL RECEIPT. (A AND B PAUSE FOR APPROPRIATE RESPONSE OR ACKNOWLEDGEMENT).

(8) ALERT TO OPERATOR IF TRAFFIC INTENDED.

(9) TIME APPROXIMATION, PROPAGATION AND TURNAROUND

(10) REDUNDANT WORD PHASE DELAY, 0 TO T_{RW}, TO ACCOMODATE STATIONS WHICH MIGHT INCLUDE WORD PHASE TRACKING IN THEIR TRANSMISSIONS.

(11) IF ACKNOWLEDGEMENT NOT SENT, POLLED STATION DOES NOT ALERT AND WILL RETURN TO NORMAL AFTER WAIT.

FIGURE A-21. Individual call protocol.

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shall suppress B's response (6) and terminate the protocol. Therefore, if the individual call contained "THIS WAS A," B would receive A's call (and the message, if any), realize that it was a one-way broadcast for B, and B would not respond (unless otherwise compelled by the message, his operator, or his controller). Similarly, B's use of "THIS IS" compels A to complete the handshake and send an acknowledgement. However, if B sends a "THIS WAS," A shall not alert or send an acknowledgement, and the protocol shall be terminated. A station such as B would terminate the handshake under several circumstances, such as being unavailable (but active), being engaged in traffic, realizing that the channel is busy (at B's end), or being compelled (by prearrangement or protocol) to respond without having an obligation to continue (mandatory roll call, optional chat).

It should be noted that A's acknowledgement to B appears identical to A's individual call to B, but it does not cause B to provide another response to the acknowledgement (resulting in an endless "ping-pong" handshake) because A's acknowledgement arrives within the narrow time window (Twr) of B's first response, and A is responsible for sending the ACK within this time limit. If A does not receive B's response within this reset time, the call is considered unsuccessful and A may terminate, or A may try again with additional call attempts (preset, controller, or operator choice). If A's acknowledgement arrives late (after Twr), then B treats it as a new (or second) individual call (and provides a new response, if A uses THIS IS).

While receiving an ALE signal, it is possible for the continuity of the received signal to be lost (due to such factors as interference or fading) as indicated by failure to periodically (Trw) detect good ALE words. If such a dropout occurs during an initial received call, and continues for a period in excess of 3 Trw (1176ms) beyond the last good received words without detection of additional good received words, the receiving stations shall abandon the attempt to link and, if multichannel, shall immediately return to normal receive scanning. In all cases each individual ALE received signal must have all of its included words at a consistent and uniform redundant word phase, despite dropouts, to be acceptable and valid. Any variation indicates an interference or a collision and such variation shall be rejected as not part of the signal.

NOTE: Stations should be able to read interfering ALE signals, as they may contain useful (or critical) information, and the station is therefore "always listening".

Also, if a station receives a complete individual call (TO with the whole address), but does not receive the expected conclusion (THIS IS or THIS WAS), it should attempt a single-channel call acceptance sound (THIS IS, as described in 70.5.4) to reinitiate the calling station.

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70.4.3 Multiple channels. All ALE stations shall be capable of performing the individual scanning calling protocol described herein, even if on a fixed frequency. See figure A-22. If multichannel, they should be "always scanning." This protocol establishes and positively confirms bilateral connectivity between stations on any available mutually scanned channel. Stations shall employ this protocol for multichannel linking. This protocol is fully compatible with the previously described individual calling protocol shown on figure A-21, and is essentially identical except for the longer calling cycle and the following modifications.

All stations, when operational and not otherwise committed, shall continually scan a preselected set of channels, or "scan set," listening for calls and ready to respond. The minimum dwell time (Td min) on each channel is the reciprocal of the scan rate, and the channels in the scan set are repeatedly scanned in the same order and for the same period. This minimum scan period (Ts min) is equal to the product of the number of channels (C) times the minimum dwell time on each channel (Td min); that is, Ts min = C x Td min. However, the receive scan period (ts) (for calling transmit (Tsc) computations) should be based on the probable maximum pause (Td) to read words on each channel, or Tdrw = 784 ms. Thus, Ts = C x Td = C x 784 ms. The net manager may adjust the Td to optimize system performance.

All stations, when attempting to contact another station in a multichannel environment, shall scan through the preselected set of channels, pausing on each channel of the set to transmit an individual scanning call, and waiting for a preset, limited time for responses. The calling cycle (Tcc) is composed of a scan calling time (Tsc) plus a leading call time (Tlc). The scan calling time (Tsc), in order to capture the scanning receiver, must equal or exceed the total scan period (Ts) of the called station and shall also be composed of multiple address first words (Σ Tal = Tcl), which are a multiple of the redundant word time, Trw; that is, Tsc = n x Σ Tal = n x Tcl $\geq$ Ts. The scanning call contains only the called address(es) different first words (Σ Tal) in rotation. The leading call contains only the whole called station(s) address(es), repeated twice (2Tc = 2 Σ Ta). Therefore, the calling cycle should be: Tcc = Tsc + Tlc = (n x Σ Tal) + 2Tc $\geq$ Ts + 2 (Σ Ta). The relative timing of the receive and transmit scan cycles shall ensure that the scanning receiver samples the entire channel scan set within the period of a scanning call.

The scanning calling station shall stop and link on the first channel which supports the handshake with the called station(s). After scan stop, unmute, and operator alert, the operators (or controllers) use the link and the channel as necessary. If they reject it as unsuitable, they may restart the scan sequence to seek another, better channel by muting (resetting) their stations and reinitiating scanning calling (usually by the original caller). If the calling station has an LQA memory and scoring capability it shall rerank the channels (with the rejected and the previously failed channels being downgraded) and restart the calling on the newly expected best channel. If the station has a fixed calling channel sequence, it shall restart the scanning call on the next channel which would have been tried

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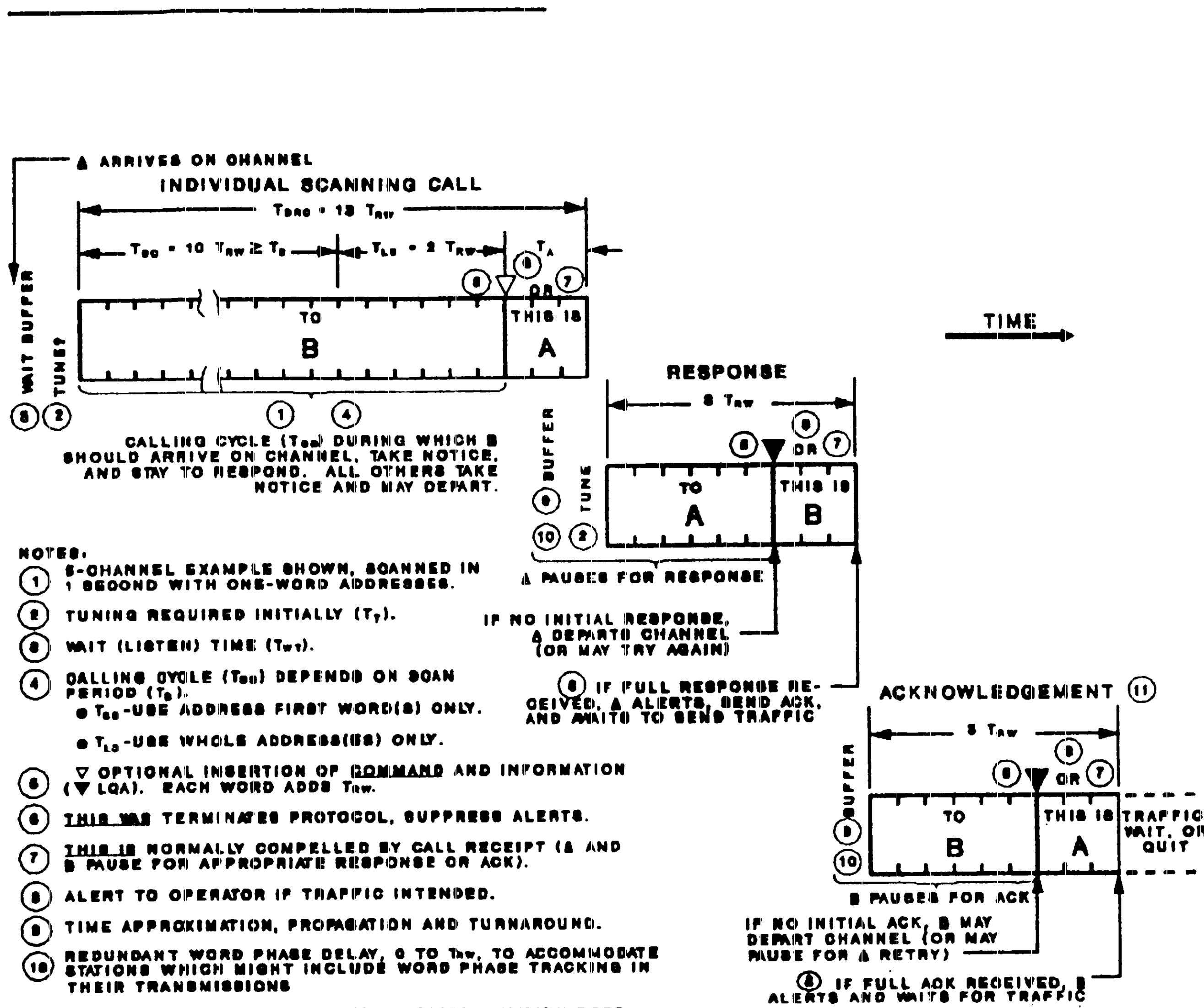

NOTES:

1. 5-CHANNEL EXAMPLE SHOWN, SCANNED IN 1 SECOND WITH ONE-WORD ADDRESSES.
2. TUNING REQUIRED INITIALLY (T_T).
3. WAIT (LISTEN) TIME (T_{WT}).
4. CALLING CYCLE (T_{SC}) DEPENDS ON SCAN PERIOD (T_S).
   - T_{SC}-USE ADDRESS FIRST WORD(S) ONLY.
   - T_{LS}-USE WHOLE ADDRESS(ES) ONLY.
5. ▽ OPTIONAL INSERTION OF COMMAND AND INFORMATION (▼ LQA). EACH WORD ADDS T_{RW}.
6. THIS WAS TERMINATES PROTOCOL, SUPPRESS ALERTS.
7. THIS IS NORMALLY COMPELLED BY CALL RECEIPT (A AND B PAUSE FOR APPROPRIATE RESPONSE OR ACK).
8. ALERT TO OPERATOR IF TRAFFIC INTENDED.
9. TIME APPROXIMATION, PROPAGATION AND TURNAROUND.
10. REDUNDANT WORD PHASE DELAY, 0 TO T_{RW}, TO ACCOMMODATE STATIONS WHICH MIGHT INCLUDE WORD PHASE TRACKING IN THEIR TRANSMISSIONS
11. IF ACKNOWLEDGEMENT NOT SENT, POLLED STATION DOES NOT ALERT AND WILL RETURN TO NORMAL AFTER WAIT.

FIGURE A-22. Individual scanning calling protocol.

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earlier had a link not been established, and it does not restart at the top frequency (or first channel) as before (unless directed by operator or controller). Often during the scanning calling cycle, the caller will encounter occupied channels which are skipped to avoid interference to traffic and activity. After all available channels have been tried, and no contact has been successful, the caller may optionally revisit the previously occupied channels and, if they are free, attempt to call. In either case, when the calling station has exhausted all the prearranged scan set channels and failed to establish a link, it shall immediately return to normal receive scanning. It shall also alert the operator (and controller) that the calling attempt was unsuccessful. If the scanning call is reinitiated, the ALE station shall restart and try again. Refer to 70.4.4 for the specific details of ALE timing.

When an appropriately addressed call ("TO B") is detected by, and addressed to, scanning station B, the station shall stop (for a preset, limited time) to read the rest of the signal and to perform the standard handshake (unless otherwise directed) with the calling station (A). If the call is not addressed to station B, B shall leave the channel immediately and resume scanning (unless otherwise directed by the selected protocol, or its operator or controller). Figure A-22 illustrates the individual scanning calling protocol handshake for stations in a typical five-channel network and employing a standard scan rate of five chps. The protocol starts with A's arrival on channel, shown at the left. Upon arrival, A shall pause for a preset buffer time (Twt) to monitor the channel and listen for traffic or occupancy (3). If the channel appears clear (or if A is forced by the operator or controller), A shall tune its coupler (2) as rapidly as possible (Tt), and initiate the transmission. The scan calling time (Tsc) of the calling cycle (Tcc) is deliberately longer than B's scan period (Ts) to ensure that B will be "captured" as it scan to, and samples, the channel.

When station B arrives on channel, sometime during its scan period (Ts), and therefore during A's additional and longer scan calling time (Tsc), B shall attempt to detect ALE signaling (within dwell time Td min) and then shall decide to wait a preset time (Tdrw) to read possible ALE words if ALE signaling was detected. If no signaling is detected within Td min, B shall resume scanning. If non-ALE signaling or interference is detected, B shall resume scanning.

If B does not read appropriate ALE words within Tdrw, B shall leave and resume scanning. If B reads "TO B" (or an acceptable equivalent according to protocols), it shall stop scan, plan to reply (response), and wait a preset, limited time (Twce) for the calling cycle to end and the message or conclusion to begin. Meanwhile, B shall continually read the ALE signaling to identify additional information, such as type of call (and additional station addresses if any). B shall attempt to detect invalid sequences, in which case B shall automatically reject the call and immediately resume scan (unless otherwise directed by the operator or controller). If a quick-ID or a message (COMMAND sequence) starts within Twce, B shall wait and attempt to read the message within a new preset, limited time (Tm max). If no quick-ID or message starts within Twce, or no terminator starts within Tm max (or Twce

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if no message), B shall resume scan. If an invalid message sequence is read, B shall resume scan immediately. If a terminator starts, such as "THIS IS A", B shall wait and attempt to read the calling station's address (A) within a new preset, limited time (Tx max). If an unacceptable terminator address sequence is read, B shall resume scan immediately. If an acceptable terminator sequence with THIS IS is read, B shall wait to respond (while identifying the entire address). B shall also expect A to continue the handshake (with an acknowledgement) within B's reply window, Twr, after B's response. If THIS WAS is read instead, B shall not respond and shall resume scan immediately (after identifying the entire address).

All receiving stations shall identify the end of a received ALE signal by the following methods. The station shall search for a valid terminator (THIS IS or THIS WAS, possibly followed by DATA and REPEAT for a maximum of five words, or Tx max). The terminator shall maintain constant redundant word phase within itself (if a sound) and with associated previous words (if a call). The station shall examine each successive redundant word phase (Trw) following the THIS IS (or THIS WAS) for the first (of up to four) nonreadable or nonvalid word(s). Failure to detect a proper word (or detection of an improper word) or detection of the last REPEAT, plus the last word wait delay time, Tlww, or Trw), indicates the end of the received transmission. The only acceptable terminator sequence is THIS IS (or THIS WAS), DATA, REPEAT, DATA, REPEAT.

If all of the above sequential criteria are satisfied, and if B is not otherwise directed by the operator or controller, B shall immediately initiate an ALE response. All stations (such as B), even in single-channel mode, shall perform these analytical and timing discrimination functions. Therefore, in the single channel case, where no scan is available, the station shall reject the call if inappropriate, invalid, improper, or outside of the time limits.

After transmitting its individual scanning call to B, A shall pause (9) for B's reply (response) for a slightly extended wait time (Twrt), as B must be provided an additional period (Tt) to tune (2) for an initial reply. However, called station B shall use the shorter single channel wait time (Twr) when waiting for A's reply (acknowledgement), because A has already tuned.

A shall wait and attempt to detect any ALE signals and read a reply (response) from B within the preset limited time, Twrt. If A successfully reads an appropriate response ("TO A") starting within Twrt, it shall plan to reply (acknowledge) and shall wait a preset limited time (Tdrrw) to read the next rotating redundant word, which in the protocol shown is the "THIS IS B" terminator. If A does not receive this appropriate response calling cycle ("TO A") starting within Twrt, or if A does not later receive the appropriate terminator ("THIS IS B") starting after Tlc, (plus Tm max, if message included), A shall automatically terminate the protocol and resume scanning calling. If A receives the proper terminator word from B ("THIS IS B") starting within Tlc (plus Tm max, if message included), A shall wait to reply (acknowledge), and shall expect the handshake to be successfully completed

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within the time window Twr. Meanwhile, A shall continue to read the incoming ALE signal and shall search for a new preset, limited "last word wait" time Tlww = Trw for additional words (if any) and the end of the terminator signal (absence of detected word), which will trigger A's acknowledgement. If "THIS WAS B" is received, A's linking attempt is terminated. If an invalid sequence occurs, or the terminator end is not detected within Tlww, (plus the additional multiples of Trw if an extended address), A shall terminate the protocol and resume scanning calling. If all the above sequential criteria are satisfied, if the terminator end is detected within Tlww, and if not otherwise directed by the operator or controller, A shall alert its operator that a correct response has been received, shall initiate the ALE acknowledgement (using "THIS IS A"), and shall unmute A's speaker. Both A and B shall continue to use the same methodology, criteria, and timing described above for the successful transfer of the acknowledgement, in which case, station B shall alert his operator that the correct acknowledgement has been received and shall unmute B's speaker. The bilateral link is now set up, confirmed, and available for the operator. If A is to terminate the handshake, it does not alert or unmute and uses "THIS WAS A" in the acknowledgement. This causes B to stay muted, not alert, and to resume scanning. If the entire set of scanned channels to be used for calling have been tried, and no successful handshake has been completed, the calling station (A) shall immediately resume receive scanning and shall alert the operator (or controller) of the failure.

NOTE: The total elapsed handshake time (Ths) in the example given on figure A-22 is about nine seconds on the channel.

70.4.4 Timing. The ALE system depends on a selection of timing functions for optimizing the efficiency and effectiveness of automatic link establishment. The primary timing functions and values are listed in table A-XIV. Annex A defines the timing symbols and annex B explains the timing analysis and computation.

TABLE A-XIV. Timing.

NOTE: Refer to annex A and annex B for details.

Basic system timing

- o Tone rate = 125 symbols per second (sps)
- o Tone period = Ttone = 8 ms
- o On-air rate = 375 bps
- o On-air word: Tw = 130.66... ms
- o On-air redundant word: Trw = 3 Tw = 392 ms

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TABLE A-XIV. Timing -- Continued.

- On-air leading redundant word: Tlrw = 2 Trw = 784 ms
- On-air individual (net address time: Ta = m x Trw for m = 1 to 5 max words. Ta = 392 ms to 1960 ms
- Propagation: Tp = 0 to 70 ms

System timing limits

- Address size limit 5 word: Ta max = 1960 ms
- Address first word limit: Tal = 392 ms
- Call time limit 12 words of the call: Tc max = 4704 ms
- Group addresses first word limit: Tcl = 1960 ms
- Maximum scan period: Ts max = 50 s
- Message section basic time (unless modified by AMD extension, or by COMMAND (such as DTM or DBM)): Tm max basic = 11.76 s
- Message section, time limit of AMD (90 characters): Tm max AMD=11.76s
- Message section time limit, DTM (1053 characters): Tm max DTM = 2.29 min (entire data block)
- Message section time limit, DBM, (37377 characters): Tm max DBM = 23.26 min (entire deeply interleaved block with COMMAND
- Termination time limit: Tx max = 1960 ms

If an orderwire protocol such as AMD, DTM, or DBM is used to extend the basic message section, it shall start no later than the start of the 30th word (11.368 s). Such extension of the message section shall be determined by the length of the extended orderwire protocol, and the message section shall terminate at the end of the orderwire without additional extension. The conclusion shall start at the end of the message section.

Individual calling

- Minimum dwell time: Td(5) min = 200 ms, basic receive scanning (5 channels per second)
- Minimum dwell time: Td(2) min = 500 ms, minimum receive scanning (2 characters per second (chps))

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TABLE A-XIV. Timing -- Continued.

- o Probable maximum dwell per channel, for Ts computations, let Td = Tdrw = 784 ms
- o Number of channels: C
- o Scan period: Ts = C x Td
- o Call time: Tc = Ta (or more whole addresses as required, Σ Ta) in Tlc

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TABLE A-XIV. Timing -- Continued.

- o Call Time: Tcl = Tal (or more different first words, Σ Tal) in Tsc
- o Leading call Time: Tlc = 2Tc
- o Redundant call time: Trc = Tlc + Tx
- o Scanning call time: Tsc = n x Tcl ≥ Ts
- o Calling cycle time: Tcc = Tsc + Tlc ≥ Ts + Tlc
- o Scanning redundant call time: Tsrc = Tsc + Trc
- o Last word wait delay: Tlww = Trw = 392 ms
- o Wait for response time delay: Twr = Ttd + Tp + Tlww + Tta + Trwp (if not first transmission...) + Tld + Tp + Trd
- o Late detect delay: Tld = Tw = 130.66... ms
- o Redundant word phase delay: Trwp = 0 to Trw (0 to 392 ms)
- o Turnaround time: Tta = Trd + Tdek + Tenk + Ttc + Ttk + Ttd
- o Wait for calling cycle end time: Twce = 2 x own Ts (default)
- o Tune Time: Tt (as required by slowest tuner)
- o Wait for reply and tune time: Twrt = Twr +Tt
- o Detect signaling period: Tds ≤ (Td(5) = 200 ms)
- o Detect redundant word period: Tdrw = Trw + spare Trw = 784...ms
- o Detect rotating redundant word period: Tdrrw = 2 Trw + spare Trw = 1176 ms

Sounding

- o Redundant sound time (similar to Tlc): Trs = 2 Ta (caller)
- o Scanning sound time (similar to Tsc): Tss = n x Ta (caller) ≥ Ts
- o Scanning redundant sound time (similar to Tcc): Tsrs = Tss + Trs ≥ Ts + Trs

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TABLE A-XIV. Timing -- Continued.

Star calling

- o Minimum standard slot widths: Tsw min = 14, 17 Tw for 1st handshake slots, or 17, 20 for subsequent handshake slots, or other Tw as set by COMMAND.
- o Slot widths: Tsw = 14, 17, 9, or other Tw
- o Slot number: SN
- o Slot wait time: Tswt = Tsw X SN (uniform case)
- o Slot wait time (delay to start reply): Twst for each slot is the sum of all the previous slot times and so must be different for each slot and is cumulative. Tswt(SN) = Tsw x SN for uniform slots or generally Tswt(SN) = SN x [5 Tw +2 Ta (caller) + (optional LQA)Trw + (optional message)Tm] + Ta (caller) + [(sum of all previous called addresses) $\sum_{m=1}^{m=SN-1} Ta(m)$ (called)]
- o Number of slots: NS
- o Wait for net reply (at calling station): Twrn = (Tsw x NS) for uniform slots, or generally Twrn = Tswt(NS)
- o Wait for net acknowledgement (at called stations): Twan = Twrn + Tdrw
- o Turnaround and tune limits: Tta + Tt $\leq$ 360,2100, or 1500 ms depending on whether slot 0, 1, or others
- o Maximum star group wait for acknowledgement: Twan max = 107 Tw + 27 Ta (caller) + 13 Trw (optional LQA) + 13 Tm (optional message)
- o For late arrival stations, if caller uses one word addresses and no message calling: Twan max = 188 Tw, or 227 Tw if LQA

Programmable timing parameters: typical values

- o Wait (listen first): Twt = 2 seconds, general uses; = 784 ms, ALE/ data only channels
- o Tune time: Tt = 8 Tw = 1045.33... ms (default), "blind" first call; = 20 seconds, next try
- o Automatic sounding: Tps = 30 minutes
- o Wait for activity: Twa = 30 seconds

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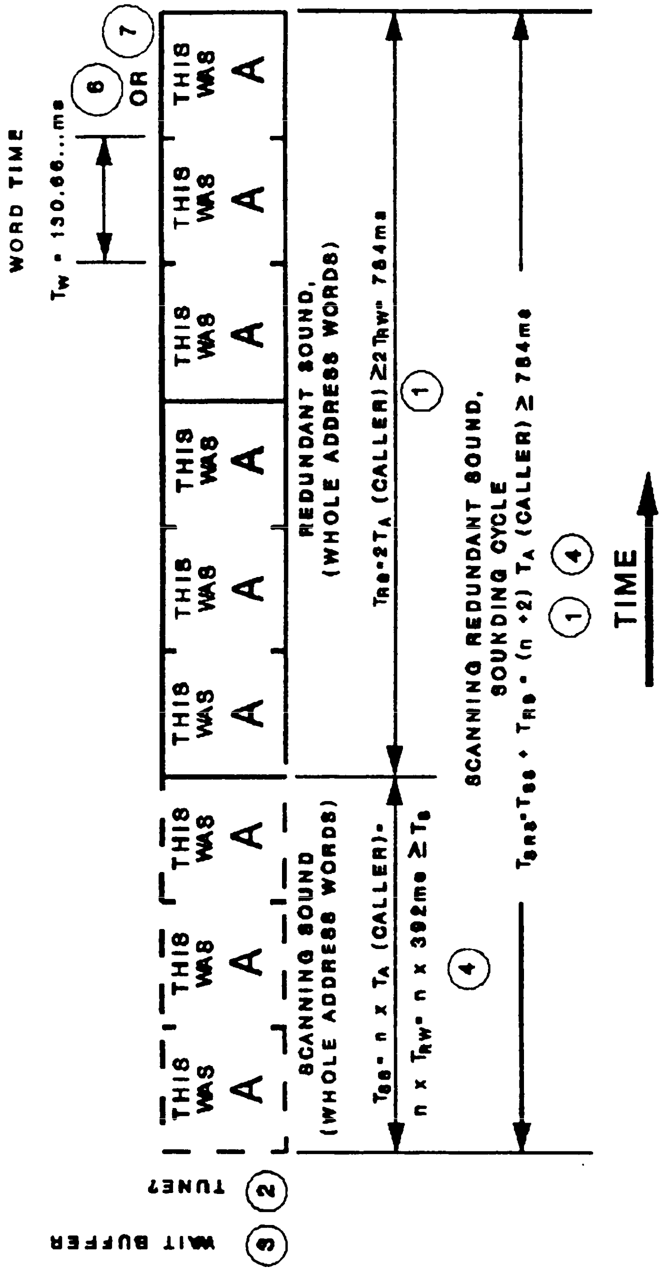

NOTES:

1. SINGLE-CHANNEL (AND MULTIPLE-CHANNEL) EXAMPLES SHOWN WITH ONE-WORD ADDRESSES.
2. TUNING REQUIRED INITIALLY (T_T).
3. WAIT (LISTEN) TIME (T_{WT}).
4. SOUNDING CYCLE (T_{SRS}) DEPENDS ON SCAN PERIOD (T_S).
   - T_{SRS} -USE WHOLE ADDRESS ONLY.
   - T_{SS} (OPTIONAL IF NONSCAN).
6. THIS WAS INDICATES CALL REJECTION.
7. THIS IS INDICATES CALL ACCEPTANCE (A WILL PAUSE AFTERWARDS).

FIGURE A-23. Basic sounding structure.

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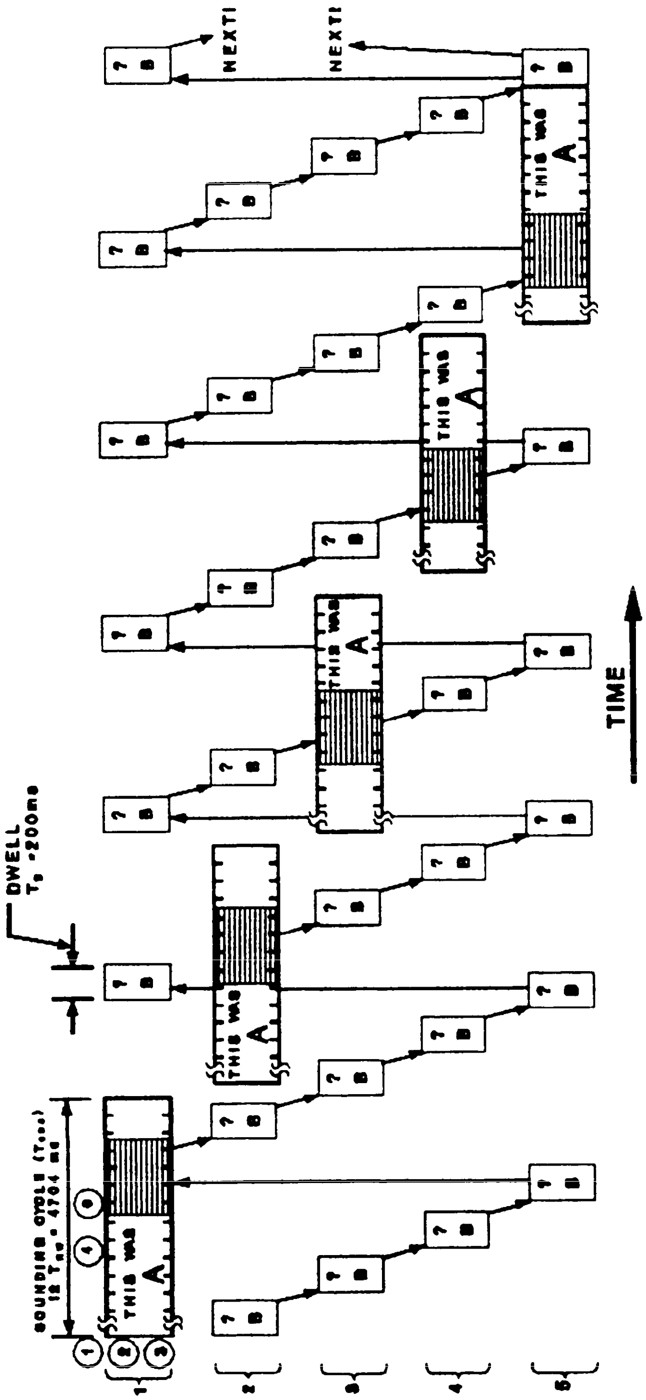

NOTES:

1. 5 CHANNEL EXAMPLE SHOWN, SCANNED IN ONE SECOND.
2. TUNING REQUIRED INITIALLY (T_T) ON EACH CHANNEL.
3. WAIT (LISTEN) TIME (T_{WT}) BEFORE SOUNDING.
4. SOUNDING CYCLE (T_{SC}) DEPENDS ON SCAN PERIOD (T_S).
   - T_{SC}-USE WHOLE ADDRESS ONLY.
5. THIS WAS INDICATES CALL REJECTION.

INDICATES COINCIDENCE OF A SOUND AND B SCANNING RECEIVER DWELL (AND READ)

? B INDICATES PERIOD OF B RECEIVING DWELL ON CHANNEL

FIGURE A-24. Call rejection scanning sounding protocol.

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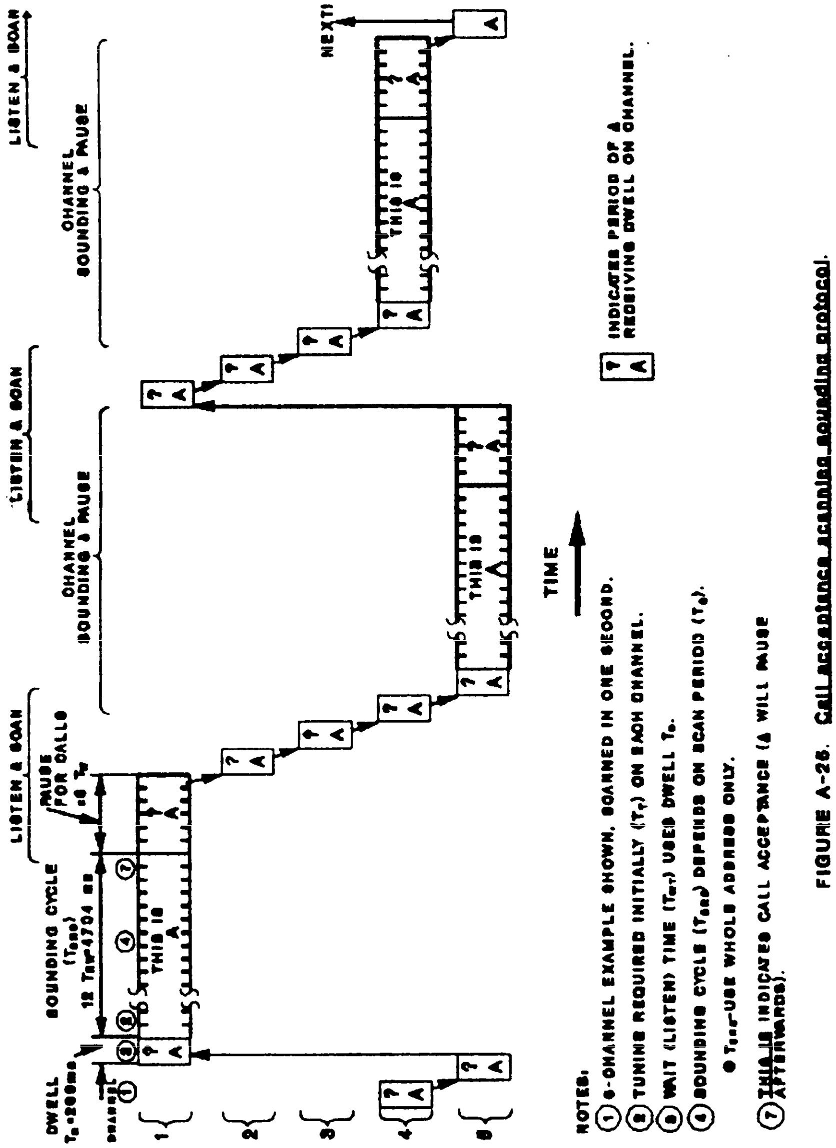

FIGURE A 25. Call acceptance scanning sounding protocol.

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The basic protocol consists of only one part, the scanning sound. See figure A-23. All timing considerations and computations for individual scanning calling shall apply to scanning sounding, including sounding cycle times and (optional) handshake times.

NOTE: The scanning sound is identical to the single-channel sound except for the extension of the redundant sound time (Trs) by adding words to the scan sounding time (Tss) to form a scanning redundant sound time (Tsrs); that is, Tsrs = Tss + Trs. The scan sounding time (Tss) is identical in purpose to the scan calling time (Tsc) for an equivalent scanning situation, but it only uses the whole address of the transmitter.

The channel-scanning sequences and selection criteria for individual scanning calling shall also apply to scanning sounding. The channels to be sounded are termed a "sound set," and usually are identical to the "scan set" used for scanning. See figure A-24. In this illustration, station A is sounding and station B is scanning normally. If a station (A) plans to ignore calls (from B) which may follow A's sound, the following call rejection scanning sounding protocol shall be used. In a manner identical to the previously described individual scanning call, A lands on the first channel in the scan set (1), waits (Twt) to see if the channel is clear (3), tunes (Tt) its coupler, comes to full power, and initiates the frame of the scanning redundant sound time (Tsrs). This scanning sound is computed to exceed B's (and any others) scan period (Ts) by at least a redundant sound time (Trs), which will ensure an available detection period exceeding Tdrw = 784 ms. In this five-channel example, with B scanning at 5 chps, A sounds for at least 12 Trw (4704 ms). A also uses "THIS WAS A", redundantly, to indicate that calls are not invited. Upon completion of the scanning sounding frame transmission, A immediately leaves the channel and goes to the next in the sound set. This procedure repeats until all channels have been sounded, or skipped if occupied. When the calling ALE station has exhausted all the prearranged sound set channels, it shall automatically return to the normal "available" receive scan mode. As shown in the illustration, the timing of both A and B have been prearranged to ensure that B has at least one opportunity, on each channel, to arrive and "capture" A's sound. Specifically, B arrives, detects sounds, waits for good words, reads at least three (redundant) "THIS WAS A" (in 3 to 4 Tw), stores the connectivity information (if capable), and departs immediately to resume scan.

There are several specific protocol differences when station A plans to welcome calls after the sound. See figure A-25. In this illustration, A is sounding and B is scanning normally. If a station (A) plans to welcome calls (from B) which may follow his sound, the following call acceptance scanning sounding protocol shall be used. In this protocol, A sounds for the same time period as before. However, since A is receptive to calls, he shall use his normal scanning dwell time (Td) or his preset wait before transmit time (Twt), whichever is longer, to listen for both channel activity and calls before sounding. If the channel is clear, A shall initiate the scanning sound identically to before, but with "THIS IS A". At the end of the sounding frame, A shall wait for calls identically to the wait for reply and

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tune time (Twrt) in the individual scanning calling protocol, in this case shown to be 6 Tw (for fast-tuning stations). During this wait, A shall (as always) be listening for calls which may coincidentally arrive even though unassociated with A's sound, plus any other sound heard, which A shall store as connectivity information if polling capable. If no calls are received, A shall leave the channel.

70.5.4 Optional handshake. In the previous descriptions, one alternative action is the implementation of an optional handshake with a station immediately after its sound. This protocol is identical in all regards to the single channel individual call protocol, except that it is manually or (DO) automatically (operator or controller) triggered by acquisition of connectivity from the station which is to be called. See figure A-26. In this illustration, A is scanning sounding and is receptive to calls, and B is receive scanning (or waiting in ambush on a channel) and requires contact with A if heard. A uses the standard call acceptance scanning sound, including the "THIS IS A" and the pause for calls. In this case, B calls A. When ALE stations are scanning sounding and receptive to calls, or require contact with such a station, the optional handshake protocol should be used. The calling station should immediately initiate the call upon the determination that the station to be called has terminated its transmission. A wait time before transmit time is not required. Therefore, if B hears A's sound and is seeking A, B calls immediately using the simple single-channel call. Also, if B's operator or controller identifies A's address it can attempt the optional handshake.

70.6 Multiple stations operations.

70.6.1 General. A critical requirement for MF/HF systems is the capability to rapidly initiate links with, and interoperate with, multiple stations. Linking among multiple stations is significantly more difficult than linking between two individual stations because the quantity of required MF/HF links can increase exponentially as stations are added, and all the links still retain their individual challenges of propagation and interference. In many cases, total interconnectivity cannot be achieved on any single frequency because, regardless of power or effort, propagation will not support communications between several stations. This section describes these multiple-station operations.

There are three fundamental network configurations from which any network may be constructed, and each requires significantly different quantities of links (L), depending on the numbers of stations (N) which are included:

- o Link $L = 1$
- o Star $L = (N-1)$
- o Multipoint $L = (N^2-N)/2$

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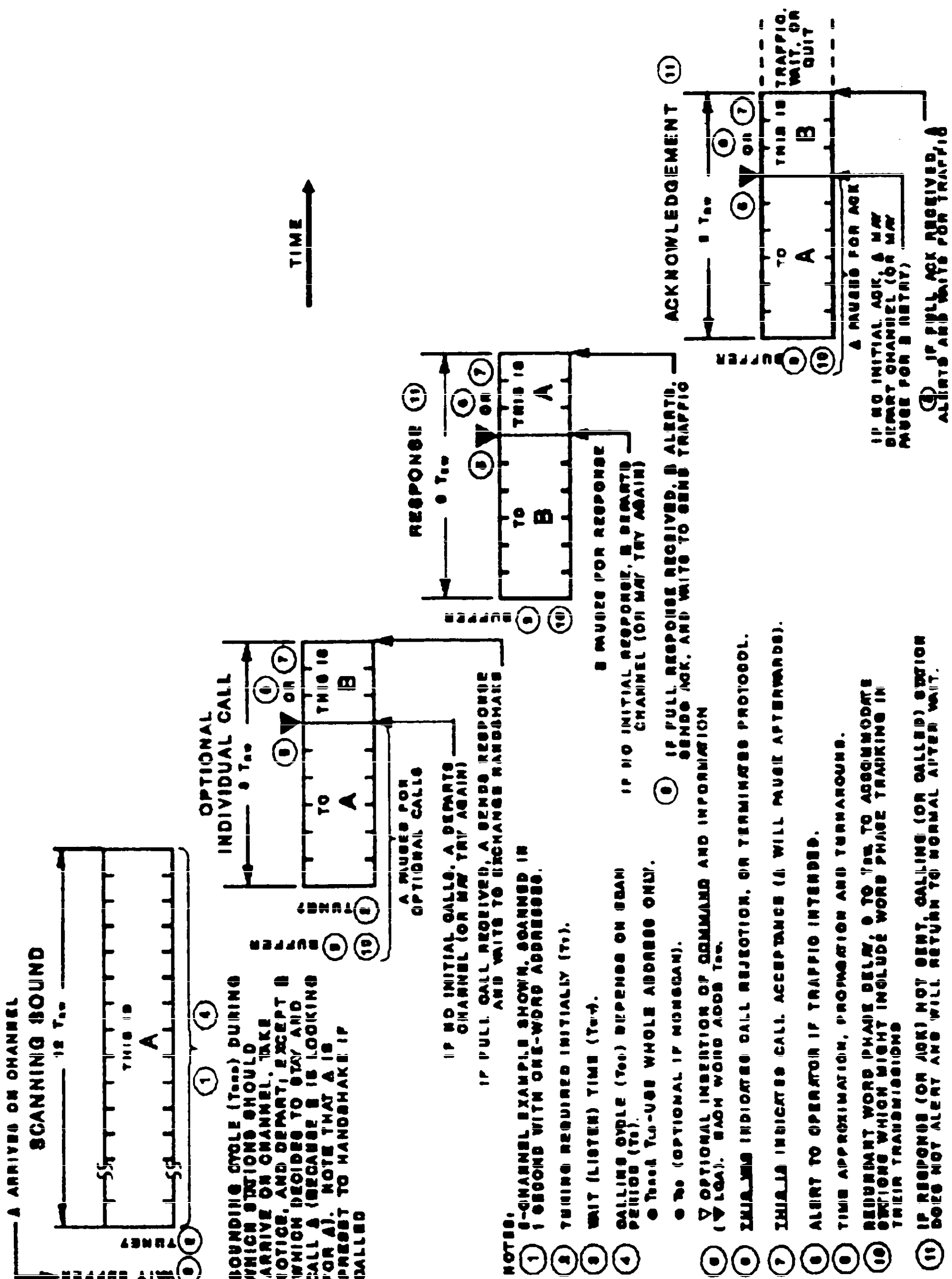

FIGURE A-26. Scanning sounding with optional handshake protocol.

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A link involves only two stations and requires only a single point-to-point path. A star involves several stations in a "one-to-many" configuration and requires one less link than the number of stations. A multipoint involves several stations in a "many-to-many" configuration and requires an exponential quality of links. In this section, two fundamental types of multiple-station operations are described:

- o Star net
- o Star group

70.6.2 Star net. A star net is a prearranged collection of stations which is to link and interoperate primarily with a single hub station which, in most cases, has the separate function of net control station (NCS). A star net is usually organized and managed with significant prior knowledge of the member stations, including their quantity, identities, capabilities, requirements, and in most cases, their locations and necessary connectivities. The purpose of a star net call, like any net call, is to rapidly and efficiently establish contact with multiple prearranged (net) stations, simultaneously (or nearly simultaneously), by the use of a single net address. This address is common to all net members. See section 60.5. In association with the net address, each station must also store information regarding its proper response(s) and timing(s), as described below and as described in 40.4 and 40.5. A net manager may select minimum, uniform, or variable slot widths as required and as described herein.

When a star net calling type function is required, stations shall use the star net (scanning) calling protocols described herein for all single-channel (and multichannel) calling, polling, and interoperations. See figure A-27. As shown, station A is calling NET, which consists of three stations, B, C, and D. The initial net scanning call shall be identical to the individual scanning call except that the net address shall be substituted for the individual address. At the end of the net call, the net stations shall not respond immediately as in the individual call case. Instead, they shall respond in prearranged time slots to avoid mutual interference and to greatly speed the response process. If the caller is a member of the called net, his assigned slot should remain empty.

In the example illustrated, there are four time slots, designated slot 0 through slot 3, and one-word addresses are used. In this case, they have been preset (by net management) at the standard system uniform minimum slot width of 14 Tw (1829.66... ms). Station B is assigned to slot 1, C to slot 2, and D to slot 3. At the end of A's call to NET, the net members B, C, and D (if they heard the net call), prepare to respond within their preset slots, as follows. When the end of A's terminator (THIS IS A) is detected, the net stations immediately start an internal "slot wait timer" (SWT), preset to identify their slot time (Tswt), start their normal tuneup and prepare to go to full power and start the frames of their responses. Slot 0 is reserved primarily for these purposes. However, after each station has tuned and is ready to respond, it ceases all emissions, returns to receive, and waits for the SWT to timeout (Tswt = 0). Each station's SWT is set to a time value (Tswt) which, in this uniform and minimum case, equals the product of his assigned slot number (SN) times the standard (or prearranged) slot width (Tsw).

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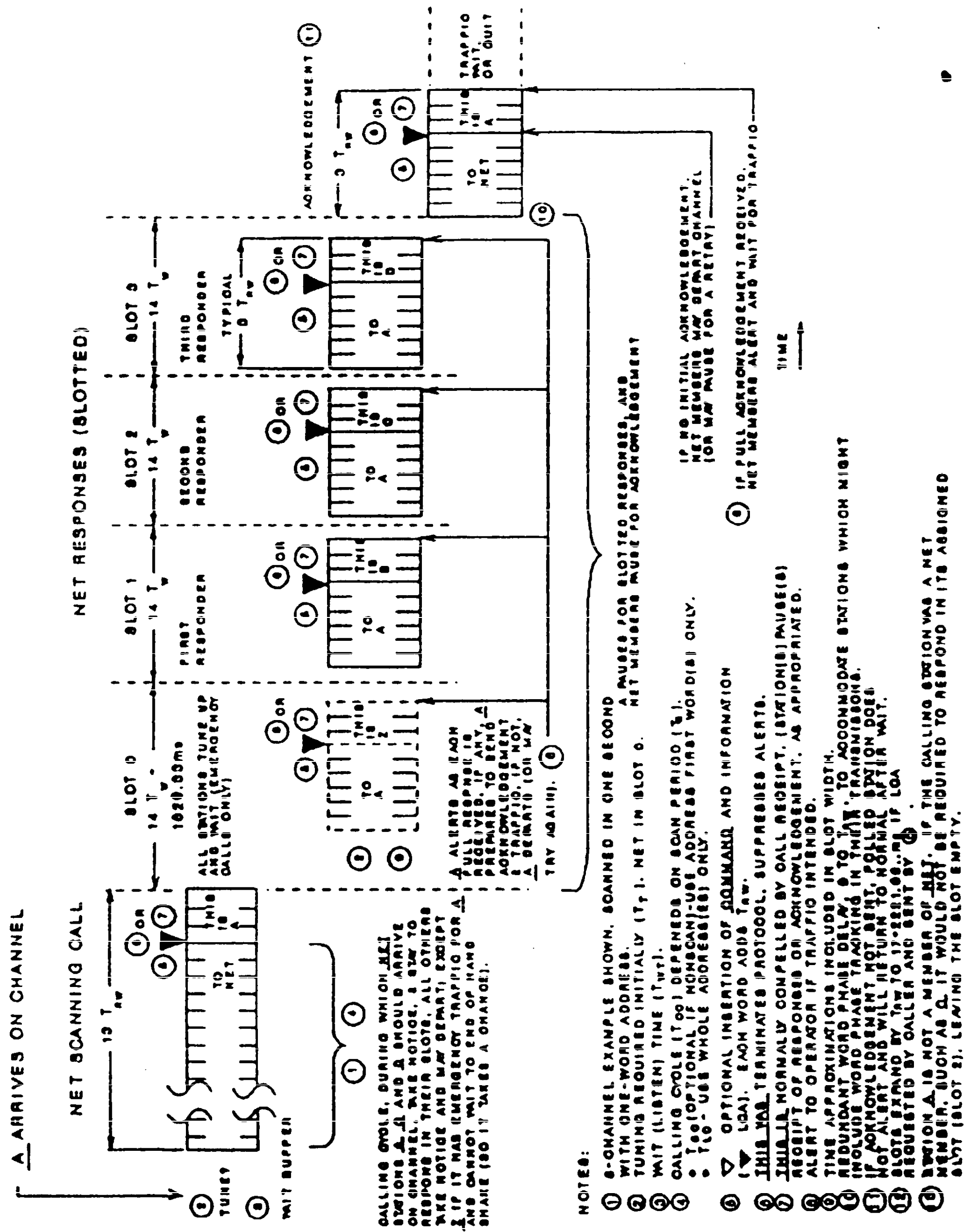

FIGURE A-27. Star net scanning protocol.

That is, Tswt = Tsw x SN. However, as a system standard default, Tsw is usually the minimum 14 Tw = 1829.33... ms, but in any case shall always be an integral multiple of the word time (Tw); that is, Tsw = n x Tw, therefore Tswt = n x Tw x SN. For a net call, each net station's Tswt associated with that net is preprogrammed along with the net address (NET). After all net stations have tuned and are ready to respond, they shall wait for their SWT to timeout and trigger their responses, and (as always) continue to monitor the channel for any other ALE signals, including those from the other net members. If capable, they shall store this unilateral connectivity information in memory.

Once the star net protocol has been initiated, the stations shall be locked into the protocol timing and shall not be deferred or delayed even by extraneous or legitimate calls (unless emergency or priority override). Valid calls shall be read (if possible) and should be stored for recall as soon as the net protocol is ended.

Meanwhile, A has automatically set its "wait for response and tune timer" (WRTT) to a preset "wait reply net" call value (Twrn) equal to the product of the total number of slots (NS) and the slot width (Tsw); that is, in this uniform case, Twrn = (NS x Tsw). A shall start its WRTT at the moment that its net call terminator (THIS IS A) ends and its transmission ceases. Unless otherwise directed by the operator or controller, A shall remain on channel throughout all slot times (entire Twrn), regardless of which responses are received, if any. As each slotted response arrives, A shall alert the operator and display the responding station's address. In addition, if A is also capable, A shall store the bilateral connectivity information in memory. At the end of the slots (Swt = 0), A shall immediately send an acknowledgement to the net (unless inhibited).

As each net member's SWT triggers its slotted response, it shall immediately key its (already tuned) transmitter, wait until up to at least 90 percent of full power, release its response frame, and return to receiving on the channel. The responses shall be identical to those in the individual call, but in the slots. If capable, the station continues to acquire and store connectivity information. Each net member station shall have its own "wait for response and tune timer" (WRTT) for use in determining the calling stations's (A) expected acknowledgement. Upon receipt of the net call, the called net member station's WRTT timers are automatically preset to the value (Twan) equal (in this uniform case) to the product of the total number of slots (NS) and the slot width (Tsw) plus a minimum leading call (Tlc min = 2 Trw). That is, Twan = (NS x Tsw) + Tlc min = Twrn + 2 Trw. The net members stations start their WRTT at the detected end of A's net call (not at the end of their own response, as in the individual call protocol) and wait for the acknowledgement from A before their WRTT times out. Note that the value for their WRTT (Twan) is the same as that for the caller's (A's) WRTT, except that it shall add a margin (Tlc min) to detect the acknowledgement (TO NET).

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At the end of the slot times, net calling station A should have acquired all successful responses from the net stations B, C, and D, its WRTT (starting at Twrn) should time out to 0, and A shall automatically send its acknowledgement, unless no responses have arrived or A is otherwise directed by the operator, controller, or protocol. A's acknowledgement shall be identical to the individual call protocol acknowledgement, except that the net address NET shall be substituted for the individual address as in the initiating call. Just as in the individual call protocol, if A sends "THIS WAS A", the net members B, C, and D shall immediately return to normal scanning. If A sends "THIS IS A", they shall stay, for a preset, limited time, to handle traffic.

As a variation to the net acknowledgement, A may select one or any combination of responding stations (including any station responding in emergency slot 0) and substitute an individual (or group) call acknowledgement to any selected station(s) to retain them. If the calling station sends an acknowledgement in individual or group call format (and uses THIS IS), following a net call, the specified stations shall remain and be linked. The nonspecified responders shall depart and resume scanning. The caller shall not use THIS WAS in this variation. If rejection of selected stations is required, the caller shall use the standard net acknowledgement. The caller should follow the acknowledgement with a standard link termination call (THIS WAS) addressed to the specific rejected stations.

NOTE: in the five-channel net call example shown on figure A-27, the total elapsed handshake time (Ths) is less than 14 seconds on the channel without tuning. Since a net call is prearranged, the number of slots and their sizes may be tailored to fit the net, including speed of tuning and turnaround, propagation times, address sizes, inclusions of LQA and messages, and any other relevant factors. Slot width (Tws) is affected by many factors including maximum propagation times each way, signal detection delays, station turnaround and tuning times. The 14-Tw standard minimum slot size has been designed to enable full responses (TO and THIS IS) with single-word addresses to propagate to the from the other side of the globe and use commonly available HF transceivers and tuners.

If LQA is required, the slots and responses shall require an additional Trw = 3 Tw for the data. The standard slot shall be Tsw = 14 Tw (1829.33... ms), shall contain a standard basic response word of 9 Tw (1176 ms), and shall employ single-word (no more than three characters) addressing. If the net calling station requests LQA, all slots and responses shall automatically expand by Trw (392 ms), regardless of the preset referenced slots, unless otherwise directed by the specific pre-arrangements when the net was set up. When pre-arranging the specific slots and sizes for a specialized network, and if the net requires more than on-word addressing for any net member address, or the inclusion of any other prearranged message(s), that specific response and slot shall be expanded by Trw (392 ms) per additional word required. All following slots shall be shifted over (delayed) by Trw per word also.

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The slotted general formula for determining the correct timing for tailored net responses in nonminimum or nonuniform cases shall be as follows. The slot wait timer time (Tswt) for a selected slot number (SN) is:

$$Tswt(SN) = SN \times [5\ Tw + 2\ Ta\ (caller) + (optional\ LQA)\ Trw\ (optional\ message)\ Tm] + Ta\ (caller) + [(sum\ of\ all\ previous\ addresses) \sum_{m=1}^{m=sn-1} Ta(m)\ (called)]$$

Ta (caller) is the address length (in Trw) of the calling station; Ta(m) (called) is the address length of a preceding called station (in slot m). (Optional LQA) Trw is an optional LQA if requested by COMMAND LQA, and (optional message)Tm is an optional message section (same size for all) if requested by COMMAND. The slotted general formula for the calling station wait for net reply timer shall be Twrn (calling) = Tswt (NS) where Tswt (NS) is Tswt (SN) computed for maximum NS used. The slotted general formula for the called station acknowledgement timer shall be Twan (called) = Twrn (calling) + 2 Trw.

Slot 0 shall normally be used at the net tuneup period. This enables commonly available MF/HF equipment to participate in fast-slotted response operations despite relatively slow tuner and turnaround times. When used in multiple-station slotted operations (net or group calls) and when initiating normal responses, stations shall be capable of performing a complete turnaround including tuning (but not Tlww) in no more than 1500 ms (Tta + Tt), from the arrival of the end of the call terminator to the start of the proper response frame calling cycle, as measured at the antenna input/output connection. Tta, the turnaround time, shall include decoding, encoding, transmit/receive switching, control handshaking, propagation within the transmitter and receiver, and all other delays internal to the station. Tt is the tune time. The sole exception is a station assigned to slot 1, which must turn around and tune in not more than 2100 ms (Tta + Tt).

An additional function for slot 0 is to provide a method for emergency "interrupt" calling by other stations not in the net, or net stations with critical needs. See figure A-27. Upon receipt of the net call from A, the unassociated station Z decides that an emergency call is required, and it initiates the optional handshake protocol described previously. If calling station A desires to acknowledge station Z in slot 0, A shall include the Z address in the Tc (with the NET or a group call to selected NET members, if any). Station Z must be a fast turnaround station, to avoid colliding with proper net stations' responses. When used in a multiple station slotted operations (net or group calls), and initiating an emergency call into slot 0, stations shall be capable of performing a complete turnaround and tune in no more than 360 ms (Tta + Tt), as defined previously for normal responses.

A second mode which is necessary for nets with very slow tuners (over one second) or which require operator manual interaction, is the "net tune and standby." In this case, all net stations tune up in slot 0 (and more time if necessary) and stand by for a preset, limited time. This limited time is typically implemented through the standard WRTT, being preset to a selected

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"net wait response time" (Twrn), which allows the necessary actions to occur and provides a default (timeout) termination limit. The suppression of slotted responses is accomplished by setting the SWT timer value Tswt to a maximum (default) value, or at least to exceed Twrn, in which case the net member quits before any response is sent. After the net calling station has used one net address (perhaps NET TUN) to stop and tune the net members, it may send the standard net call (NET) and trigger the standard slotted responses from the now-tuned stations. This is the primary methodology for a mixed net which includes modern fast-tuning stations plus older generation, slow-tuning (over one second) stations. The net manager, when prearranging the net, assigns a net call such as "NET" to all stations, a subnet call such as "NET TUN" to the slow stations, and directs that a complete net call up should use NET TUN first, wait, then use NET. As an alternative procedure, the net calling station could send a COMMAND Tune and Wait, which causes all net members to tune up and wait for a specified, limited time. After all have tuned (both slow and fast), a standard net call (without the special command) would cause the desired fast responses. See section 80, which also presents several other relevant commands, such as halt and wait, which would be especially useful for a one-way broadcast which does not require responses.

70.6.3 Star group. A star group is a nonprearranged collection of stations which, like a star net, is to link and interoperate primarily with a single "hub" station, which in most cases has the separate function of net control station (NCS). In many cases, little or nothing is known about the stations except their individual addresses and scanned frequencies. Despite this minimum of data, it is critical to be able to create a new group where none existed, and it requires a standardized protocol which is compatible with virtually all stations, essentially regardless of their individual, net, and other characteristics. The purpose of a star group call, like any group call, is to rapidly and efficiently establish contact with multiple nonprearranged (group) stations, simultaneously, by the use of a compact combination of their own addresses which are assigned individually. See 60.5. Unlike the star net call, in which each additional net address has associated with it the necessary slotted response data, a group call cannot have preset slots, because the stations' own individual addresses are used and nothing is prearranged. As will be shown, the group call members derive and construct their own response action, based on the actual received call structure. Basically, the group call protocol is identical in all regards to the net call protocol, except as specified herein.

When a star group calling-type function is required, stations shall use the star group (scanning) calling protocols described herein for all single-channel (and multichannel) calling, polling, and interoperations. The star group (scanning) calling protocol enables rapid and flexible linking with multiple stations without using a common address. See figure A-28. As shown, station A is calling a group of three nonprearranged stations: B, C, and D. All essential parts of star group (scanning) protocol are virtually identical to those of star net (scanning) protocol described previously, and all timing and functional considerations shall apply identically, except as noted herein.

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Considering first the simpler, single-channel case with minimum uniform slots and using single word addresses, the initial group call is modified to incorporate the called station's addresses in the following ways. The calling cycle does not consist of an individual address as in the previously described protocols. In group calling, each called station's whole address is included in the leading call (Tlc) twice in rotation; that is, D, C, and B, then D, C, and B again. See the acknowledgement, at the right, on figure A-28. If a single-channel call is to be made, the first word of the standard leading call (Tlc) would be "TO D" as usual for the individual calling protocol. However, the next address would follow immediately with the standard redundant words (Trw) as "REPEAT C" and then the next "TO B" and similarly until all group whole addresses have been included twice in rotation. The single-channel calling cycle, therefore, consists of all of the redundant whole addresses, rotated through twice. The leading call time, Tlc, is twice the sum (Σ Ta) of the lengths for all the individual whole address words (Ta), (at n x Trw each). That is, single-channel Tlc = 2 x (sum of all called whole address words) Σ Ta(m) = 2 x (NAW x Trw), where NAW is the number of original individual address words. Obviously, if it were an individual call, NAW = 1, therefore Tlc = 2 Trw, as expected.

In this example a single-channel group call, stations D, C, and B each would hear a call addressed to them and plan to respond. However, they would notice that other station addresses also appear in the calling cycle. Therefore, it must be a group call. Specifically, as shown on figure A-28, a station such as D would hear its address ("TO D") being called. It would plan to respond immediately to whichever station is calling (A), because it appears to be (and at this point is) identical to an individual call. However, upon reading another called address ("REPEAT C"). D realizes that it is actually a group call and slotted responses are required, so D starts to count addresses (starting with his own) until the calling cycle ends. When the "TO B" arrives, D identifies another group-called address and counts to two. If the call repeats, as shown for scanning cases at the left on figure A-28, when "REPEAT D" arrives, D has counted to three. D immediately knows that there are only three stations involved in the group call (D, C, and B). D now must find its slot, so it resets its counter to one (itself). D continues to read the following rotated addresses (C and B again) and continues to count, until the calling cycle ends. Meanwhile, C and B are doing the same thing, and they also determine that three stations (D, C, and B) are involved. However, when counting up to the end of the calling cycle, "THIS IS A" in this case, D reaches three, C reaches two, and B reaches one. They have automatically identified their response slots: D in slot 3, C in slot 2, and B in slot 1. The remainder of the protocol is identical to the star net protocol. Note that if one of the stations, such as C, were to miss the earlier parts of the calling cycle but receive its last "TO C", it would still respond properly in slot 2 because it would read the "REPEAT B" which follows, realize that this is a group call, and should nave counted to two by the time the call ended. Similarly, if the last called station heard only the very last words in the calling cycle which were addresses to him, it would mistake it for an individual call and respond immediately (essentially in slot 0) instead of slot 1. Therefore, in a group call, the called stations automatically sort themselves into their proper response slots.

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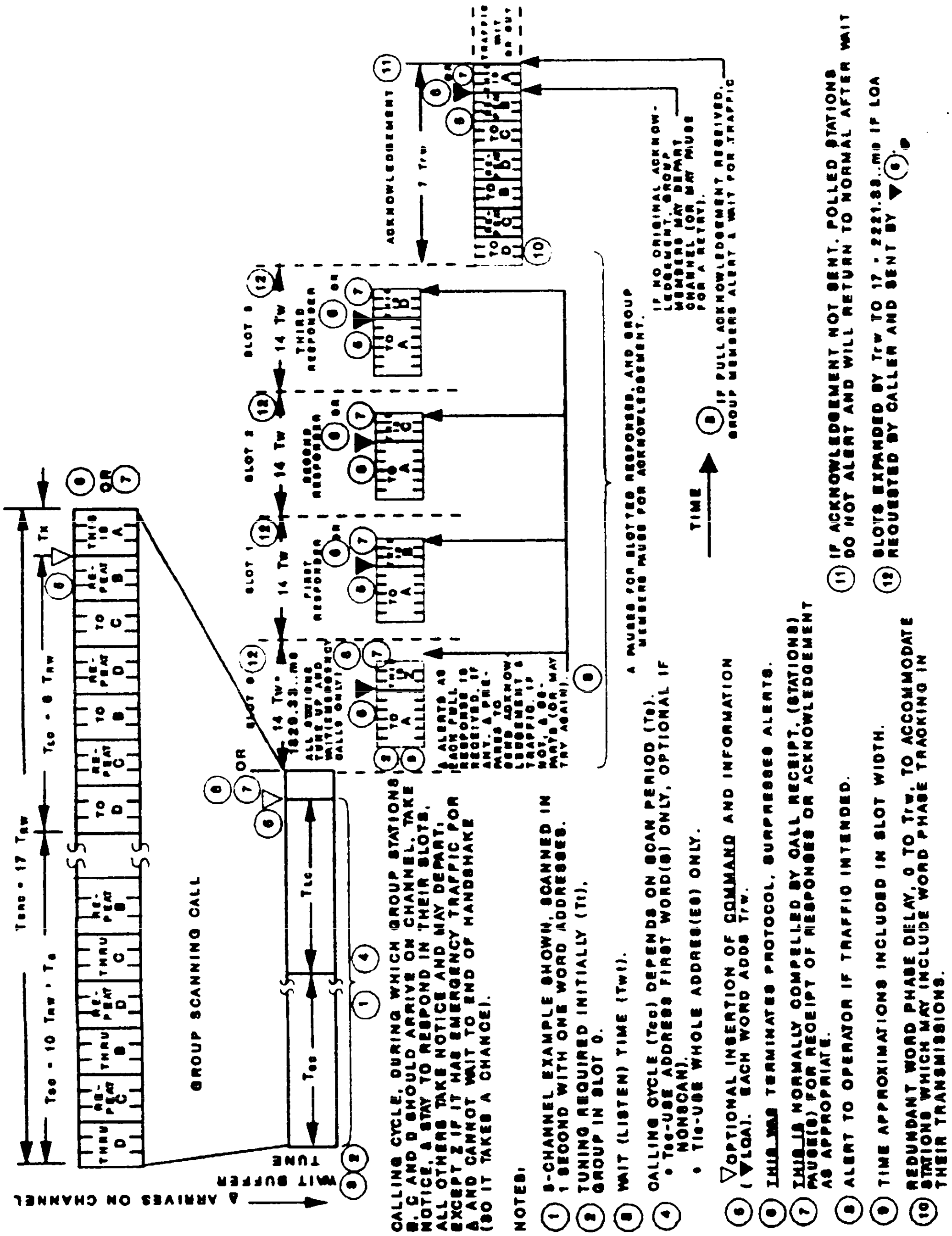

FIGURE A-28. Star group scanning calling protocol.

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In a multichannel scanning group call protocol, the caller call, Tlc, must be lengthened, as in the individual scanning call protocol. In that case, Tcc was increased beyond the basic Tlc by the scan call time Tsc, which was larger than the scan time Ts of the called station; that is, Tcc = Tsc + Tlc = n x Td + Tlc ≥ Ts + Tlc. Similarly, the Tcc for the scanning group call must increase by a group scan call time Tsc ≥ Ts. In the group call, as noted above, the basic leading call, Tlc = 2Tc = 2 x (sum of all called whole addressed) Σ Ta(m). The group scan call time, Tsc, shall be composed of a rotated combination (Tcl) of only the different first words (Tal) of the called group addresses such that the sum (n x Tcl) exceeds Ts and is a multiple of Trw. To indicate that this is a group call, the address first word(s), in Tsc, shall be within <u>THRU</u> (and alternating with <u>REPEAT</u>), and in Tlc, shall be in <u>TO</u> (and <u>REPEAT</u>). The addresses first words (Tcl) rotated in Tsc are not required to be an integral multiple of the addresses in Tc, as some first words may be duplicated and will be deleted (to produce a minimum set Tcl). The addresses in both Tsc (Tcl) and Tlc (Tc) shall be rotated in the same basic sequence. Therefore, the scan call time Tsc = n x Tcl = n x Σ Tal ≥ Ts = C x Td, where, as before, C is the number of channels scanned and Td is the potential dwell time on each. Therefore, the total calling cycle time Tcc = Tsc + Tlc = 2 x (NAW x Trw) + Tsc = (n + 2 NAW) x Trw, provided n ≥ Ts/Trw.

Note that n is any integer sufficient to make the last equation true, and the total number of times address first words (Tal) are included in the entire scanning call (Tsc) for the scanning case is n. Also, when Tsc (and Ts) < Tcl, it is possible for some addresses to appear only once in the final Tcl period before the end of Tsc. In the example on figure A-24, Ts = 3920 ms, n ≥ Ts/Trw = 3920/392, therefore n = 10, at least. Since NAW = 3, the calling cycle Tcc = (n + 2 NAW) x Trw = (10 + 6) x Trw = 16 Trw, as shown. The "<u>THIS IS A</u>" terminator of Trw increases the entire group scanning call to 17 Trw. As can be seen on figure A-24, the multichannel scanning version of the group call only increases the calling cycle by slightly more than the scan time, regardless of the number of stations called in the group. As a standard upper system limit, the maximum group size in a single call has been set at five different address first words (Tcl max = 5 Trw = 1960 ms), or twelve whole address words in Tc, which allows up to twelve one-word, six two-word, four three-word, three four-word, or two five-word addresses, or any other combination which does not exceed a rotating address cycle period (Tc) (each address once) of 12 Trw.

Unlike the net calls, the slot sizes in group calls are not pretailored for the specific network situation, although as a system minimum uniform standard they shall be 14 Tw wide (17 Tw with LQA) as described above. These 14-Tw response slots require the basic, single-word, intranet addressing for both calling and called stations, resulting in a 9-Tw wide response, plus adequate propagation and turnaround margins. If the calling station uses a two or more word address for itself, each slot shall be expanded by Trw, for each address word in excess of one, in addition to optional Trw expansions, such as for LQA or messages. Similarly, if a particular station is called using an address which uses two or more words, that called station's own slot shall also be expanded by Trw per address word in excess of one, (in addition to the caller address and any LQA and message expansions). Therefore, all slots

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are automatically adjusted to the proper, minimum necessary width for their associated responses. If any called station arrives on channel late and is unaware of other previously called group stations, it shall be able to derive sufficient information to respond properly. The slotted general formulas for designing nonuniform, nonstandard star net slotted responses (Tsw, Tswt, Twrn, Twan) shall also be used to determine the star group slotted responses.

In the event that a called station does not identify the magnitude of the called group and therefore the correct Twan, it shall use a default value for Twan which is equal to the longest possible group call of twelve one-word addresses. Based on the slotted general formula, Twan = 107 Tw + 27 Ta (called) + 13 Trw (optional LQA) + 13 Tm (optional message). In the case of no message field and a one-word address caller, Twrn max = 188 Tw (25 seconds), or 227 Tw (30 seconds) with LQA.

In the special but not excluded case where a called station is intended by the caller to use a longer transmission for his response than he can fit in his assigned slot (such as to add a special message), the calling station may insert a "NULL" address in the previous adjacent position in only the leading call of the calling cycle which will provide a "blank" slot for "overflow", immediately following that responder's slot. This overflow slot, typically the minimum width (because "NULL" is a one-word address), provides almost a five additional data-word (Trw) capacity. As another special, but not excluded, case, a station may be called multiple times in a group call, even by different addresses, and it shall properly respond in the derived slots as though it were multiple separate stations.

NOTE: The fact that the called station has multiple addresses may not be known to the caller. In some cases, it would be confusing or inappropriate to respond to one but not another address. Redundant calling address conflicts can be resolved after successful linking, if there is a problem.

In the leading call (Tlc), (when receiving a group call) the preambles TO and REPEAT after TO shall be used to indicate the start of each called stations(s) whole addresses. In the scan call (Tsc), the address first words shall be in alternating THRU and REPEAT. However, if there is only one unique address first word, it shall be repeated in THRU only, in Tsc.

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80. ORDERWIRE MESSAGES.

80.1 Introduction. In addition to automatically establishing links, stations shall have the capability to transfer information within the orderwire, or message, section of the frame. This section describes these messages, including data, control, error checking, networking, and special purpose functions. Table A-XV provides a summary of the COMMAND functions.

NOTE: For critical orderwire message which require increased protection from interference and noise, several ALE techniques are available. Any message may be specially encoded off-line and then transmitted using the full 128 ASCII COMMAND data text message (DTM) mode (which also accepts random data bits). Larger blocks of information may be Golay FEC coded and deeply interleaved using the COMMAND data block message (DBM) mode. Both modes have an automatic repeat request (ARQ) error-control capability. Integrity of the data may be ensured using the COMMAND CRC mode. See 80.6. In addition, once a link has been established, totally separate equipment, such as heavily coded and robust modems, may be switched onto the rf link in the normal circuit (traffic-bearing) mode.

80.2 Link quality analysis (LQA). This mandatory function is designed to support the exchange of LQA information among ALE stations. The COMMAND LQA word shall be constructed as shown in table A-XVI. The preamble shall be COMMAND (110) in bits P3 through P1 (W1 through W3). The first character shall be "a" (1100001) in bits C1-7 through C1-1 (W4 through W10), which shall identify the LQA function "analysis". It carries three types of analysis information (BER, SINAD, and MP) which are separately generated by the ALE analysis capability. Note that when the control bit KA1 (W11) is set to "1", the receiving station shall respond with a LQA report in the handshake. If KA1 is set to "0", the report is not required, as would be the case for a basic station which is incapable of using the report if received.

80.2.1 Bit error ratio (BER). The mandatory BER shall be empirically derived by all ALE stations from the basic digital signaling, and shall be communicated as follows. The transmitted BER is represented as five bits of information, BE5 through BE1 (W20 through W24). Refer to table A-XII for the assigned values.

80.2.2 Signal plus noise plus distortion to noise plus distortion ratio (SINAD). If the optional SINAD is analytically derived by suitably equipped stations from the ALE analog signaling, it shall be communicated as follows. The SINAD is represented as five bits of information SN5 through SN1 (W15 through W19). The range is 0 to 30 dB in 1-dB steps. 00000 is 0 dB or less, and 11111 is no measurement.

80.2.3 Multipath (MP). Three bits, MP3 through MP1 (W12 through W14), are reserved for multipath information exchange. Until standardized, these bits shall be set to 111 (meaning no measurement available).

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TABLE A-XV. Summary of COMMAND functions.

<table>
<tr><td>COMMAND ABC</td><td>(ext. 64)</td><td>Automatic message display (AMD) (mandatory). Contains text message for automatic display to the receiving station operator.</td></tr>
<tr><td>COMMAND a . .</td><td>(1100001)</td><td>Link quality analysis (LQA) (mandatory). Contains BER, SINAD, MP.</td></tr>
<tr><td>COMMAND b . .</td><td>(1100010)</td><td>Data block message (DBM) (optional). Contains compressed text message for automatic output to receiving station I/O port.</td></tr>
<tr><td>COMMAND d . .</td><td>(1100100)</td><td>Data text message (DTM) (optional). Contains text message for automatic output to receiving station input/output (I/O) port.</td></tr>
<tr><td>COMMAND t . .</td><td>(1110100)</td><td>Time (optional). Contains time and timing information. This feature is mandatory when the user unique function (UUF) is implemented.</td></tr>
<tr><td>COMMAND x . .
y . .
z . .
{ . .</td><td>(1111000)
(1111001)
(1111010)
(1111011)</td><td>Cyclic redundancy check (CRC) (optional); mandatory with DTM and DBM. Contains error detection information for preceding words.</td></tr>
<tr><td>COMMAND | . .</td><td>(1111100)</td><td>User unique functions (UUF) (optional). Contains unique information for a specific user system (special registration).</td></tr>
</table>

NOTE: All others are reserved until standardized.

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TABLE A-XVI. Link quality analysis structure.

	LQA bits		Word bits	
COMMAND preamble	MSB	P3=1	MSB	W1
		P2=1		W2
	LSB	P1=0		W3
First character "a"	MSB	C1-7=1		W4
		C1-6=1		W5
		C1-5=0		W6
		C1-4=0		W7
		C1-3=0		W8
		C1-2=0		W9
	LSB	C1-1=1		W10
Control		KA1		W11
Multipath bits	MSB	MP3		W12
		MP2		W13
	LSB	MP1		W14
SINAD bits	MSB	SN5		W15
		SN4		W16
		SN3		W17
		SN2		W18
	LSB	SN1		W19
BER bits	MSB	BE5		W20
		BE4		W21
		BE3		W22
		BE2		W23
	LSB	BE1	LSB	W24

NOTES:

1. COMMAND LQA first character is "a" (1100001) for "analysis".
2. Control bit KA1 (W11) requests an LQA within the handshake from the called station, if set to "1", and suppresses LQA if set to "0".

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80.3 Automatic message display (AMD) mode. The mandatory AMD mode enables stations to communicate short orderwire messages or prearranged codes to any selected station(s). This basic data transfer function exploits the communications, processing, and operator (and controller) interfaces already embedded within the stations and system. The operators and controllers shall be able to send and receive simple ASCII text messages using only the existing station equipment. The entire expanded 64 ASCII character subset shall be available for this purpose. The station shall have the capability to both send and receive AMD messages from and to both the operator and the controller. The station shall also have the capability to display any received AMD messages directly to the operator and controller upon arrival, and to alert them. The operator and controller shall have the capability to disable the display and the alarm when their functions would be operationally inappropriate.

When an ASCII short orderwire AMD type function is required, the following COMMAND AMD protocol shall be used, unless another protocol in this standard is substituted. An AMD message shall be constructed in the standard word format, as described herein, and the AMD message shall be inserted in the message section of the frame. The receiving station shall be capable of receiving an AMD message which is contained in any ALE frame, including calls, responses, and acknowledgements. Within the AMD structure, the first word shall be a COMMAND AMD word, which shall contain the first three characters of the message. It shall be followed by a sequence of alternating DATA and REPEAT words which shall contain the remainder of the message. The COMMAND, DATA, and REPEAT words shall all contain only characters from the expanded ASCII 64 subset, which shall identify them as an AMD transmission. Each separate AMD message shall be kept intact and shall only be sent in a single frame, and in the exact sequence of the message itself. If one or two additional characters are required to fill the triplet in the last word sent, the position(s) shall be "stuffed" with the "space" character (0100000) automatically by the controller, without operator action. The end of the AMD message shall be indicated by the start of the frame conclusion, or by the receipt of another COMMAND. Multiple AMD messages may be sent within a frame, but they each shall start with their own COMMAND AMD with the first three characters.

Receipt of the COMMAND AMD word shall warn the receiving station that an AMD message is arriving and shall instruct it to alert the operator and controller and display the message, unless they disable these outputs. The station shall have the capability to distinguish among, and separately display, multiple separate AMD messages which were in one or several transmissions.

The AMD word format shall consist of a COMMAND (110) in bits P3 through P1 (W1 through W3), followed by the three standard character fields C1, C2, and C3. In each character field, each character shall have its most significant bits (MSBs) b7 and b6 (C1-7 and C1-6, C2-7 and C2-6, and C3-7 and C3-6) set

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to the values of "01" or "10" (that is, all three characters are members of the expanded ASCII 64 subset). The rest of the AMD message shall be constructed identically, except for the alternating use of the DATA and REPEAT preambles.

Any quantity of AMD words may be sent within the message section of the frame, within the Tm max limitation of 30 words (90 characters). Tm max shall be expanded from 30 words, to a maximum of 59 words, with the inclusion of COMMAND words within the message section. The maximum AMD message shall remain 30 words, exclusive of additional COMMAND words included within the message section of the frame. The maximum number of COMMAND words within the message section shall be 30. The message characters within the AMD structure shall be displayed verbatim as received. If a detectable information loss or error occurs, the station shall warn of this by the substitution of a unique and distinct error indication, such as all display elements activated (like a "block"). The display shall have a capacity of at least 20 characters (DO: at least 40). The AMD message storage capacity, for recall of the most recently received message(s), shall be at least 90 characters plus sending station address. (DO: at least 400.) By operator or controller direction, the display shall be capable of reviewing all messages in the AMD memory and shall also be capable of identifying the originating station's address. If words are received which have the proper AMD format, but are within a portion of the message section under the control of another message protocol (such as DTM), the other protocol shall take precedence and the words shall be ignored by the station's AMD function.

NOTE: If higher data integrity or reliability is required, the COMMAND DTM or DBM protocols should be used.

80.4 Data text message (DTM) mode. The DTM orderwire message function enables stations to communicate (full ASCII, or unformatted binary bits), messages to and from any selected station(s) for direct output to, and input from, associated data terminals or other DTE devices through their standard DCE ports. The DTM data transfer function is a standard speed mode (like AMD) with improved robustness, especially against weak signals and short noise bursts. When used over MF/HF by the ALE system, DTM orderwire messages may be unilateral or bilateral, and broadcast or acknowledged. As the DTM data blocks are of moderate sizes, this special orderwire message function enables utilization of the inherent redundancy and FEC techniques to detect weak HF signals and tolerate short noise bursts.

The DTM data blocks shall be fully buffered at each station and should appear transparent to the using DTEs or data terminals. As a design objective, and under direction of the operator or the controller, the stations should have the capability of using the DTM data traffic mode (ASCII or binary bits) to control switching of the DTM data traffic to the appropriate DCE port or associated DTE equipment, such as to printers and terminals (if ASCII mode), or computers and cryptographic devices (if binary bits mode). As an operator or controller selected option, the received DTM message may also be presented on the operator display, similar to the method for AMD in 80.3.

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There are four COMMAND DTM modes: BASIC, EXTENDED, NULL, and ARQ. The DTM BASIC block ranges over a moderate size and contains a variable quantity of data, from zero to full as required, which is exactly measured to ensure integrity of the data during transfer. The DTM EXTENDED blocks are variable over a large range of sizes, in integral multiples of the ALE basic word, and are filled with integral multiples of message data, The DTM NULL and ARQ modes are used for both link management, and error and flow control. The characteristics of the COMMAND DTM orderwire message functions are listed in table A-XVII and are summarized below:

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COMMAND DTM mode	BASIC	EXTENDED	ARQ NULL
Maximum size, bits	651	7371	0
Cyclic redundancy check	16 bits	16 bits	0
Data capacity, ASCII	0 - 93	3 - 1053, by 3	0
Data capacity, bits	1 - 651	21 - 7371, by 21	0
ALE word redundancy	3 fixed	3 fixed	0
Data transmission	392 ms - 12.152 sec	392 ms - 2.29 min	0

When an ASCII, or binary bit, digital data message function is required, the following COMMAND DTM orderwire structures and protocols shall be used as specified herein, unless another standardized protocol is substituted. The DTM structure shall be inserted within the message section of the standard ALE frame. A COMMAND DTM word shall be constructed in the standard 24-bit format, using the COMMAND preamble. See table A-XVIII. The message data to be transferred shall always be inserted in words, using the DATA and REPEAT preambles. The words shall then be Golay FEC encoded and interleaved, and then shall be transmitted immediately following the COMMAND DTM word. A COMMAND CRC shall immediately follow the data block words, and it shall carry the error control CRC frame check sequence (FCS).

When the DTM structure transmission time exceeds the maximum limit for the message section (Tm max), the DTM protocol shall take precedence and shall extend the Tm limit to accommodate the DTM. The DTM mode preserves the required consistency of redundant word phase during the transmission. The message expansion due to the DTM is always a multiple of one Trw, as the basic ALE word structure is used. The transmission time of the DTM data block (DTM words x 392 ms) does not include the Trw for the preceding COMMAND DTM word or the following COMMAND CRC. Figure A-29 shows an example of a DTM message structure.

The DTM protocol shall be as described herein. The COMMAND DTM BASIC and EXTENDED formats (herein referred to as DTM data blocks) shall be used to transfer messages and information among stations. The COMMAND DTM ARQ format shall be used to acknowledge other COMMAND DTM formats and for error and flow control, except for non-ARQ and one-way broadcasts. The COMMAND DTM NULL format shall be used to (a) interrupt ("break") the DTM and message flow, (b) to interrogate stations to confirm DTM capability before initiation of the DTM message transfer protocols, and (c) to terminate the DTM protocols while remaining linked. When used in ALE handshakes and subsequent exchanges, the protocol frame terminations for all involved stations shall be THIS IS until all the DTM messages are successfully transferred, and all are acknowledged if ARQ error control is required. The only exceptions shall be when the protocol is a one-way broadcast or the station is forced to abandon the exchange by the operator or controller, in which cases the termination should be THIS WAS.

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There are four COMMAND DBM modes: BASIC, EXTENDED, NULL, and ARQ. The DBM BASIC block is a fixed size and contains a variable quantity of data, from zero to full as required, which is exactly measured to ensure integrity of the data during transfer. The DBM EXTENDED blocks are variable in size in integral multiples of the BASIC block, and are filled with integral multiples of message data. The DBM NULL and ARQ modes are used for both link management, and error and flow control. The characteristics of the COMMAND DBM orderwire message functions are listed in table A-XIX, and they are summarized below:

COMMAND DBM mode	BASIC	EXTENDED	ARQ, NULL
Maximum size, bits	588	261660	0
Cyclic redundancy check	16 bits	16 bits	0
Data capacity, ASCII	0 - 81	81 - 37377, by 84	0
Data capacity, bits	0 - 572	572 - 261644, by 588	0
Interleaver depth (ID)	49 fixed	49 - 21805, by 49	0
Block transmission	3.136 sec	3.136 sec - 23.26 min, by 3.136 sec increments	0

When an ASCII, or binary bit, digital data message function is required, the following COMMAND DBM orderwire structures and protocols shall be used as specified herein, unless another standardized protocol is substituted. The DBM structure shall be inserted within the message section of the standard frame. A COMMAND DBM word shall be constructed in the standard format. The data to be transferred shall be Golay FEC encoded, interleaved (for error spreading during decoding), and transmitted immediately following the COMMAND DBM word.

When the DBM structure transmission time exceeds the maximum for the message section (Tm max), the DBM protocol shall take precedence and shall extend the Tm limit to accommodate the DBM. The DBM mode preserves the required consistency of redundant word phase during the transmission. The message expansion due to the DBM is always a multiple of 8 Trw, as the interleaver depth (ID) is always a multiple of 49. The transmission time of the DBM data block (Tdbm) itself is equal to (ID x 64ms), not including the Trw for the preceding COMMAND DBM word. Figure A-31 shows an example of an exchange using the DBM orderwire to transfer and acknowledge messages. Figure A-32 shows an example of a DBM data interleaver, and figure A-33 shows the transmitted DBM bit-stream sequence.

The DBM protocol shall be as described herein. The COMMAND DBM BASIC and EXTENDED formats (herein referred to as DBM data blocks) shall be used to transfer messages and information among ALE stations. The COMMAND DBM ARQ format shall be used to acknowledge other COMMAND DBM formats and for error and flow control, except for non-ARQ and one-way broadcasts. The COMMAND DBM NULL format shall be used to: (a) interrupt ("break") the DBM and message flow; (b) to interrogate stations to confirm DBM capability before initiation of the DBM message transfer protocols; and (c) to terminate the DBM protocols while remaining linked. When used in handshakes and subsequent exchanges, the protocol frame terminations for all involved stations shall be THIS IS

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TABLE A-XIX. Data block message characteristics.

	WORD BITS W 16---------W 24 DBM CODE BITS BC 10---------BC 1	DBM CODE (DC) DECIMAL (n)	INTER-LEAVE DEPTH (ID)	BINARY BITS DATA	ASCII CHAR DATA	BLOCK TIME	TOTAL DBM (T_{dw})
DBM NULL•	0 0 0 0 0 0 0 0 0 0	0	0	0	0	0•	1•
DBM EXTENDED (FULL)	0 0 0 0 0 0 0 0 0 1	1	49	572	81	3.136s	9
	0 0 0 0 0 0 0 0 1 0	2	98	1160	165	6.272s	17
	↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	n	49n	12ID-16	BITS+7	IDx64ms	8n+1
	0 1 1 0 1 1 1 1 0 0	444	21756	261056	37293	23.21min	3553
	0 1 1 0 1 1 1 1 0 1	445	21805	261644	37377	23.26min	3561
(RESERVED)	0 1 1 0 1 1 1 1 1 0	446	- - -	- - -	- - -	- - -	- - -
	0 1 1 0 1 1 1 1 1 1	447	- - -	- - -	- - -	- - -	- - -
DBM BASIC (EXACT)	0 1 1 1 0 0 0 0 0 0	448	49	0	0	3.136s	9
	0 1 1 1 0 0 0 0 0 1	449	↓	1	0	↓	↓
	0 1 1 1 0 0 0 0 1 1	450	↓	2	0	↓	↓
	↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓	↓	↓	n-448	BITS+7	↓	↓
	1 1 1 1 1 1 1 0 1 1	1019	↓	571	81	↓	↓
	1 1 1 1 1 1 1 1 0 0	1020	49	572	81	3.136s	9
DBM ARQ•	1 1 1 1 1 1 1 1 0 1	1021	0	0	0	0•	1•
(RESERVED)•	1 1 1 1 1 1 1 1 1 0	1022	- - -	- - -	- - -	- - -	- - -
(RESERVED)•	1 1 1 1 1 1 1 1 1 1	1023	- - -	- - -	- - -	- - -	- - -

NOTE:
•NO INTERNAL CRC USED

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The COMMAND DBM words shall be constructed as shown in table A-XX. The preamble shall be COMMAND (110) in bits P3 through P1 (W1 through W3). The first character shall be "b" (1100010) in bits C1-7 through C1-1 (W4 through W10), which shall identify the DBM "block" function.

For DBM BASIC, EXTENDED, and NULL, when the ARQ control bit KB4 (W11) is set to "0" no correct data receipt acknowledgement is required; and when set to "1" it is required. For DBM ARQ, ARQ control bit KB4 is set to "0" to indicate acknowledgement or correct data block receipt (ACK); and when set to "1" it indicates a failure to receive the data and is therefore a request-for-repeat (NAK). For DBM ARQ responding to a DBM NULL interrogation, KB4 "0" indicates nonparticipation in the DBM protocol or traffic type, and KB4 "1" indicates affirmative participation in both the DBM protocol and traffic type.

For DBM BASIC, EXTENDED, and NULL, when the data type control bit KB3 (W12) is set to "0", the message data contained within the DBM data block shall be binary bits with no required format or pattern; and when KB3 is set to "1", the message data is 7-bit ASCII characters. For DBM ARQ, flow control bit KB3 is set to "0" to indicate that the DBM transfer flow should continue or resume; and when KB3 is set to "1", it indicates that the sending station should pause (until another and identical DBM ARQ is returned, except that KB3 shall be "0").

For DBM BASIC, EXTENDED, and NULL, when the "message" control bit KB2 (W13) is set to the same value as the KB2 in any sequentially adjacent DBM data block, the message data contained within those adjacent blocks (after individual error control) shall be recombined with the message data within the present DBM data block to reconstitute (segment-by-segment) the original whole message; and when KB2 is set opposite to any sequentially adjacent DBM data blocks, those data blocks contain separate message data and shall not be combined. For DBM ARQ, "message" control bit KB2 shall be set to match the referenced DBM data block KB2 value to provide message confirmation.

For DBM BASIC, EXTENDED, and NULL, the sequence control bit KB1 (W14) shall be set opposite to the KB1 value in the sequentially adjacent DBM BASIC, EXTENDED, or NULLs to be sent (the KB1 values therefore alternate, regardless of their message dependencies). When KB1 is set the same as any sequentially adjacent DBM sent, it indicates a duplicate. For DBM ARQ, sequence control bit KB1 shall be set to match the referenced DBM data block or NULL KB1 value to provide sequence confirmation.

When used for the DBM protocols, the ten DBM block code (BC) bits BC10 through BC1 (W15 through W24) shall indicate the DBM mode (BASIC, EXTENDED, ARQ, or NULL). They shall also indicate the size of the message data and the length of the data block. The DBM NULL BC value shall be "0" (0000000000), and it shall designate the single COMMAND DBM NULL word. The DBM EXTENDED BC values shall range from "1" (0000000001) to "445" (0110111101), and they shall designate the COMMAND DBM EXTENDED word and the data block multiple (of 49 ID) which defines the variable data block sizes, in increments of 588 binary bits or 84 ASCII characters. NOTE: The values 446 (0110111110) and 447 (0110111111) are reserved. The DBM BASIC BC values shall range from "448" (0111000000) to "1020" (1111111100), and they shall designate the

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COMMAND DBM BASIC word and the exact size of the message data in a fixed size (ID = 49) data block, with up to 572 binary bits or 81 ASCII characters. The DBM ARQ BC value shall be "1021" (1111111101), and it shall designate the single COMMAND DBM ARQ word. The BC values "1022" (1111111110) and "1023" (1111111111) shall be reserved until standardized. See table A-XIX.

80.6 Cyclic redundancy check (CRC). This special error-checking function is available to provide data integrity assurance for any form of message in an ALE call.

NOTE: The CRC function is optional, but mandatory when used with the DTM or DBM modes.

The sixteen-bit frame check sequence (FCS) and method as specified by FED-STD 1003, shall be used herein. The FCS provides a probability of undetected error of 2^{-16}, independent of the number of bits checked. The generator polynomial is

$$X^{16} + X^{12} + X^{5} + 1$$

and the sixteen FCS bits are designated

$$(MSB)\ X^{15},\ X^{14},\ X^{13},\ X^{12} \ldots X^{1},\ X^{0}\ (LSB).$$

The ALE CRC is employed two ways: within the DTM data words, and following the DBM data field, described in 80.4 and 80.5, respectively. The first, and the standard, usages are described in this section.

The COMMAND CRC word shall be constructed as shown in table A-XXI. The preamble shall be COMMAND (110) in bits P3 through P1 (W1 through W3). The first character shall be "x" (1111000), "y" (1111001), "z" (1111010), or "{" (1111011) in bits C1-7 through C1-1 (W4 through W10). Note that four identifying characters result from FCS bits X^{15} and X^{14} which occupy C1-2 and C1-1 (W9 and W10) in the first character field respectively. The conversion of FCS bits to and from ALE CRC format bits shall be as described in table A-XXI where X^{15} through X^{0} correspond to W9 through W24.

The COMMAND CRC message should normally appear at the end of the message section of a transmission, but it may be inserted within the message section (but not within the message being checked) any number of times for any number of separately checked messages, and at any point except the first word (except as noted below). The CRC analysis shall be performed on all ALE words in the message section which precede the COMMAND CRC word bearing the FCS information, and which are bounded by the end of the calling cycle, or the previous COMMAND CRC word, whichever is closest. The selected ALE words shall be analyzed in their nonredundant and unencoded (or FEC decoded) basic ALE word (24-bit) form in the bit sequence, (MSB) W1, W2, W3, W4...W24 (LSB), followed by the unencoded bits W1 through W24 from the next word sent (or received), followed by the bits of the next word, until the first COMMAND CRC is inserted (or found). Therefore, each COMMAND CRC inserted and sent in the message section ensures the data integrity of all the bits in the previous

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There are several specific functions which utilize these special timing controls. All use the COMMAND (110) preamble in bits P3 through P1 (W1 through W3). The first character is "t" (1110100) for "time". The second character indicates the function as shown in table A-XXIV. The basic structure is the same as in table A-XXII.

TABLE A-XXII. Tune and wait structure.

		Tune and wait bits		Word bits
COMMAND preamble	MSB	P3 = 1	MSB	W1
		P2 = 1		W2
	LSB	P1 = 0		W3
First Character "t"	MSB	C1-7 = 1		W4
		C1-6 = 1		W5
		C1-5 = 1		W6
		C1-4 = 0		W7
		C1-3 = 1		W8
		C1-2 = 0		W9
	LSB	C1-1 = 0		W10
Second Character "t"	MSB	C2-7 = 1		W11
		C2-6 = 1		W12
		C2-5 = 1		W13
		C2-4 = 0		W14
		C2-3 = 1		W15
		C2-2 = 0		W16
	LSB	C2-1 = 0		W17
Time bits	MSB	TB7		W18
		TB6		W19
		TB5		W20
		TB4		W21
		TB3		W22
		TB2		W23
	LSB	TB1	LSB	W24

NOTES:

1. COMMAND tune and wait first two characters are "t" (1110100) and "t" (1110100) for "time tuneup."
2. Time bits TB7 through TB1 from table A-XXIII.

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TABLE A-XXIII. Time values.

MULTIPLIER: Most significant bits (MSBs)

MSB TB7 (W18)	TB6 (W19)	Exact increment	Approximate increment	Approximate range of "T" values
0	0	Tw 130.66... ms	1/8 second	0 - 4 seconds
0	1	3 Trw 1176 ms	1 second	0 - 36 seconds
1	0	153 Trw 59.976 sec	1 minute	0 - 31 minutes
1	1	9184 Trw 60.002 min	1 hour	0 - 29 hours

INDEX: Least significant bits (LSBs)

TB5 (W20)	TB4 (W21)	TB3 (W22)	TB2 (W23)	LSB TB1 (W24)	Index Value	"T" value for MSB=00	"T" value for MSB=01	"T" value for MSB=10	"T" value for MSB=11
0	0	0	0	0	0	0(1)	0	0	0
0	0	0	0	1	1	130.66ms	1.176s	1.00min	1.00hr
0	0	0	1	0	2	261.33ms	2.352s	2.00min	2.00hr
0	0	0	1	1	3	392.00ms	3.528s	3.00min	3.00hr
0	0	1	0	0	4	523.66ms	4.204s	4.00min	4.00hr
0	0	1	0	1	5	653.33ms	5.880s	5.00min	5.00hr
.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.
1	1	1	0	1	29	3789.3ms	34.10s	29.0min	29.0hr
1	1	1	1	0	30	3920.0ms	35.28s	30.0min	(3)
1	1	1	1	1	31	4050.7ms	36.46s	31.0min	(2)

NOTES:

1. The minimum value "0" (TB = 0000000) is interpreted as "do immediately" if a delay, or "zero size" if a time width, as specified in usage.
2. The maximum value "127" (TB = 1111111) is interpreted as "do it at time or date following," as specified in next COMMAND.
3. The next maximum value "126" (TB = 1111110) is interpreted as "indefinite time," unlimited except by other COMMAND or timeout protocol.

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TABLE A-XXIV. Time-related COMMAND functions.

Identification	First character	Second character	Function
Adjust slot width	"t"	"a" (1100001)	Add T to width of all slots for this response. TB=0, normal. TB7 = 0 as 36 second limit.
Halt and wait	"t"	"h" (1101000)	Stop scan on channel, do not tune or respond, wait T for instruction; quit and resume scan if nothing. TB = 0, quit after call. TB7 = 0 as 36 second limit.
Operator NAK	"t"	"n" (1101110)	Same as "t,o" operator ACK, except that at T, if no input, automatic tuneup and respond NAK (THIS IS), in slots if any. TB = 0, NAK now.
Operator ACK	"t"	"o" (1101111)	Stop scan, alert operator to manually input ACK (or NAK), which causes tuneup (if needed) and ACK response THIS WAS, or THIS IS; if no input by operator by T, simply quit. TB = 0, ACK now. TB7 = 0 as 36 second time limit. TB = 1111111, do at date/time following.
Respond and wait	"t"	"r" (1110010)	Stop scan, tuneup and respond as normal, wait T for instructions, quit and resume scan if nothing. TB = 0, quit after response. TB7 = 0 as 36 second limit. TB = 1111111, do at date/time following.
Stay (see note 4)	"t"	(≤0011111) (see note 5)	Wait on channel for time T and stay linked, don't transmit unless commanded, and ignore all signals during T if not understood; except ALE frame reacquisition by T (must be in correct redundant word phase). T in multiples of Trw, as indicated by binary value of last 14 bits (≤0011111 1111111 = 4095 s), range of 0 to 26.754 minutes.

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TABLE A-XXIV. Time-related COMMAND functions -- Continued.

Identification	First character	Second character	Function
Tune and wait	"t"	"t" (1110100)	Stop scan, tuneup, do not respond, wait T for instructions, quit and resume scan if nothing. TB = 0, quit after tuneup. TB7 = 0 as 36 second limit.
Width of slots	"t"	"w" (1110111)	Set all slots to T wide for this response. TB = 0, no responses. TB7 = 0 as 36 second limit.

NOTES:

1. Preamble is COMMAND (110).
2. First character is "t" (1110100) for all.
3. Third-character field is binary bits TB7 through TB1 (W18 through W24), designating a time interval "T" as a standardized value in table A-XXIII.
4. When the optional UUF is implemented, the STAY command function is required.
5. This second ASCII character will vary, depending on the resulting binary value.

80.9 User unique functions (UUFs). The user unique functions (UUFs) are for special uses, as coordinated with specific users or manufacturers, which use the ALE system in conjunction with unique, nonstandard or non-ALE, purposes. UUF enables stations to perform an "escape" function which preserves the basic and underlying protocol and also permits the use of the channel or link for activities unique to a specific user or manufacturer group or system. The unique function itself may be anything that the users select to use, and the ALE waveform and signal structures may be used, but are not required. An example is a user which requires the capability to link using ALE, transmits an HF channel characterization (non-ALE) waveform during the ALE frame or handshake, and concludes the underlying protocol.

There are 16384 specific types of COMMAND UUF codes available, as indicated by a 14- bit (or two-character) unique index (UI). Each unique type of special function which employs a UUF shall have a specific UI assigned to it to ensure interoperability, compatibility, and identification. The UI shall be assigned for use before any transmission of the UUF or the associated unique activity, and the ALE UUF shall always include the appropriate UI when sent.

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The UUF shall be used only among stations which are specifically addressed and included within the protocol, and shall be used only with stations specifically capable of participating in the UUF activity, and all other (nonparticipating) stations should be terminated. There are two exceptions for stations which are not capable of participating in the UUF and are required to be retained in the protocol until concluded. They shall be handled using either one of the two following procedures. First, the calling station shall direct all the addressed and included stations to stay linked for the duration of the UUF, to read and use anything that they are capable of during that time, and to resume acquisition and tracking of the ALE frame and protocol after the UUF ends. To accomplish this, and immediately before the COMMAND UUF, the sending station shall send the COMMAND STAY, which shall indicate the time period (T) for which the receiving stations shall wait for resumption of the frame and protocol. Second, the sending station shall use any standard COMMAND function to direct the nonparticipating stations to wait or return later, or do anything else which is appropriate and controllable through the standard orderwire functions.

If a COMMAND UUF is included within an ALE frame, it shall only be within the message section. The UUF activity itself should be conducted completely outside of the frame and should not interfere with the protocols. If the UUF activity itself must be conducted within the message section, will occupy time on the channel, and is incompatible with the ALE system, that activity shall be conducted immediately after the COMMAND UUF and it shall be for a limited amount of time (T). A COMMAND STAY shall precede the UUF instruction, as described herein, to indicate that time (T). The sending station shall resume the same previous redundant word phase when the frame and protocol resumes, to ensure synchronization. The STAY function preserves maintenance of the frame and link. It instructs the stations to wait, because the amount of time occupied by the UUF activity or its signaling may conflict with functions such as the wait-for-activity timer (Twa). This may interfere with the protocols or maintenance of the link. In any case, the users of the UUF shall be responsible for noninterference with other stations and users, and also for controlling their own stations and link management functions to avoid these conflicts.

The user unique function (UUF) shall be constructed as follows and as shown in table A-XXV. The UUF word shall use the COMMAND (110) preamble in bits P3 through P1 (W1 through W3). The character in the first position shall be the "pipe" or "vertical bar" "|" (1111100) in bits C1-7 through C1-1 (W4 through W10), which shall identify the "unique" function. The user or manufacturer specific unique index (UI) shall be a 14-bit (or two-character, 7-bit ASCII) code using bits UI14 through UI1 (W11 through W24). All unassigned UI codes shall be reserved and shall not be used until assigned for a specific use.

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TABLE A-XXV. User unique functions structure.

		User unique function bits		Word bits
COMMAND preamble	MSB	P3 = 1	MSB	W1
		P2 = 1		W2
	LSB	P1 = 0		W3
First character "|"	MSB	C1-7 = 1		W4
		C1-6 = 1		W5
		C1-5 = 1		W6
		C1-4 = 1		W7
		C1-3 = 1		W8
		C1-2 = 0		W9
	LSB	C1-1 = 0		W10
First UI character	MSB	UI1-7		W11
		UI1-6		W12
		UI1-5		W13
		UI1-4		W14
		UI1-3		W15
		UI1-2		W16
	LSB	UI1-1		W17
Second UI character	MSB	UI2-7		W18
		UI2-6		W19
		UI2-5		W20
		UI2-4		W21
		UI2-3		W22
		UI2-2		W23
	LSB	UI2-1		W24

NOTES:

1. COMMAND user unique functions first character is "|" (1111100) for "unique".
2. Unique index (UI) characters UI1 and UI2 from central registry and assignment.

Supersedes page 164 of 15 September 1988.

ANNEX A. DEFINITIONS OF TIMING SYMBOLS

C	Number of channels in scan sequence
H	Handshake. Completed sequence of call, response, and acknowledgement
n	Integer
NA	Number of addresses
NAm	Number of addresses with "m" words
NAW	Number of original individual address words
NS	Number of slots in response period, total (includes slot 0)
Pl	Probability of linking (three-way handshake)
s	Seconds
SN	Slot number identification
T	Time
Ta	Individual station (or net) whole address time
Tal	Individual station (or net) address first word time
Ta max	Maximum individual station (or net) whole address time limit
Tar	Acknowledgement received event time
Tc	Call time, combination of whole address(es), which is usually repeated as a leading call Tlc
Tcl	Combined different first words of group station address
Tcc	Calling cycle time
Tc max	Maximum call time limit (of the call)
Td(5) & Td(2)	Basic dwell time on each channel during scan. Number is channels per second scanning rate.
Tdbm	Data block message time
Tdek	Decode time

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Tdrrw	Detect rotating redundant word time
Tdrw	Detect redundant word time
Tds	Detect signaling (tones and timing) time
Tenk	Encode time
Ths	Handshake time, start to finish total (without tuning)
Tlc	Leading call time
Tld	Late detect word additional time
Tlww	Last word wait delay
Tm	Orderwire message section time
Tm max	Maximum orderwire message section time limit
Tp	Propagation time
Tps	Periodic sounding interval
Trc	Redundant call time
Trd	Receiver internal signal delay time
Trr	Response received event time
Trs	Redundant sound time
Trw	Redundant word time (392 ms)
Trwp	Redundant word phase delay (0 to Trw)
Ts	Scan period
Tsc	Scan calling time, same as Tss
Ts max	Maximum scan period
Ts min	Minimum scan period
Tsrc	Scanning redundant call time
Tsrs	Scanning redundant sound time
Tss	Scan sounding time, same as Tsc

Replaces page 170 of 15 September 1988.

Tsw	Slot width time
Tswf	Fixed slot width time
Tswt	Slot wait time delay after end of call, until slotted response starts
Tt	Tuneup time delay of antenna tuner or coupler
Tta	Turnaround time, receipt of end of signal to start of reply
Ttc	Transmitter command (to transmit) time
Ttd	Transmitter internal signal delay time
Ttk	Transmitter acknowledgement (that it is transmitting) time
Ttone	Tone (8 ms)
Tw	Word time (130.66...ms)
Twa	Wait for activity time
Twan	Wait for net acknowledgement time (for called stations).
Twan max	Maximum limit group call wait for reply time (for late arrival called stations)
Twce	Wait for calling cycle end (message or terminator sections)
Twr	Wait for reply time
Twrn	Wait for net/group reply time (for calling stations)
Twrt	Wait for reply and tune (scanning) time
Twt	Wait (listen first) time before tune or transmit
Tx	Termination section time
Tx max	Maximum termination section time limit
w	Word
Wmax	Maximum words
WRT	Wait for reply timer (load with Twr)
WRTT	Wait for response and tune timer (load with Twrn or Twrt)

Replaces page 171/172 of 15 September 1988.

ANNEX B. TIMING

Note: Refer to annex A and table A-XIV.

Basic system timing

- Tone (symbol) rate = 125 symbols per second
- Tone period:

  Ttone = 8 ms per symbol

- On-air bit rate = 375 bits per second
- On-air individual word period (never sent alone):

  Tw = 16.33... symbols x Ttone = 130.66... ms

- On-air (triple) redundant word period:

  Trw = 3Tw = 49 tone = 392 ms

- On-air individual (or net) address time, for m = 1 to 5 words:

  Ta = m x Trw = 392 ms to 1960 ms

- Propagation time, range divided by speed of wave, for MF/HF signals, local to global:

  Tp = 0 to 70 ms

Supersedes page 173 of 15 September 1988.

System timing limits

- o Maximum individual station (or net) address time limit, based on 15-character (or 5-word) maximum:

  Ta max = 5 Trw = 1,960 ms

- o Individual (or net) address first word, used in scan call Tsc:

  Tal = Trw = 392 ms

- o Maximum group combined addresses different first words time limit, maximum 5 first words, in scan call Tsc:

  Tcl = Σ Tal (different)
  Tcl max = 5 Tal = 5 Trw = 1960 ms

- o Maximum call time limit, based on 12-word maximum, whole addresses in Tlc:

  Tc max = 12 Trw = 4,704 ms

- o Maximum scan cycle period limit, based on 2 channels per second and 100 channels:

  Ts max = 50 s

- o Maximum message (orderwire) section time limit, unless adjusted by COMMAND:

  Tm max basic = 30 Trw = 11.76 s

  Tm max including Tm max AMD = 29 Trw* + 30 Trw = 23.128 s

  Tm max including Tm max DTM = 29 Trw* + 353 Trw = 382 Trw(149.744s)

  Tm max including Tm max DBM = 29 Trw* + 3560 Trw = 3589 Trw(1406.888s)

  * NOTE: Tm max basic equals 29 Trw when combined with AMD, DTM, or DBM. This is due to the requirement to commence the AMD, DTM, or DBM transmission one Trw (392 ms) prior to the close of Tm max basic which effectively reduces the value of Tm max basic to 29 Trw in these equations.

- o Maximum termination section time limit, same as Ta max:

  Tx max = Ta max = 1,960 ms

Individual calling

- o Initial and minimum dwell time on each channel by receiving station during normal receive scanning; inverse of scanning rate; not including extended pause to read words:

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Td(5)min = 200 ms at 5 channels per second basic scan rate, or
Td(2)min = 500 ms at 2 channels per second minimum scan rate
Td(10)min = 100 ms at 10 channels per second (DO)

o Scan period for receiving station to scan all scanned channels during normal receive scanning, where "C" is the number of scanned channels; not including extended pause to read words:

Ts min = C x Td min

For example,

Ts min = 0 for single-channel, nonscan case, or
= 2 seconds for typical C = 10 at 5 chps, or
= 5 seconds for C = 10 at 2 chps minimum rate
= 1 second for C = 10 at 10 chps (DO)

o For scan call Tsc computations, use Ts based on probable maximum pause on each channel (Td, to read words) of Tdrw = 2 Trw (Td may be adjusted by net managers for best system performance):

Ts = C x Td = C x Tdrw

For example,

Ts = 7,840 ms for C = 10 channels and Td = Tdrw

o Call time, the called whole address (or combination of called whole addresses, if a group call), which may be repeated in the leading call Tlc; maximum limit 12 address words:

Tc = Ta (called) for single-station (or net) calls, or
= Ta (first) + Ta (second) + . . . Ta (last) if group call

o First-word call time, the called address first word (or combination of addresses first words, if a group call), which is repeated in the scanning call Tsc; maximum limit 5 different first words:

Tcl = Tal (called) for single-station (or net) calls, or
= Tal (first) + Tal (second different) + . . . Tal (last different) if group call

o Leading call time, composed of two complete repetitions of Tc, which contains the whole address(es):

Tlc = 2Tc = 2Ta (called) for single-station (or net) calls, or
= 2(Ta (first) + Ta (second) +...Ta (last)), if group call

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o Scanning call time, consisting of repetitions of only the first word(s) Tal of the called address (or combination of addresses, if a group call), for calling station to "capture" scanning receivers during normal scanning calling. Therefore, Tsc is a multiple Tcl (group of Tal's if a group call) of words, which is $\geq$ the receiver's scan period Ts, where n is any integer such that Tsc $\geq$ Ts:

$$Tsc = n \times Tcl \geq Ts = C \times Td$$

For example,

Tsc = 0 for single-channel individual call case, or

$\geq$20 Trw = 7840 ms if C = 10 and Td = Tdrw

o Calling cycle time for calling station to both "capture" scanning receivers and ensure reading the called station address(es), consisting of scan calling time (Tsc) plus leading call time (Tlc), respectively:

$$Tcc = Tsc + Tlc \geq Ts + Tlc$$

For example,

Tcc = Tlc = 2Ta (called) = 784 ms for single-channel one-word address individual (or net) call case (Ts = 0), or
= Tsc + Tlc = (20 + 2) Trw = 8624 ms if C = 10 and Td = Tdrw

o Single-channel redundant call time, consisting of individual (or net) leading call Tlc (with TO) plus terminator Ta (with THIS IS or THIS WAS), not including any message section time:

Trc = Tlc + Tx = 2Tc + Tx = 2Ta (called) + Ta (caller)
= 3 Trw min = 1176 ms minimum, for individual station (or net) call using one-word addresses.
= 15 Trw min = 5880 ms max for 5-word addresses

o Scanning redundant call time, consisting of scanning call time Tsc, and redundant call time Trc, respectively:

$$Tsrc = Tsc + Trc$$

For example, using one-word addresses:

Tsrc = (20 + 3) Trw = 9016 ms if C = 10 and Td = Tdrw

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- <u>Last word wait</u> additional fixed delay at replying or receiving station, after (possibly early) detected end of received call and before start of reply, to avoid on-air overlap, loss of additional termination (caller address) words, and to allow margin for transmitter turnaround for reception:

  <u>Tlww</u> = Trw = <u>392 ms</u>

- <u>Late word detection</u> additional fixed delay at calling station, to increase wait for reply time in case of possibly late detection at called station:

  <u>Tld</u> = Tw = <u>130.66... ms</u>

- <u>Redundant word phase delay</u>. To synchronize a transmission to any recently preceding transmissions, and used on all but first transmission of a handshake or exchange until terminated period:

  <u>Trwp</u> = <u>0 to 392 ms</u> ≤ Trw

- <u>Turnaround time</u> at replying station, measured at rf port(s); from end of received signal to start of transmitted reply, not including delays such as Tlww or Tld and including receiver and transmitter internal signal delays, Trd and Ttd; decode and encode time, Tdek and Tenk; and transmitter command and acknowledgement delays, Ttc and Ttk:

  <u>Tta</u> = <u>Trd + Tdek + Tenk + Ttc + Ttk + Ttd</u>

  For example approximations,

  <u>Tta</u> = 0 for new, fast equipment, or
  = 2 Tw = 261.33...ms estimated allowances for old slower equipment

- <u>Wait for calling cycle end time</u> at receiving station, is delineated by receipt of start of message, terminator, or quick-ID section:

  Twce = 2 x Ts (of own station) as default value

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- Wait for reply time at calling station, from end of transmitter signal to start of received reply detection periods (Tds, Tdrw, and Tdrrw, below); including propagation, Tp; last word wait, Tlww; late word detection, Tld; turnaround, Tta; redundant word phase delay (if not first transmission in handshake or exchange), Trwp; and receiver and transmitter internal signal delays, Trd and Ttd; in a single-channel case without tune times, or multi-channel scanning case after first tune and transmission:

  Twr = Ttd + Tp + Tlww + Tta + Trwp (if not first) + Tld + Tp + Trd

  For example approximations,

  Twr = 5 Tw = 653.33... ms for fast equipment, or
  = 7 Tw = 914.66... ms for slower equipment, maximum
  = 8 Tw = 1045.33...ms for fast equipment if not first
  = 10 Tw = 1306.66...ms for slower equipment if not first

- Tune time delay, after issuance of tuneup command and before ready to transmit the reply signal:

  Tt = maximum tuneup delay for slowest tuner in system (or net/group being called)

  For examples, typical allowance ranges are

  Tt ≤ Tw = 130.66... ms for fast (solid state) tuners or
  ≤ 8 Tw = 1,045.33... ms for fast relay tuners, or
  ≤ 20 seconds for old electromechanical (servo drive) tuners, or as required by available equipment

  NOTE: If tune time(s) of called station(s) is unknown, first try default value shall be 8 Tw and second try default value shall be at least 20 seconds.

- Wait for response and tune time, same as wait for reply Twr, plus tune time Tt in scanning cases, and relevant only to first transmission on a channel (which requires tuning time):

  Twrt = Twr + Tt

  For examples, typical allowance ranges are

  Twrt = 6 Tw = 784 ms for fast tuners, or
  15 Tw = 1,960 ms for slower tuners, or
  adjusted as required by available equipment

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NOTE: If tune time(s) of called station(s) is unknown, first try default value shall be 15 Tw and second try default value shall be at least 20 seconds.

- Detect signaling tones and timing (of call or reply) detection period; after arrival on channel during normal receive scanning, or after end of wait for reply time Twr or Twrt during normal calling, and before automatic return to normal receive scanning; used to identify channel vacancy or occupancy with standard ALE signaling.

  Tds Td(5) = 200 ms

- Detect redundant words detection period, starting same as Tds, and used to continue beyond Tds if tones and timing are detected, before automatic return to normal receive scanning; used for acceptance of basic single-word (and address first word) addressing and to read calls:

  Tdrw = Trw + spare Trw = 6 Tw = 784...ms

- Detect rotating redundant words detection period, starting same time as Tds, and used to continue beyond Tdrw if redundant words are detected, before automatic return to normal receive scanning; used for acceptance of extended (multiword) addressing and/or group calls:

  Tdrrw = 2 Trw + spare Trw = 9 Tw = 1,176 ms

Sounding

- Single-channel redundant sound time, like leading call Tlc, but with only the "THIS IS or THIS WAS" terminator, using twice the whole address:

  Trs = 2Ta (caller)

  For examples

  Trs = 2Trw = 784 ms minimum, individual single-word address sound on a single channel

- Scanning sound time. Like Tsc, but using whole address only (not just first word of address):

  Tss = n x Ta (caller) ≥ Ts

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- Scanning redundant sound time, like calling cycle time, Tcc, consisting of redundant sound time Trs, with addition of scanning sounding time Tss (which is identical to Tsc):

  $$\underline{Tsrs} = \underline{Tss + Trs} = (2 + n)Ta(caller) \geq Ts + Trs$$

  For examples,

  $$Tsrs = (20 + 2)\ Trw = 8624\ ms \text{ if C and } Td = Tdrw$$

Star calling

- Minimum uniform slot width for automatic slotted responses in normal single-word address star net and group calling protocols (but may be modified by COMMAND):

  Tsw (min) = 14 Tw = 1,829.33... ms for standard replies, or
  = 17 Tw = 2221.33...ms for LQA replies, or
  = 9 Tw = 1,176 ms for only fixed "tight slot" replies, or
  = n x Tw by COMMAND

  NOTE: Replies above are for first transmissions; if not, Tsw min = 17, 20, and 12 Tw respectively, (due to redundant word-phase delay).

- Slot wait time before start of slotted response and after detection of end of calling signal, where "SN" is the assigned (or derived) slot number, for group or preset net calling:

  Tswt(SN) = Tsw x SN for uniform slot widths (by COMMAND or net manager), or if nonuniform (customized) slot width

  $$Tswt(SN) = SN\ [5\ Tw + 2Ta\ (caller) + (\text{optional LQA})\ Trw + (\text{optional message})\ Tm] + Ta\ (caller) + [(\text{sum of all previous called addresses}) \sum_{m=1}^{m=SN-1} Ta(m)\ (called)]$$

  as the general case.

  For example,

  Tswt(5) = 14 Tw x 5 = 70 Tw = 9,146.66... ms delay for start of normal 5th slot response, first time, no LQA, single word address.

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- o <u>Wait for net reply</u> buffer time at <u>calling</u> station, after end of star <u>net or group</u> call, until responses should be received and an acknowledgement can be started, where "NS" is the total number of slots (including slot 0):

  <u>Twrn</u>(calling) = (<u>Tsw x NS</u>) for uniform slots or generally,
  = Tswt(NS)

- o <u>Wait for net</u> acknowledge buffer time at <u>called</u> stations, to receive acknowledgement after end of star net or group call:

  <u>Twan</u>(called) = <u>(Tsw x NS) + Tdrw</u>
  = Twrn(calling) + 2 Trw

- o <u>Turnaround plus tune time totals for slotted responses</u> have the following limits (not including Tlww):

  <u>Tta + Tt</u> 1500 ms for standard slots, except
  2100 ms for slot 1 only, or
  360 ms for slot 0 emergency or interrupt

- o <u>Maximum star group wait for acknowledgement time</u> at called stations:

  Twan max = 107 Tw + 27 Ta (caller) + 13 Trw (optional LQA) + 13 Tm (optional message)

- o Default maximum star group wait for acknowledgement time for late arrival, called stations, not knowing the size of the group. There are two default maximum waiting values, before automatically returning to normal receive scanning, if no message and caller uses single-word address:

  <u>Twan max</u> = 188 Tw = <u>24,565.33...ms</u> if standard, or
  227 Tw = <u>29,661.33...ms</u> if LQA requested

<u>Programmable timing parameters</u>

Unless otherwise programmed by the network manager, the following typical timing values are recommended:

- o <u>Dwell time</u> per channel, basic <u>receive</u> scanning:

  <u>Td</u>(5) = <u>200 ms</u> for 5 chps basic scan rate

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- Dwell time per channel, minimum receive scanning:

  Td(2) = 500 ms for 2 chps minimum scan rate

- Dwell time for calculations of Ts (and Tsc), based on probable maximum typical pause (may be adjusted by net manager for best system performance):

  Td = Tdrw = 2Trw = 784 ms

- Wait (listen first) time before tune or transmit:

  Twt = 2 seconds for voice or general purpose channels or,
  = Tdrw = 784 ms for ALE and data only channels

- Tune time allowance for wait for response time is normally set for slowest known tuner in associated network; except if unknown parameter (such as in blind internet calls to "strangers"):

  Tt = 8Tw = 1045.33... ms for first call, and
  = 20 seconds for next try

- Automatic periodic sounding intervals (when channels are clear):

  Tps = 30 minutes when enabled (disableable).

- Wait for activity time after linking or use, before automatic return to normal receive scanning:

  Twa = 30 minutes when enabled (disableable).

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ANNEX C. SUMMARY OF ALE SIGNAL PARAMETERS

ALE occupied bandwidth	500-2750 Hz
Quantity of tones	8 (one per symbol period)
Tone frequencies	750; 1000; 1250; 1500; 1750; 2000; 2250; 2500 Hz
Tone values	000 001 011 010 110 111 101 100
Symbol changes	Tone transitions are phase continuous
Symbol structure	3 bits of binary coded data
Symbol rate; period	125 symbols per second (sps); 8 ms
Coded data rate	375 bits per second (bps) transmitted
Forward error correction (FEC)	Golay (24, 12, 3) half-rate coding (4 modes of correct/detect; 3/4, 2/5, 1/6, or 0/7)
Auxiliary coding (DTM, AMD, basic ALE)	Redundant x 3, with 2/3 majority vote (with 49 transmitted bits)
Auxiliary coding (DBM)	Interleaving depth (ID) = 49 to 21805 = (n x 49)
Uncoded data rate (DTM, AMD, basic ALE)	61.22 bps
Uncoded data rate (DBM)	187.5 bps
Uncoded data bits per basic ALE word (DTM, AMD)	24 (21 (3 characters) plus 3 preamble), per word
Uncoded data bits per message (DTM)	From 0 to 7371 bits per block
Uncoded data bits per message (DBM)	From 0 to 261644 bits per block, plus 16 bits CRC
Throughput maximum data rate (DTM, AMD, basic ALE)	53.57 bps data bits
Throughput maximum data rate (DBM)	187.5 bps data bits
Characters per word (AMD or basic ALE)	0 to 3 expanded 64 or full ASCII

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Characters per message (DTM)	0 to 1053 full ASCII characters per block
Characters per message (DBM)	0 to 37377 full ASCII characters per block
Character rate (DTM, AMD, basic ALE)	7.653 cps
Character rate (DBM)	26.79 cps
Equivalent throughput maximum word rate (DTM, AMD)	76.53 words per minute (wpm) (5 characters plus space per word)
Equivalent throughput maximum word rate (DBM)	267.9 wpm (5 characters + space per word)
Unit period (DTM, AMD, or ALE word)	130.66... ms per word (Tw) or 392 ms per triple redundant word (Trw)
Message period (DTM)	0 to 2.29 minutes per block
Message period (DBM)	0 to 23.26 minutes per block
Minimum sound time	784 ms (2 Trw)
Minimum call time	1176 ms (3 Trw)
Minimum handshake time	3528 ms (9 Trw) three-way linking
Preambles (word types)	8 (3 bits)
Character sets	ASCII (basic 38, expanded 64, full 128), or random bits
Link quality analysis (LQA)	ALE (BER, SINAD, and MP)

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LINKING PROTECTION

10. GENERAL.

10.1 Scope. This appendix contains the requirements for the prescribed protocols and directions for the implementation and use of HF ALE radio linking protection.

10.2 Applicability. This appendix is a mandatory part of MIL-STD-188-141A whenever LP is a requirement for the HF radio implementation. The functional capability herein described includes linking protection control module, unclassified application level (AL-1) linking protection, and timing protocols. The capability for manual operation of the radio in order to conduct communications with existing, older generation, nonautomated radios shall not be impaired by implementation of these automated procedures.

20. APPLICABLE DOCUMENTS.

20.1 Government documents.

20.1.1 Specifications, standards, and handbooks. The specifications, standards, and handbooks that form a part of this document are listed in section 2. 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. (Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (STANDARDIZATION DOCUMENT ORDER DESK), 700 Robins Avenue, Building #4, Section D, Philadelphia, PA 19111-5094.

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

Technical Report, US Army Information Systems Engineering Command, ASQB-OSE-TR-92-04, Dated March 1992, Subject: A 24-Bit Encryption Algorithm for Linking Protection.

20.2 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD adopted are those listed in the DODISS.

30. DEFINITIONS.

30.1 Standard definitions and acronyms. See section 3.

30.2 Definitions of timing signals. The abbreviations and acronyms used for timing symbols are contained in annex A to appendix A.

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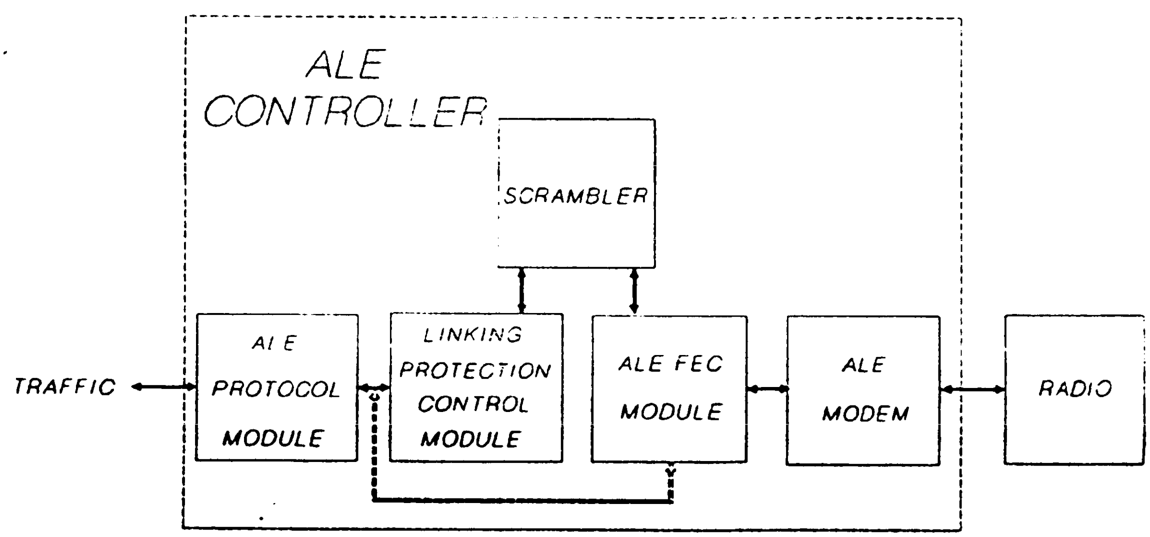
40. DETAILED REQUIREMENTS.

40.1 Introduction. Linking protection (LP) refers to the protection of the linking function required to establish the radio link. Voice transmissions or data transmissions from external modems are not affected by the LP and are transmitted in the clear unless externally encrypted. The LP unclassified application level and its corresponding protection interval (PI) is defined in 40.2.2.

40.2 Linking protection. The LP procedures specified herein shall be implemented as distinct functional entities for control functions and bit randomization functions. (Unless otherwise indicated, distinct hardware for each function is not required.) The linking protection control module (LPCM) shall perform all control functions specified herein and interface to the automatic link establishment (ALE) controller as shown on Figure B-1. Scrambler(s) shall perform all cryptographic operations on ALE words, under the control of the LPCM. Use of LP shall neither increase the time to establish a link compared to the non-protected radio, nor degrade the probability of linking below the standard set for non-protected linking in appendix A, table A-1. A means shall be provided to disable the LP functions and operate the radio in the clear unprotected application level (AL-0). Hardware scramblers shall be removable without impairment of the unprotected application level functionality of a radio.



NOTE: ⟷ **Indicates unprotected mode.**

FIGURE B-1. Data flow in a protected radio.

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40.2.1 Unprotected application level (AL-0). Assignment of the unprotected application level (AL-0) indicates that no linking protection is being employed. No protection is provided to linking attempts.

40.2.2 Unclassified application level (AL-1) linking protection. The unclassified application level scrambler shall employ the lattice encryption algorithm specified in U.S. Army Information Systems Engineering Command (USAISEC), Fort Huachuca, Arizona, Technical Report, ASQB-OSI-S-TR-92-04, "A 24-bit Encryption Algorithm for Linking Protection," March 1992, and may be implemented in hardware or software, with manufacturer-specified interfaces. This scrambler is for general U.S. Government and commercial use. This unclassified application level is mandatory for all protected radio systems, and therefore provides protected interoperability within the U.S. Government. The unclassified application level protection interval shall be 60 seconds, which provides slightly lower protection than any of the other available modes, but which permits for relaxed synchronization requirements. All protected radios shall be capable of operation at the unclassified application level. A means shall be provided to disable unprotected ALE. This disable mechanism shall not preclude the operator from manually initiating an unprotected ALE call. This manual override capability is required for interoperability.

40.2.3 Linking protection control module. The LPCM shall execute the LP procedure specified in 40.2.3.4 and control the attached scrambler(s) as specified below.

40.2.3.1 Scrambler interfaces. The LPCM shall interact with scrambler(s) in accordance with (IAW) the circuits and protocols specified in the interface control document (ICD) for each scrambler (see 40.2.2). For the unclassified application level the ICD is prepared and controlled by the manufacturer.

40.2.3.2 Time of day (TOD). The LPCM requires accurate time and date for use in the LP procedure. The local time base shall not drift more than ±1 second per day when the station is in operation.

40.2.3.2.1 TOD entry. A means shall be provided for entry of TOD (date and time) via either an operator interface or an electronic fill port such as a GPS time receiving port (DO: provide both operator interface and electronic port). This interface should also provide for the entry of the uncertainty of the time entered. If time uncertainty is not provided, a default time uncertainty shall be used. Defaults for the various time fill ports may be separately programmable. Default time uncertainty will be determined by the procuring agency or manufacturer. Default uncertainty of ± 15 seconds is suggested.

40.2.3.2.2 Time exchange protocols. After initialization of TOD, the LPCM shall execute the time protocols of 40.2.4 as required, to maintain total time uncertainty less than the protection interval (PI) length of the most secure LP mode it is using. The LPCM shall respond to time requests IAW 40.2.4.3.2 unless this function is disabled by the operator.

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40.2.3.3 Seed format. The LPCM shall maintain randomization information for use by scrambler(s), and shall provide this information, or "seed", to each scrambler IAW the applicable ICD. The 64-bit seed shall contain the frequency, the current PI number, the date, and a word number in the format shown on figure B-2A, where the most significant bits of the seed and of each field are on the left. The TOD portion of the seed shall be monotone non-decreasing. The remaining bits are not so constrained. The date field shall be formatted IAW figure B-2B. The month field shall contain a 4-bit integer for the current month (1 for January through 12 for December). The day field shall contain a 5-bit integer for the current day of the month (1 through 31). A mechanism shall be provided to accommodate leap years. The PI field shall be formatted IAW figure B-2C. The coarse time field shall contain an 11-bit integer which counts minutes since midnight (except that temporary discrepancies may occur as discussed in 40.2.3.4). The 6-bit fine time field shall be set to all 1's when time is not known more accurately than within one minute (i.e., time quality of 6 or 7). When a time synchronization protocol (see 40.2.4) is employed to obtain more accurate time, the fine time field shall be set to the time obtained using this protocol and incremented as described in 40.2.3.4. The fine time field shall always be a multiple of the PI length, and shall be aligned to PI boundaries (e.g., with a 2-second PI, fine time shall always be even). The word field shall be used to count words within a PI, as specified in 40.2.3.4. The frequency field shall be formatted IAW figure B-2D. Each 4-bit field shall contain one binary-coded decimal digit of the frequency of the current protected transmission. Regardless of time quality, the fine time field shall be set to all 1's for the unclassified application level of LP.

40.2.3.4 Procedure. The procedure to be employed in protecting transmissions consisting entirely of 24-bit ALE words is presented in 40.2.3.4.1 and 40.2.3.4.2. When a radio is neither transmitting or receiving, the PI number shall be incremented as follows. When local time quality is 5 or better, the fine time field shall be incremented at the end of each PI by the length of the PI, modulo 60. When the fine time field rolls over to 0, the coarse time field shall be incremented, modulo 1440. At midnight, the coarse and fine time fields shall be set to 0, and the date fields updated. When the local time quality is 6 or 7, the fine time field shall contain all 1's and the coarse time field shall be incremented once per minute, modulo 1440. At midnight, the coarse time field shall be set to 0, and the date and month fields updated.

40.2.3.4.1 Transmitting station. Each word to be transmitted shall be encrypted by the scrambler using the current seed information. In the course of a transmission the protocol described below may cause a discrepancy between the TOD fields in the seed and the real time. Such discrepancy shall persist until the conclusion of each transmission, whereupon the TOD fields of the seed shall be corrected. The word number field w shall be as follows:

a. During the scanning call phase (Tsc) of a call, or throughout a sound, the calling stations shall alternate transmission of words encrypted using w = 0 and w = 1. The first word of Tsc shall

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EXAMPLE SEED

DATE=8 MAY TIME=15:57:34 WORD=0 FREQUENCY=1755 KHz

A

9	17	8	2	28
Date	PI	Word	00	Frequency
0101 01000	01110111101 100010	00000000	00	0000 0000 0001 0111 0101 0101 0000
1 – 9	10 – 26	27 – 34		37 – 64

TOD (bits 1 – 26)

B

4	5
Month	Day
0101	01000
1 – 4	5 – 9

C

11	6
Coarse Time	Fine Time
01110111101	100010
10 – 20	21 – 26

D

4	4	4	4	4	4	4
100 MHz	10 MHz	1 MHz	100 KHz	10 KHz	1 KHz	100 Hz
0000	0000	0001	0111	0101	0101	0000
37 – 40	41 – 44	45 – 48	49 – 52	53 – 56	57 – 60	61 – 64

FIGURE B-2. Seed formats.

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begin with w = 0 or w = 1, as required, such that the last word of Tsc is encrypted using w = 1. The TOD used during Tsc shall change as required to keep pace with real time, except that TOD shall only change when w = 0. Words encrypted with w = 1 shall use the same TOD as the preceding word.

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

c. All succeeding words of the call shall use succeeding word numbers up to and including w = wmax. For the word following a word encrypted with w = wmax, the TOD shall be incremented and w shall be reset to 0.

(1) wmax = 2 for a 1-second PI.
(2) wmax = 5 for a 2-second PI.
(3) wmax = 153 for a 60-second PI.

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

Figure B-3A illustrates the permissible TOD/w combinations for a transmitting station using a 60-second PI (wmax = 153), and the permissible sequences of these combinations. Sounds are protected in the same fashion with Trs in place of Tlc.

40.2.3.4.2 Receiving station. Because of the possibility of acceptable decodes under multiple TOD/word number combinations, receivers shall attempt to decode received words under all allowed combinations (the current and adjacent PIs (future and past), and both w = 0 and w = 1) when attempting to achieve word synchronization with a calling station (six combinations). Stations prepared to accept time requests (see 40.2.4.3.2) shall also attempt to decode received words using coarse TOD (fine time = all 1's, correct coarse time only) with both w = 0 and w = 1 (eight combinations total). All valid combinations shall be checked while seeking word sync. After achieving word sync, the number of valid combinations is greatly reduced by the link protection protocol. Figure B-3B illustrates the permissible TOD/w sequences for a receiving station using a 60-second PI after word sync is achieved. Note that, unlike the transmitter, the receiving station state machine may be non-deterministic. For example, when in Tsc and in state N/1, a received word may yield valid preambles and ASCII when decrypted using all of the valid combinations: N/0, (N + 1)/0, and N/2 (the latter implying that Tlc started two words previously), and will therefore be in three states at once until the ambiguity is resolved by evaluating the decrypted words for compliance with the LP and ALE protocols under the valid successor states to these three states.

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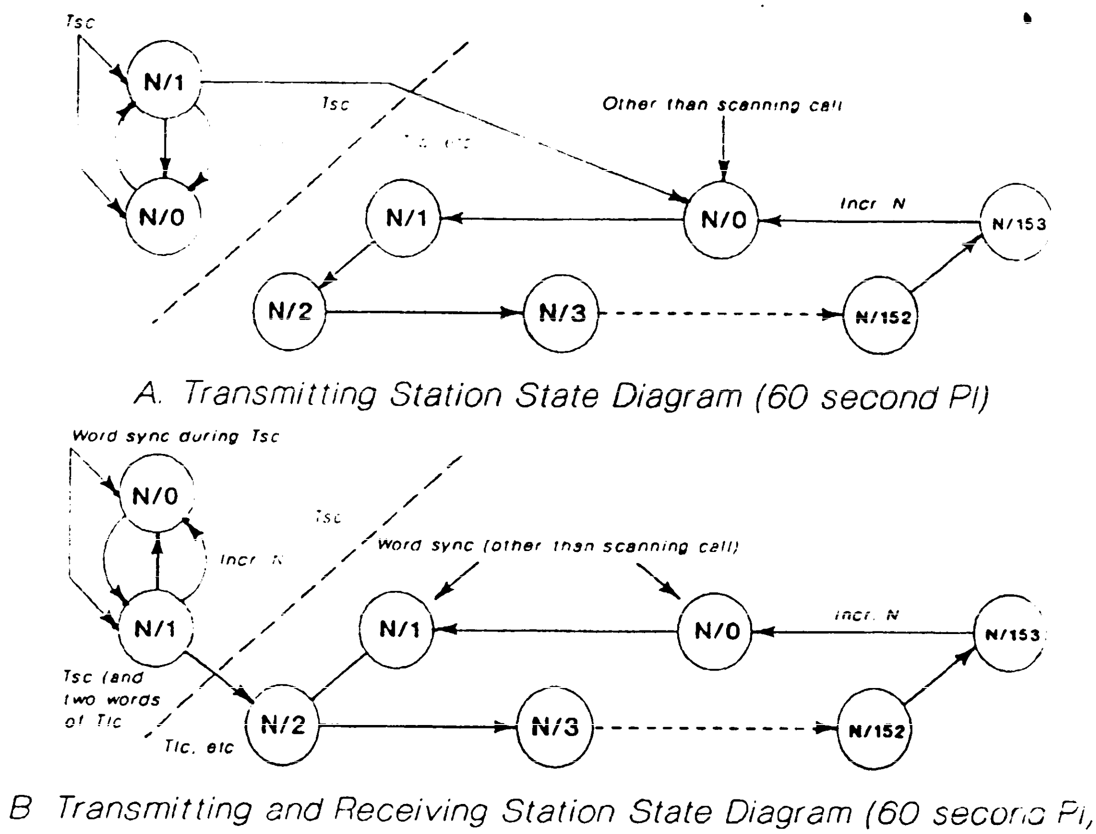

FIGURE B-3. <u>Transmitting and receiving stations state diagrams (60-second PI)</u>.

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40.2.3.4.3 Orderwire commands. Message text shall be sent in clear mode; this includes all data words following AMD or DTM CMD word, and DBM data blocks. All CMD words shall be protected, including the DTM and DBM CMD words.

40.2.4 Time protocols. The following protocols shall be employed to synchronize LP time bases. The time service protocols for active time acquisition, both protected (40.2.4.3) and non-protected (40.2.4.4), are mandatory for all implementations of LP.

40.2.4.1 Word formats. The mandatory time protocols employ the following three types of ALE words: (1) command words, (2) coarse time words, and, (3) authentication words, in the formats listed below.

40.2.4.1.1 Command word. Time exchange command words, used to request and to provide TOD data, shall be formatted as shown on figure B-4. The three most-significant bits (W_{1-3}) shall contain the standard CMD preamble (110). The next seven bits (W_{4-10}) shall contain the ASCII character '~'(1111110), indicating a time exchange command word. The three time quality bits shall indicate the magnitude of time uncertainty at the sending station IAW 40.2.4.2.

40.2.4.1.1.1 Time Is command. The Time Is command word carries the fine time current at the sending station as of the start of transmission of the word following the Time Is command word, and is used in protected time requests and all responses. In a Time Is command word, the seconds field shall be set to the current number of seconds elapsed in the current minute (0-59). The ticks field shall be set (or rounded) to the number of 40 ms intervals which have elapsed in the current second (0-24). The time quality shall reflect the sum of the uncertainty of the local time and the uncertainty of the time of transmission of the Time Is command, IAW table B-I and 40.2.4.2. When a protocol requires transmission of the Time Is command word, but no time value is available, a NULL Time Is command word shall be sent, containing a time quality of 7 and the seconds and ticks fields both set to all 1's.

40.2.4.1.1.2 Time Request command. The Time Request command word shall be used to request time when local time value is available, and is used only in non-protected transmissions. In a Time Request command word, time quality shall be set to 7, the seconds field to all 1's, and the ticks field set to 30 (11110).

40.2.4.1.1.3 Other encodings. All encodings of the seconds and ticks fields not specified here are reserved, and shall not be used until standardized.

40.2.4.1.2 Coarse time word. Coarse time words shall be formatted as shown on figure B-5, and shall contain the coarse time current as of the beginning of that word.

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Time Service Example

(Date-8 May Time-15:57:34:12 Time Quality-4)

	CMD	Time Exchange	Time Quality	Seconds	40 ms ticks
Bits	3	7	3	6	5
Value	110	1111110	100	100010	00011
Bit positions	1–3	4–10	11–13	14–19	20–24

"Time Is" Command

FIGURE B-4. Time exchange command word.

40.2.4.1.3 Authentication word. Authentication words, formatted as shown on figure B-5, shall be used to authenticate the times exchanged using the time protocols. The 21-bit authenticator shall be generated by the sender as follows:

(1) All 24 bit words in the time exchange message preceding the authentication word (starting with the Time Is or Time Request command word which begins the message) shall be exclusive-or'd.

(2) If the message to be authenticated is in response to a previous time exchange message, the authenticator from that message shall be exclusive-or'd with the result of (1).

(3) The 21 least significant bits of the final result shall be used as the authenticator.

(Note: The non-linearity necessary to produce reliable authentication is provided by the normal LP process when an authentication word is so protected. When an authenticator is to be sent in the clear, it can only provide authentication if it is encrypted off line.)

40.2.4.2 Time quality. Every time exchange command word transmitted shall report the current uncertainty in TOD at the sending station, whether or not time is transmitted in the command word. The codes listed in table B-I shall be employed for this purpose. The time uncertainty windows in the table are upper bounds on total uncertainty (with respect to coordinated universal

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Time Service Example

(Date-8 May Time=15:57:34:12 Time Quality=(4)

3	1	4	5	11
DATA	0	Month	Day	Minute
000	0	0101	01000	01110111101
1–3	4	6–8	9–13	14–24

Coarse Time Word

3	21
REP	Authenticator
111	110101110011111111110
1–3	4–24

Authenticator Word
(over Command and Coarse Time Words)

FIGURE B-5. Coarse time and authentication words.

Page added.

TABLE B-I. Time quality.

Time Quality Code	Time Uncertainty Window
0	none
1	20 ms
2	100 ms
3	500 ms
4	2 s
5	10 s
6	60 s
7	unbounded

NOTE: Time quality 0 shall be used only by UTC time standard stations.

time). For example, an uncertainty of ±6 seconds is 12 seconds total, and requires a transmitted time quality value of 6. Stations shall power up from a cold start with a time quality of 7. Time uncertainty is initialized when time is entered (see 40.2.3.2.1), and shall be maintained thereafter as follows: the uncertainty increases at a rate set by oscillator stability (e.g., 72 ms per hour with a ±10 parts per million (ppm) time base), until the uncertainty is reduced upon the acceptance of time with less uncertainty from an external source, after which the uncertainty resumes increasing at the above rate. A station accepting time from another station shall add its own uncertainty due to processing and propagation delays to determine its new internal time uncertainty. For example, if a station receives time of quality 2, it adds to the received uncertainty of 100 ms (±50 ms) its own processing delay uncertainty of, say, ±100 ms, and a propagation delay bound of ±35 ms, to obtain a new time uncertainty of ±185 ms, or 370 ms total, for a time quality of 3. With a ±10 ppm time source, this uncertainty window would grow by 72 ms per hour, so after two hours, the uncertainty becomes 514 ms, and the time quality has dropped to 4. **If a low-power clock is used to maintain time while the rest of the unit is powered off, the quality of this clock shall be used to assign time quality upon resumption of normal operation. For example, if the backup clock maintains an accuracy of ±100 ppm under the conditions expected while the station is powered off, the time uncertainty window shall be increased by 17 seconds per day. Therefore, such a radio which has been powered-off for much over three days shall not be presumed to retain even coarse sync, despite its backup clock, and may require manual entry of time.**

40.2.4.3 Active time acquisition (protected). **A station which knows the correct date and time to within one minute may attempt to actively acquire time from any station with which it can communicate in protected mode by**

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employing the protocol in the following paragraphs. The quality of time so acquired is necessarily at least one grade more uncertain than that of the selected time server. A station which does not know the correct date and time to within one minute may nevertheless employ this protected protocol by repeatedly guessing the time until it successfully communicates with a time server.

40.2.4.3.1 Time Request call. A station requiring fine time shall request the current value of the network time by transmitting a Time Request call, formatted as follows. (In principle, any station may be asked for the time, but some stations may not be programmed to respond, and others may have poor time quality. Thus, multiple servers may need to be tried before sufficient time quality is achieved.)

TO <time server> CMD Time Is <time> DATA <coarse time>
REP <authenticator> THIS IS <requester>.

The Time Is command shall be immediately followed by a coarse time word and an authentication word. The authenticator shall be generated by the exclusive-or of the command word and the coarse time word, as specified in 40.2.4.1.2. The Time Request call transmission shall be protected using the procedure specified above. When acquiring time synchronization, the coarse seed (fine time field in the seed set to all 1's) current at the requesting station shall be used. When used to reduce the time uncertainty of a station already in time sync, the current fine seed shall be used.

40.2.4.3.2 Time Service response. A station which receives and accepts (see below) a Time Request call shall respond with a Time Service response formatted as follows:

TO <requester> CMD Time is <time> DATA <coarse time>
REP <authenticator> THIS WAS <time server>.

The Time Is command shall be immediately followed by a coarse time word and an authentication word. The authenticator shall be generated by the 3-way exclusive-or of the command word and the coarse time word from this transmission and the authentication word (including the REP preamble) from the requester, as specified in 40.2.4.1.3. The entire Time Service response shall be protected as specified above, using the time server's current coarse seed if the request used a coarse seed, or the current fine seed otherwise. The seed used in protecting a Time Service response may differ from that used in the request which caused that response. A time server shall respond only to the first Time Request call using each fine or coarse seed; i.e., one coarse request per minute. Acceptance of time request may be disabled by the operator. Stations which are prepared to accept coarse Time Request commands shall decrypt the initial words of incoming calls under eight (vs. six) possible seeds: w = 0 and w = 1 with the current coarse TOD, and with the current fine TOD ±1 PI. (Note that only one coarse TOD is checked vs. three fine TODs.)

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40.2.4.3.3 Time Server request. A time server may request authenticated time from the original requester by returning a Time Server request, which is identical to the Time Service response as given above except that the THIS WAS termination is replaced. The original requester shall then respond with a Time Service response, as above, with an authenticator generated by the 3-way exclusive-or of the command word and the coarse time word from its Time Service response and the authentication word (including the REP preamble) from the Time Server request, as specified in 40.2.4.1.3.

40.2.4.3.4 Authentication and adjustment. A station awaiting a Time Service response shall attempt to decrypt received words under the appropriate seeds. If the request used a coarse seed, the waiting station shall try the coarse seeds used to encrypt its request, with w = 0 and w = 1, and those corresponding to one minute later. If the request used a fine seed, the waiting station shall try the usual six seeds: w = 0 and w = 1 with the current fine TOD ±1 PI. Upon successful decryption of a Time Service response, the requesting station shall exclusive-or the received command and coarse time words with the authentication word it sent in its request. If the 21 least significant bits of the result match the corresponding 21 bits of the received authentication word, the internal time shall be adjusted using the time received in the Time Is command and coarse time word, and the time uncertainty shall be set IAW 40.2.4.2.

40.2.4.4 Active time acquisition (non-protected). A station which does not know the correct date and time to within one minute may attempt to actively acquire time from any station with which it can communicate in non-protected mode by employing the protocol in the following paragraphs. Because time is not known in this case with sufficient accuracy to employ LP, the entire exchange takes place in the clear, with the authentication procedure as the only barrier against deception.

40.2.4.4.1 Time Request call (non-protected). A station requiring time shall request the current value of the network time by transmitting a non-protected Time Request call, formatted as follows:

TO <time server> CMD Time Request DATA <coarse time>
REP <random #> THIS IS <requester>.

The Time Request command shall be immediately followed by a coarse time word, followed by an authentication word containing a 21-bit number, generated by the requesting station in such a fashion that future numbers are not predictable from recently used numbers from any net member. Encrypting a function of a radio-unique quantity and a sequence number which is incremented with each use (and which is retained while the radio is powered off) may meet this requirement.

40.2.4.4.2 Time Service response (non-protected). A station which receives and accepts (see below) a non-protected Time Request call shall respond with a non-protected Time Service response formatted as follows:

Page added.

TO <requester> CMD Time Is <time> DATA <coarse time>
REP <authenticator> THIS WAS <time server>.

The Time Is command shall be immediately followed by a coarse time word and an authentication word. The authenticator shall be generated by encrypting the 24-bit result of the 3-way exclusive-or of the command word and the coarse time word from this transmission and the entire random number word (including the REP preamble) from the requester, as specified in 40.2.4.1.3. The encryption shall employ the Mode Two/One algorithm and a seed containing the time sent and w = all 1's. A time server shall respond only to the first error-free non-protected Time Request call received each minute (according to its internal time). Acceptance of non-protected time requests may be disabled by the operator.

40.2.4.4.3 Authentication and adjustment (non-protected mode). Upon receipt of a non-protected Time Service response, the requesting station shall exclusive-or the received coarse time word with the received Time Is command word. Then exclusive-or the result with the entire random number word it sent in its Time Request call, and encrypt this result using w = all 1's and the coarse time contained in the Time Service response. If the 21 least significant bits of the result match the corresponding 21 bits of the received authentication word, the internal time shall be adjusted using the received coarse and fine time, and the time uncertainty shall be set IAW 40.2.4.2.

40.2.4.5 Passive time acquisition. As an alternative to the active time acquisition protocols specified above, stations may attempt to determine the correct network time passively by monitoring protected transmissions. Regardless of the technique used to otherwise accept or reject time so acquired, passive time acquisition shall include the following constraints:

a. Local time may only be adjusted to times within the local window of uncertainty. Received transmissions using times outside of the local uncertainty window shall be ignored.

b. Local time quality shall be adjusted only after receipt of transmissions from at least two stations, both of which include time quality values, and whose times are consistent with each other within the windows implied by those time qualities.

A passive time acquisition mechanism may also be used to maintain network synchronization once achieved. Passive time acquisition is optional, and if provided, the operator shall be able to disable it.

40.2.4.6 Time broadcast. To maintain network synchronization, stations shall be capable of broadcasting unsolicited Time Is commands to the network, periodically or upon request by the operator:

TO <NET> CMD Time Is <time> DATA <coarse time>
REP <authenticator> THIS WAS <time server>

Page added.

The Time Is command shall be immediately followed by a coarse time word and an authentication word. The authenticator shall be generated by the exclusive-or of the command word and the coarse time word from this transmission as specified in 40.2.4.1.2. If the broadcast is made without LP (i.e., in the clear), the authenticator must be encrypted as described in 40.2.4.1.3 to provide any authentication. The use of an authenticator which does not depend upon a challenge from a requesting station provides no protection against playback of such broadcasts. A station receiving such broadcasts must verify that the time and the time uncertainty that the broadcasts contain are consistent with the local time and uncertainty before such received time is at all useful.

40.2.4.7 Advanced time exchange protocols. Advanced timing exchange protocols for PIs of less than 1 minute (60 sec) will be addressed as required with future upgrades of MIL-STD-188-141A.

CONCLUDING MATERIAL

Custodians:
Army--SC
Navy--EC
Air Force--90

Review activities:
Army--CR
Navy--MC
DoD--DC, NS, JT

Preparing activity
Army--SC

(Project SLHC-1411)

Supersedes page 185 of 15 September 1988.