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MIL-STD-188-141A
NOTICE 2
10 SEPTEMBER 1993

**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:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
iii	10 September 1993	iii	17 June 1992
iv	10 September 1993	iv	15 September 1988
v	10 September 1993	v	17 June 1992
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x	10 September 1993	x	17 June 1992
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1/2	10 September 1993	1/2	15 September 1988
3	10 September 1993	3	15 September 1988
4	15 September 1988	4	Reprinted without change
5/6	15 September 1988	5/6	Reprinted without change
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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 checklist. 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 cancelled. Paragraphs and tables that have been changed are identified by a vertical bar in the margin.

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

Review activities:
    Army-CR   (Project TCSS-1413)
    Navy--MC, SH
    DOD---------DC, NS, DI

AMSC N/A   SLHC/TCTS

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

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MIL-STD-188-141A

1. SCOPE.

1.1 <u>Scope</u>. The purpose of this document is to establish technical parameters, in the form of mandatory standards and optional design objectives (DOs), that are considered necessary to ensure interoperability of new long-haul and tactical radio equipment in the medium frequency (MF) band and in the high frequency (HF) band. It is also the purpose of this document to establish a level of performance for new radio equipment as is considered necessary to satisfy the requirements of the majority of users. These technical parameters, therefore, represent a minimum set of interoperability and performance standards. The technical parameters of this document may be exceeded in order to satisfy certain specific requirements, provided that interoperability is maintained. That is, the capability to incorporate features such as additional standard and nonstandard interfaces is not precluded.

1.2 <u>Applicability</u>. This standard is mandatory within the Department of Defense (DoD) in the design and development of new MF and HF radio equipment. It is not intended that existing equipment and systems be immediately converted to comply with the provisions of this standard. New equipment and systems and those undergoing major modification or rehabilitation shall conform to this standard. If deviation from this standard is required, the user should contact the lead standardization activity for waiver procedures.

1.3 <u>Application guidance</u>. The terms "system standard" and "design objective" (DO) are defined in FED-STD-1037. In this document, the word "shall" identifies mandatory system standards. The word "should" identifies design objectives which are desirable but not mandatory.

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NOTICE 2

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MIL-STD-188-141A
NOTICE 2

2. APPLICABLE DOCUMENTS.

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARDS

    FEDERAL

FED-STD-1003	Telecommunications, Synchronous Bit Oriented Data Link Control Procedures (Advanced Data Communication Control Procedures)
FED-STD-1037	Telecommunications: Glossary of Telecommunication Terms

    MILITARY

MIL-STD-188-100	Common Long Haul and Tactical Communication System Technical Standards
MIL-STD-188-110	Interoperability and Performance Standards for Data Modems
MIL-STD-188-114	Electrical Characteristics of Digital Interface Circuits
MIL-STD-188-148	(S) Interoperability Standard for Anti-Jam (AJ) Communications in the High Frequency Band (2-30 MHz) (U)

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

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

U.S. DEPARTMENT OF COMMERCE

    National Telecommunications and Information Administration (NTIA)

    - NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management

This page supersedes page 3 of 15 September 1988.

(Application for copies should be addressed to the U.S. Department of
Commerce, NTIA, Room 4890, 14th and Constitution Ave N.W., Washington, DC
20230.)

2.2 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 issues
of the DODISS cited in the solicitation. Unless otherwise specified, the
issues of the documents not listed in the DODISS are the issues of the
documents cited in the solicitation (see 6.2).

INTERNATIONAL STANDARDIZATION DOCUMENTS

North Atlantic Treaty Organization (NATO) Standardization Agreements
(STANAGs)

STANAG 4203	Technical Standards for Single Channel HF Radio Equipment
STANAG 5035	Introduction of an Improved System for Maritime Air Communications on HF, LF, and UHF

(Applications for copies should be addressed to: Commanding Officer, Naval
Publications and Forms Center, ATTN: NPFC 106, 5801 Tabor Avenue,
Philadelphia, PA 19120-5099.)

Quadripartite Standardization Agreements (QSTAGs)

QSTAG 733	Technical Standards for Single Channel High Frequency Radio Equipment

(Application for copies should be addressed to: Commanding Officer, Naval
Publications and Forms Center, ATTN: NPFC 106, 5801 Tabor Avenue,
Philadelphia, PA 19120-5099.)

International Telecommunications Union (ITU), Radio Regulations

CCIR Recommendation 455-1	Improved Transmission System for HF Radiotelephone Circuits

(Application for copies should be addressed to the General Secretariat,
International Telecommunications Union, Place des Nations, 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.)

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

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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 purpose 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 throughout. Sounding information is used for reducing the set of assigned channels to be used for a particular ALE connectivity attempt.

Cosite. The deployment of RF assets with limited physical separation. Insufficient separation or inadequate Electromagnetic Interference (EMI) suppression for the site conditions can result in degraded performance due to EMI (cosite interference).

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

Linked 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.

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.

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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
(two test signals) and receiver mixer-produced third-order 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.)

This page supersedes page 8 of 17 June 1992.

3.2 <u>Abbreviations and acronyms</u>. 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 level
AL-2	unclassified enhanced application level
AL-3	unclassified but sensitive application level
AL-4	classified application level
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
bps	bits per second
CCEP	Commercial COMSEC Endorsement Program
CCIR	International Radio Consultative Committee
CMD	ALE preamble word COMMAND
COMSEC	Communications Security
CRC	cyclic redundancy check
DATA	ALE preamble word DATA
dB	decibels
dBc	decibels referenced to full-rated peak envelope power (PEP)
DBM	data block message
DCA	Defense Communications Agency
DCAC	Defense Communications Agency Circular

This page supersedes page 9 of 17 June 1992.

DCE	data circuit-terminating equipment
DCS	Defense Communications System
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
ISDN	Integrated Services Digital Network
ISO	International Organization of Standardization
ITU	International Telecommunications Union
JCS	Joint Chiefs of Staff
LP	linking protection
LPCM	linking protection control module

This page supersedes page 10 of 17 June 1992.

LQA	link quality analysis
LSB	(1) lower sideband (radio); (2) least significant bit (data)
MP	multipath
MSB	most significant bit
NAK	nonacknowledgement (request for repeat)
NATO	North American Treaty Organization
NBFM	narrowband frequency modulation
NMCS	National Military Command System
NSA	National Security Agency
NTIA	National Telecommunications and Information Administration
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 determined
TOD	time of day
uncl	unclassified

This page supersedes page 11 of 17 June 1992.

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

This page supersedes page 12 of 17 June 1992.

4. GENERAL REQUIREMENTS.

4.1 <u>General</u>. 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 been historically 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.

Basic HF radio parameters are contained in this section and in section 5. HF technology going beyond the basic radio is contained in the appendices. Figure 1 shows the relationship of the functional aspects of current HF technology in terms of International Standard 7498 (ISO 7498-1984), the Open Systems Interconnection (OSI) Reference Model. The shaded area in figure 1 indicates coverage in this section and section 5.

4.2 <u>Equipment operation mode</u>.

4.2.1 <u>Baseline mode</u>. Frequency control of all new HF equipment except manpack, 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 40.3 of appendix A) associated with each particular channel.

4.2.1.1 <u>Single-channel</u>. 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).

* Not mandatory for radios designed for ALE.

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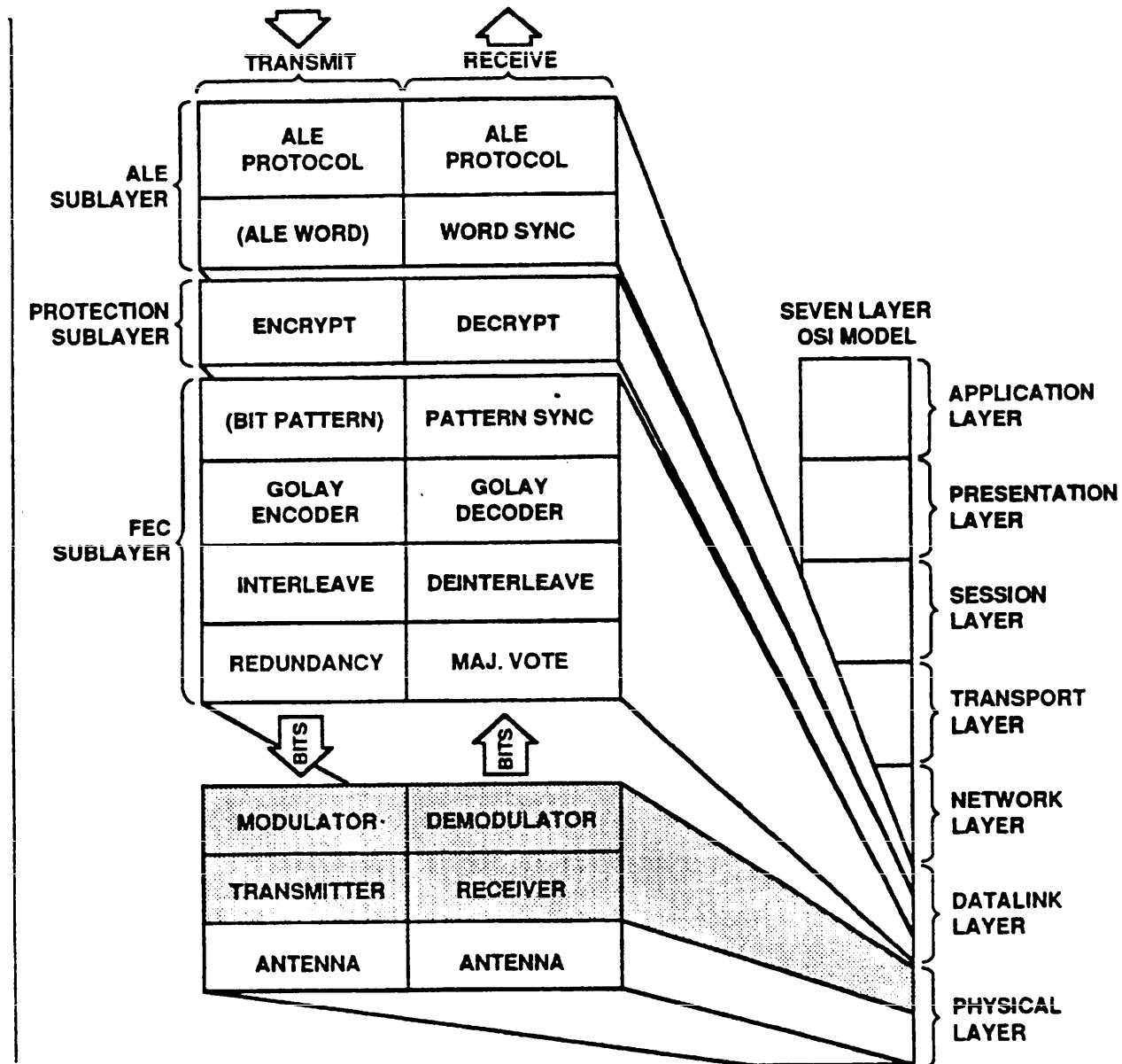
FIGURE 1. <u>Physical layer with transceiver and modem elements</u>.

Page 13a added.

4.2.1.2 <u>Multichannel</u>. All new multichannel HF equipment shall provide a single channel capability as set forth in paragraph 4.2.1.1 as a minimum and one or more of the following modes, selectable one at a time:

a. Two nominal 3-kHz channels in the USB and 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 <u>Automatic link establishment (ALE) mode</u>. 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. Detailed requirements are in appendix A. See 4.5 for the list of features required to support this operational mode.

4.2.3 <u>Anti-jam (AJ) mode</u>. 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 <u>Linking protection (LP)</u>. If LP is to be implemented, the LP capabilities and features for HF radios shall be in accordance with appendix B.

4.3 <u>Interface parameters</u>.

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

4.3.2 <u>Electrical characteristics of analog interfaces</u>. See 5.3.6 and 5.4.5.

4.3.3 <u>Modulation and data signaling rates</u>. The modulation rate (expressed in baud (Bd)) or the data signaling rate (expressed in bits per second (bps)) at interface points A and A' in figure 2 shall include those contained in the HF modem portion of MIL-STD-188-110.

4.4 <u>North Atlantic Treaty Organization (NATO) and Quadripartite interoperability requirements</u>.

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4.4.1 <u>Single-channel communications systems</u>. If interoperation with NATO member nations is required for land, air, and maritime applications, single-channel HF radio equipment shall comply with the applicable requirements of the current edition of STANAG 4203.
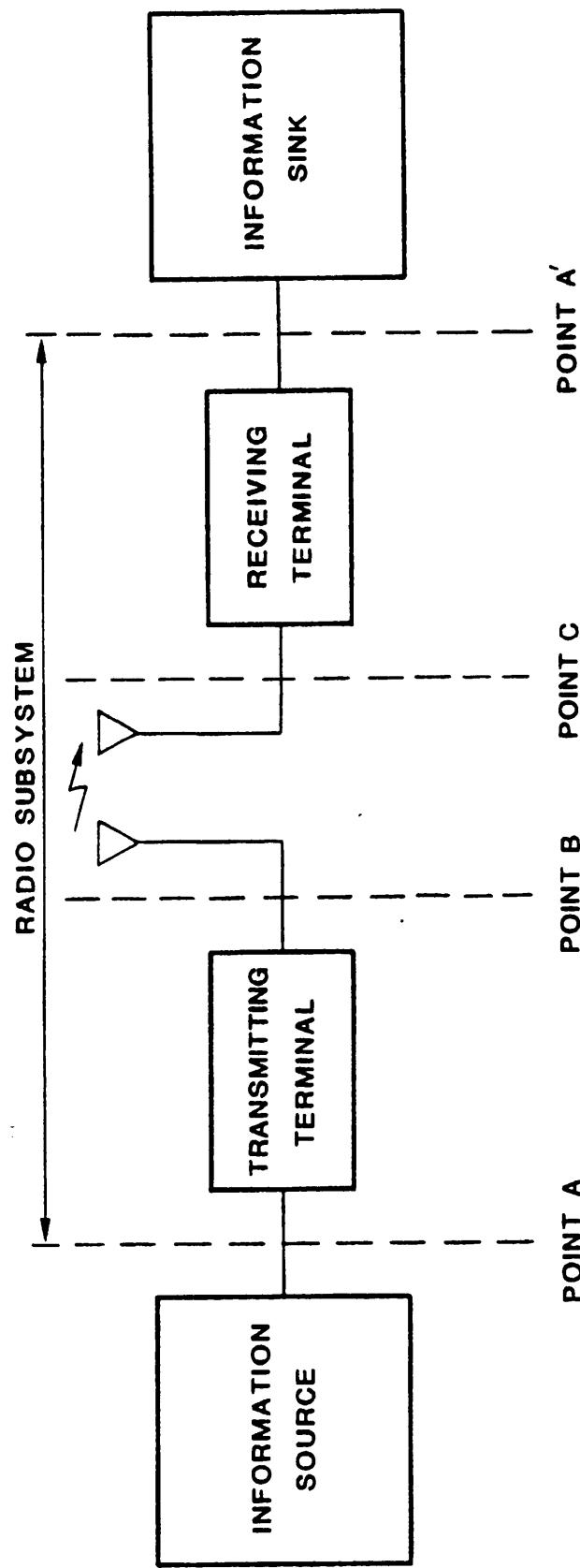
FIGURE 2. Radio subsystem interface points.

This page supersedes page 15 of 15 September 1988.

4.4.2 **Maritime air communications systems**. If interoperation with NATO member nations is required, HF maritime air communications shall comply with the applicable requirements of the current edition of STANAG 5035.

4.4.3 **High-performance HF data modems**. If interoperation with NATO member nations is required, land, air, and maritime, single-channel HF radio equipment shall comply with the applicable requirements of the appropriate STANAG.

4.4.4 **Quadripartite Standardization Agreements (QSTAGs)**. If interoperation among American, British, Canadian, Australian, and New Zealand (ABCA) Armies is required, HF combat net radio equipment shall comply with the applicable requirements of the current edition of QSTAG 733.

4.5 **Adaptive communications**. Adaptive HF describes any HF communications system that has the ability to sense its communications environment, and, if required, to automatically adjust operations to improve communications performance. Should the user elect to incorporate adaptive features, they shall be in accordance with the requirements for those features stated in this document.

The essential adaptive features are:

a. Channel (frequency) scanning capability.

b. Automatic link establishment (ALE) using an embedded selective calling capability. A disabling capability and a capability to inhibit responses shall be included.

c. Automatic sounding (station-identifiable transmissions). A capability to disable sounding and a capability to inhibit responses shall be included.

d. Limited link quality analysis (LQA) for assisting the ALE function:

   (1) Relative data error assessment.

   (2) Relative SINAD (optional).

   (3) Multipath/distortion assessment (DO).

This page supersedes page 16 of 15 September 1988.

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 signal-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 tactical application and within ±10 Hz for all others, during a period of not less than 30 days. See 4.1 for application statements on dual parameters.

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 in figures 3 and 4 under continuous carrier single-tone output conditions. Figure 3 depicts the limits of phase noise for cosited and non-cosited fixed-site and transportable long-haul radio transmitters. Figure 4 depicts the limits for tactical radio transmitters. See 4.1 for application statements on dual parameters.

This page supersedes page 17 of 17 June 1992.
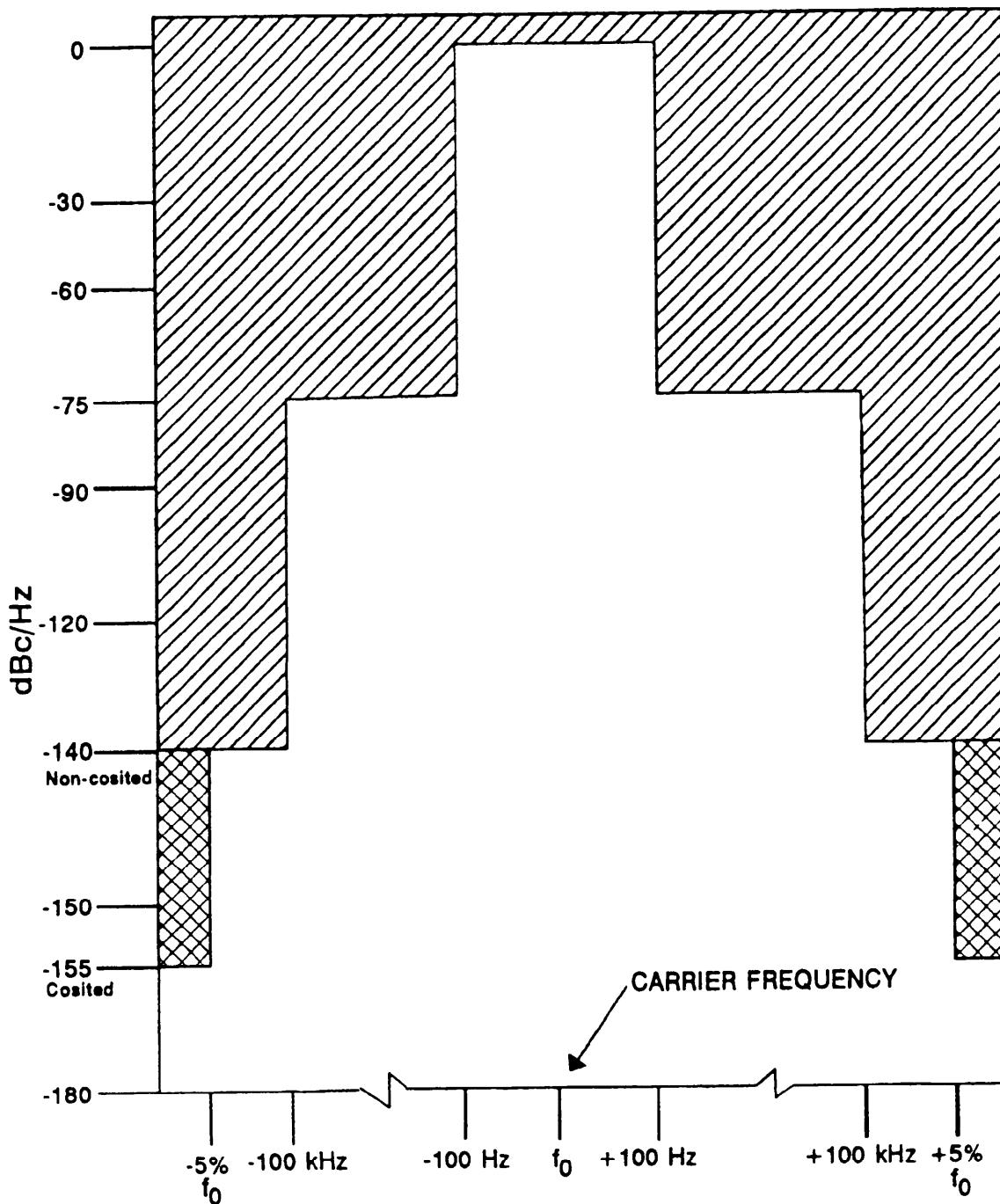
NOTE:

dBc=Decibels referenced to full-rated pep.

FIGURE 3.   <u>Phase noise limit mask for fixed site and transportable
long-haul radio transmitters</u>.

This page supersedes page 18 of 15 September 1988.

FIGURE 4. <u>**Phase noise limit mask for tactical radio transmitters**</u>.

This page supersedes page 19 of 15 September 1988.

5.2.6 <u>Bandwidths</u>. The bandwidths for high frequency band emissions shall
be as shown on table I. Use of other HF band emissions is optional; however,
if selected, shall be as shown on table I. Other high frequency band
emissions which may be required to satisfy specific user requirements can be
found in the NTIA Manual of Regulations and Procedures for Federal Radio
Frequency Management.

TABLE I. <u>Bandwidths</u>.

Emission type	Maximum Allowable 3 dB Bandwidth (kHz)	Mandatory Req.
Interrupted continuous wave (ICW)	0.5	Yes*
Frequency-shift keying (FSK) (85-Hz shift)	0.3	No
Frequency-shift keying (FSK) (850-Hz shift)	1.1	No
Single-sideband modulation (SSB) single-channel	see 5.2.7.1	Yes
Independent-sideband modulation (ISB)		
two channels	see 5.2.7.1	No
four channels	see 5.2.7.2	No

* Not mandatory for radios designed for ALE.

5.2.7 <u>Overall channel responses</u>.

5.2.7.1 <u>Single-channel or dual-channel operation</u>. The amplitude vs.
frequency response between (f_0 + 300 Hz) and (f_0 + 3050 Hz) shall be within
3 dB (total) where f_0 is the carrier frequency. The attenuation shall be at
least 20 dB from f_0 to (f_0 - 415 Hz), at least 40 dB from (f_0 - 415 Hz) to (f_0
- 1000 Hz), and at least 60 dB below (f_0 - 1000 Hz). Attenuation shall be at
least 30 dB from (f_0 + 4000 Hz) to (f_0 + 5000 Hz) and at least 60 dB above (f_0
+ 5000 Hz). See figure 5. Group delay time shall not vary by more than 1.0
ms over 80 percent of the passband of 300 Hz to 3050 Hz (575-2775 Hz).
Measurements shall be performed end-to-end (transmitter audio input to
receiver audio output) with the radio equipment configured in a back-to-back
test setup.

> NOTE: Although the response values given are for single-channel USB
> operation, an identical shape, but inverted channel response, is
> required for LSB or the inverted channel of a dual-channel independent
> sideband operation.

This page supersedes page 20 of 15 September 1988.

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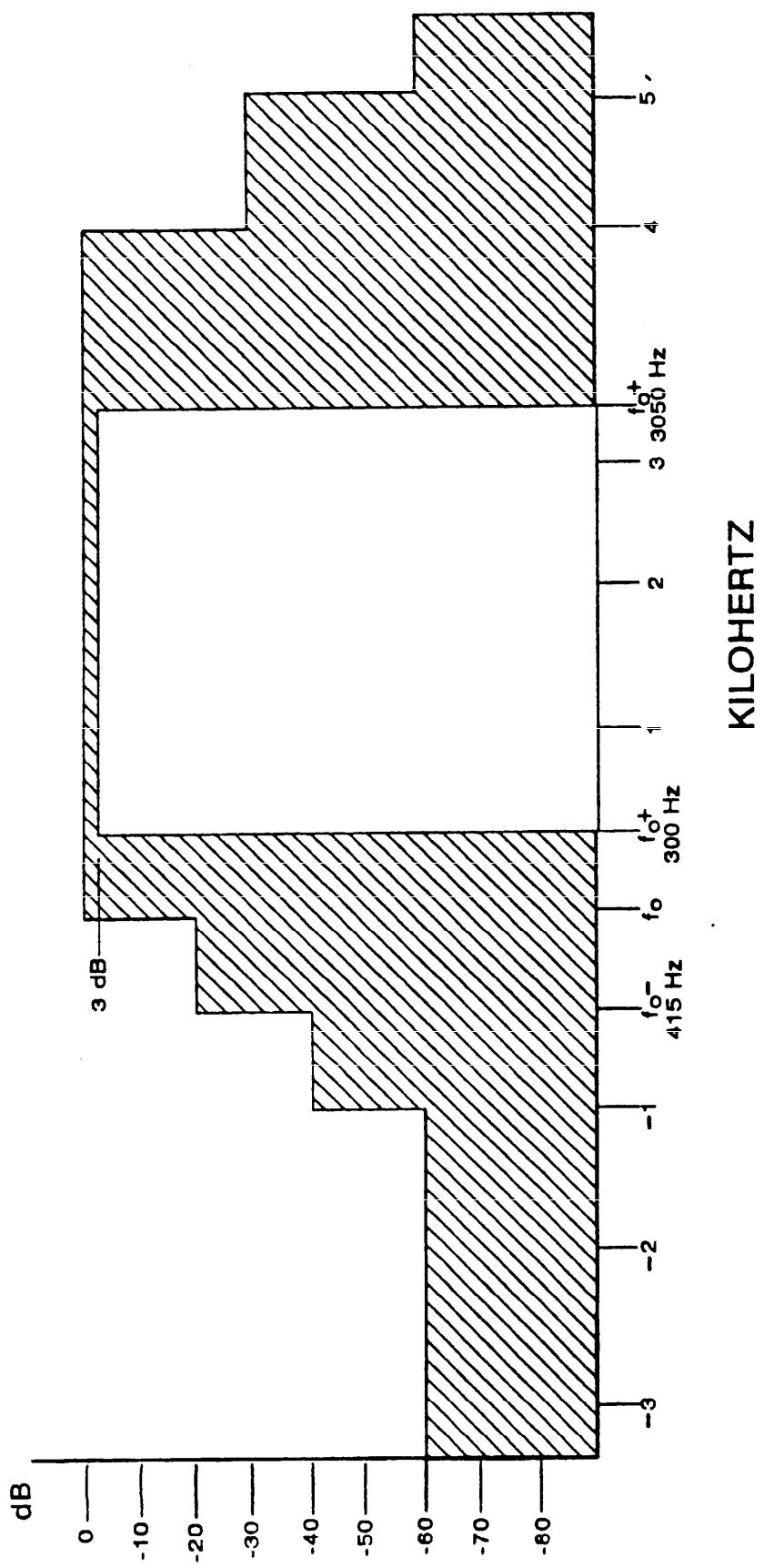
NOTES:

1. Channel response shall be within shaded portion of curve (A1 shown).

2. f_o for a single channel is the carrier frequency.

3. f_o for 2 channel ISB is the center frequency.

FIGURE 5. Overall channel response for single-channel or dual-channel equipment.

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5.2.7.2 <u>Four-channel operation</u>. When four-channel independent sideband operation is employed, the four individual 3-kHz channels shall be configured as shown in figure 6, which also shows the amplitude response for these four channels. Channels A2 and B2 shall be inverted and displaced with respect to channels A1 and B1 as shown on the figure. This can be accomplished by using subcarrier frequencies of 6290 Hz above and below the center carrier frequency, or by other suitable techniques which produce the required channel displacements and inversions. The suppression of any subcarriers used shall be at least 40 dB (DO: 50 dB) below the level of a single tone in the A2 or B2 channel modulating the transmitter to 25 percent of peak envelope power (PEP). See figure 6. The rf amplitude versus frequency response for each individual ISB channel shall be within 2 dB (DO: 1 dB) between 250 Hz and 3100 Hz, referenced to each channels's carrier (either actual or virtual). Referenced from each channel's carrier, the channel attenuation shall be at least 40 dB at 50 Hz and 3250 Hz, and at least 60 dB at -250 Hz and 3550 Hz. Group delay distortion shall not exceed 1500 microseconds over the ranges 370 Hz to 750 Hz and 3000 Hz to 3100 Hz. The distortion shall not exceed 1000 microseconds over the range 750 Hz to 3000 Hz. Group delay distortion shall not exceed 150 microseconds for any 100-Hz frequency increment between 570 Hz and 3000 Hz. Measurements shall be performed end-to-end (transmitter audio input to receiver audio output) with the radio equipment configured in a back-to-back test setup.

> NOTE: When using multichannel voice frequency carrier telegraph (VFCT) modulation, as specified on table 5.2-1 of MIL-STD-188-100, do not use channel 16 (frequencies of 2932.5 Hz, 2975 Hz, and 3017.5 Hz).

5.2.8 <u>Absolute delay</u>. The absolute delay shall not exceed 10 milliseconds (ms) (DO: 5 ms) over the frequency range of 300 Hz to 3050 Hz. Measurements shall be performed back-to-back as in 5.2.7.1.

5.2.9 <u>Lincompex</u>. Should a voice compression and expansion capability be included, it shall meet CCIR 455-1 Lincompex requirements. In addition, such a device shall incorporate calibration techniques that automatically remove radio-link frequency errors for the receiver expander function with the start of reception of each Lincompex transmission. The calibration sequence is shown in figure 7.

5.3 <u>Transmitter characteristics</u>.

5.3.1 <u>Noise and distortion</u>.

5.3.1.1 <u>In-band noise</u>. Broadband noise in a 1-Hz bandwidth within the selected sideband shall be at least 75 dBc below the level of the rated peak envelope power (PEP) of the HF transmitter for fixed station application and 65 dBc below the level of the rated PEP of the HF transmitter for tactical application.

This page supersedes page 22 of 15 September 1988.

FIGURE 6. Overall channel characteristics (four-channel equipment).
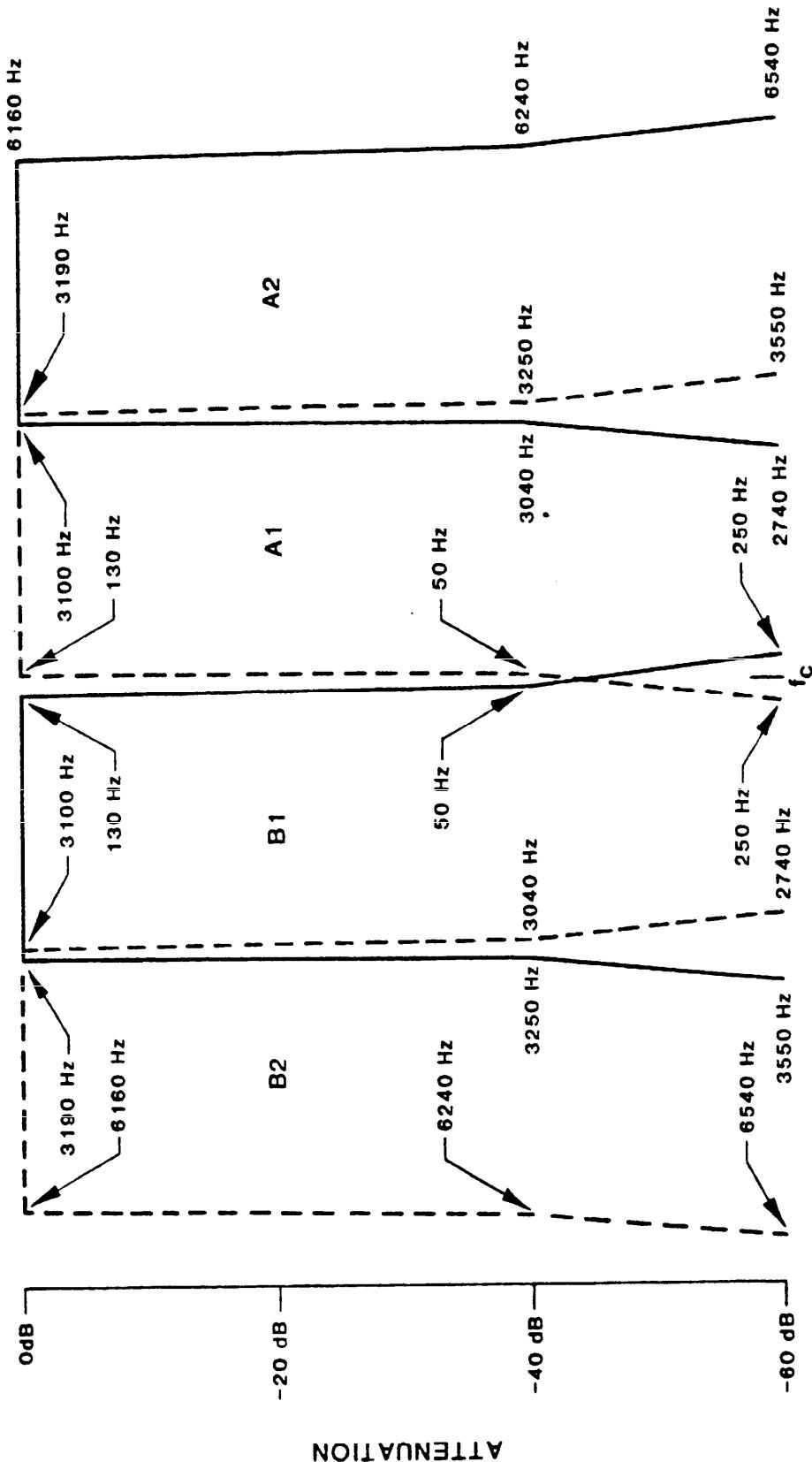
NOTES:

1. THE VIRTUAL SUBCARRIER FOR THE A2 AND B2 INVERTED CHANNELS SHALL BE $f_c \pm 6290$ Hz.

2. FREQUENCIES SHOWN ARE AT THE FILTER dB (BREAK POINT) LEVELS NOTED.

This page supersedes page 23 of 15 September 1988.
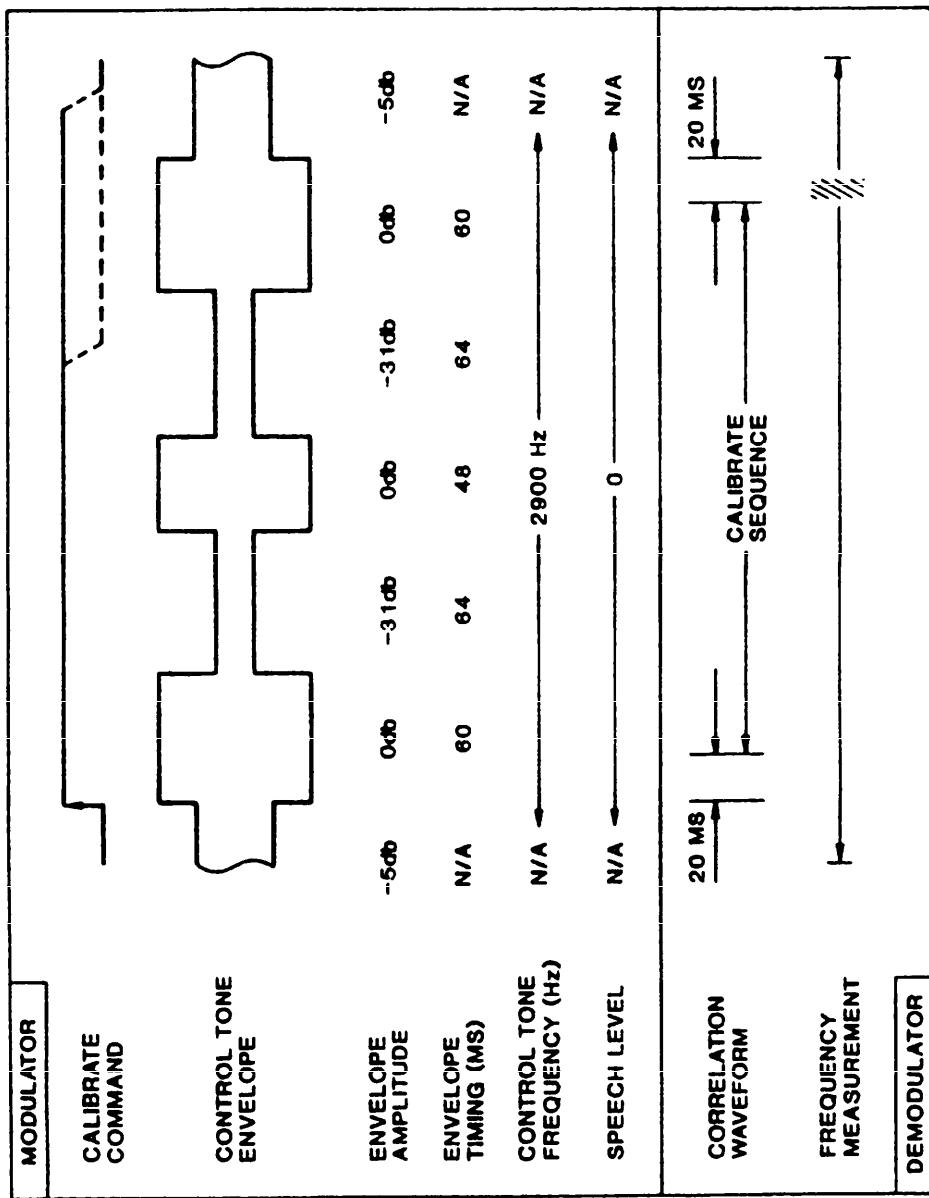
FIGURE 7. Lincompex calibration sequence.

5.3.1.2 Intermodulation distortion (IMD). The IMD products of HF
transmitters produced by any two equal-level signals within the 3 dB bandwidth
(a single-frequency audio output) shall be at least 30 dB below either tone
for fixed station application and 24 dB below either tone for tactical
application when the transmitter is operating at rated PEP. The frequencies
of the two audio test signals shall not be harmonically or subharmonically
related and shall have a minimum separation of 300 Hz.

5.3.2 Spectral purity.

5.3.2.1 Broadband emissions. When the transmitter is driven with a
single tone to the rated PEP, the power spectral density of the transmitter
broadband emission shall not exceed the level established on table II and as
shown in figure 8. Discrete spurs shall be excluded from the measurement, and
the measurement bandwidth shall be 1 Hz.

TABLE II. Out-of-band power spectral density limits for radio transmitters.

Frequency (Hz)	Attenuation Below In-Band Power Density (dB)
$f_m = f_c \pm (0.5\ B + 500)$	40 (DO: 43)
$f_m = f_c \pm 1.0\ B$	45 (DO: 48)
$f_m = f_c \pm 2.5\ B$	60 (DO: 80)
$(f_c + 4.0\ B) \leq f_m \leq 1.05\ f_c$ $0.95\ f_c \leq f_m \leq (f_c - 4.0\ B)$	70 (DO: 80)
$f_m \leq 0.95\ f_c$ $f_m \geq 1.05\ f_c$	90 (DO: 120)

Where: f_m = frequency of measurement (Hz)
        f_c = center frequency of bandwidth (Hz)
        B = bandwidth (Hz)

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FREQUENCY (Hz)

POWER SPECTRAL DENSITY LIMIT RELATIVE TO
IN-BAND POWER SPECTRAL DENSITY (dBc)
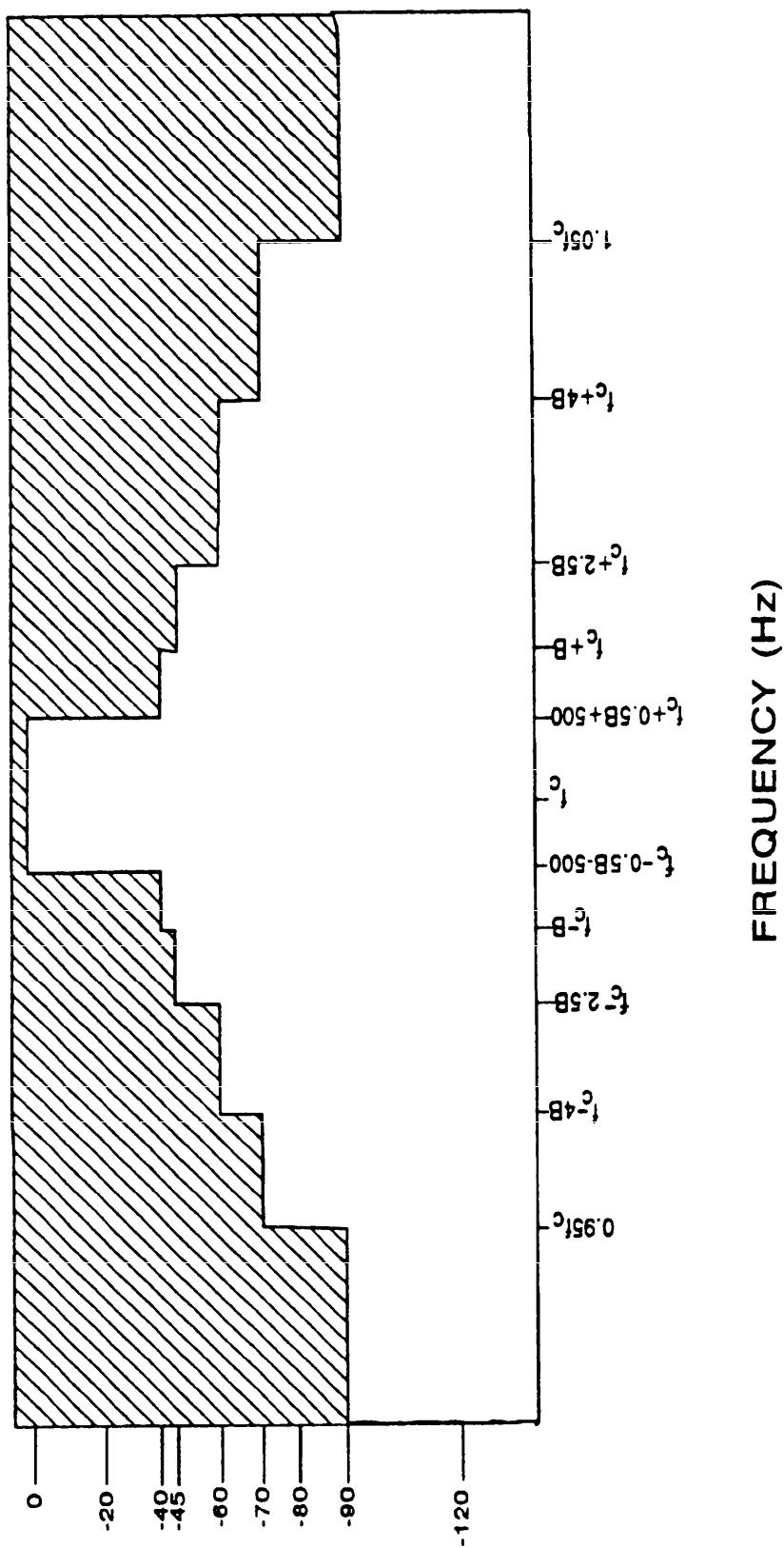
NOTES:

1. B = Necessary bandwidth (Hz).

2. f_c = Center frequency of bandwidth (Hz).

3. Emissions shall fall within the unshaded portion of the curve.

FIGURE 8. Out-of-band power spectral density for HF transmitters.

This page supersedes page 26 of 15 September 1988.

5.3.2.2 <u>Discrete frequency spurious emissions</u>. For HF transmitters, when driven with a single tone to produce an rf output of 25-percent rated PEP, all discrete frequency spurious emissions shall be suppressed as follows:

<u>For fixed application</u>

o   Between the carrier frequency f_c and $f_c \pm$ 4B (where B = bandwidth), at least 40 dBc.
o   Between $f_c \pm$ 4B and ±5 percent of f_c removed from the carrier frequency, at least 60 dBc.
o   Beyond ±5 percent removed from the carrier frequency, at least 80 dBc.
o   Harmonic performance levels shall not exceed -63 dBc.

See figure 9A.

<u>For tactical application</u>

o   Between the carrier frequency f_c and $f_c \pm$ 4B (where B = bandwidth), at least 40 dBc.
o   Beyond $f_c \pm$ 4B at least 50 dBc.
o   Harmonic performance levels shall not exceed -40 dBc.

See figure 9B.

5.3.3 <u>Carrier suppression</u>. The suppressed carrier for tactical applications shall be at least 40 dBc (DO: 60 dBc) below the output level of a single tone modulating the transmitter to rated PEP. The suppressed carrier for fixed site applications shall be at least 50 dBc (DO: 60 dBc) below the output level of a single tone modulating the transmitter to rated PEP.

5.3.4 <u>Automatic level control (ALC)</u>. Starting at ALC threshold, an increase of 20 dB in audio input shall result in less than a 1 dB increase in average rf power output.

5.3.5 <u>Attack and release time delays</u>.

5.3.5.1 <u>Attack-time delay</u>. The time interval from keying-on a transmitter until the transmitted rf signal amplitude has increased to 90 percent of its steady-state value shall not exceed 25 ms (DO: 10 ms). This delay excludes any necessary time for automatic antenna tuning.

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5.3.5.2 <u>Release-time delay</u>. The time interval from keying-off a transmitter until the transmitted rf signal amplitude has decreased to 10 percent of its key-on steady-state value shall be 10 ms or less.

5.3.6 <u>Signal input interface characteristics</u>.

5.3.6.1 <u>Input signal power</u>. Input signal power for microphone or handset input is not standardized. When a line-level input is provided (see 5.3.6.2), rated transmitter PEP shall be obtainable for single tone amplitudes from -17 dBm to +6 dBm (manual adjustment permitted).

5.3.6.2 <u>Input audio signal interface</u>.

5.3.6.2.1 <u>Unbalanced interface</u>. When an unbalanced interface is provided, it shall have an audio input impedance of a nominal 150 ohms, unbalanced with respect to ground, with a minimum return loss of 20 dB against a 150-ohm resistance over the nominal 3 kHz passband.

5.3.6.2.2 <u>Balanced interface</u>. When a balanced interface is provided, the audio input impedance shall be a nominal 600 ohms, balanced with respect to ground, with a minimum return loss of 26 dB against a 600-ohm resistance over the frequency range of 300 Hz to 3050 Hz. The electrical symmetry shall be sufficient to suppress longitudinal currents at least 40 dB below the reference signal level.

Page 27a added.

NOTES:

1. Emissions shall fall within the unshaded portion of the curve.

2. Harmonic performance levels for fixed transmitters shall not exceed -63dBc.
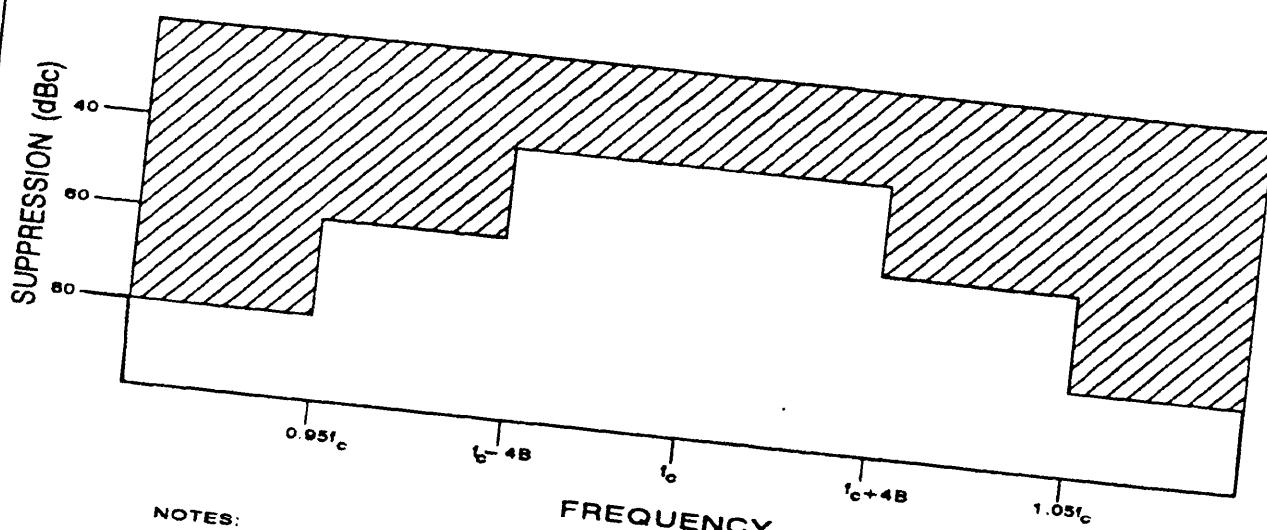
A. **Discrete spurious emissions limit for fixed HF transmitters**.

NOTES:

1. Emissions shall fall within the unshaded portion of the curve.

2. Harmonic performance levels for tactical transmitters shall not exceed -40dBc.
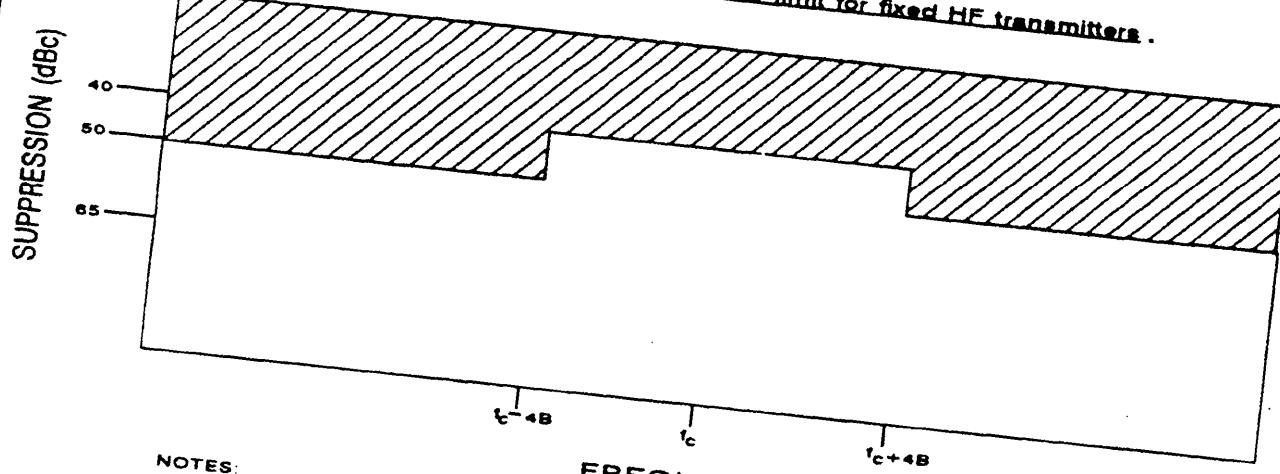
B. **Discrete spurious emissions limit for tactical HF transmitters**.

FIGURE 9. **Discrete spurious emissions limit for HF transmitters**.

This page supersedes page 28 of 15 September 1988.

5.3.7 <u>Transmitter output load impedance</u>. The nominal rf output load impedance at interface point B in figure 2 shall be 50 ohms, unbalanced with respect to ground. Transmitters shall survive any VSWR at point B, while derating the output power as a function of increasing VSWR. However, the transmitter shall deliver full rated forward power into a 1.3:1 VSWR load. Figure 10 is a design objective for the derating curve. The VSWR between an exciter and an amplifier shall be less than 1.5:1. The VSWR between an amplifier and an antenna coupler shall be less than 1.5:1 for fixed applications and less than 2.0:1 for tactical application.

NOTE: The full-rated output power of a transmitter, over the operating frequency range, is defined to be (a) the rated PEP when the transmitter is driven by a two-tone signal consisting of equal amplitude tones; and (b) the rated average power when driven by a single tone. The output rating shall be determined with the transmitter operating into a 50-ohm load.

5.4 <u>Receiver characteristics</u>.

5.4.1 <u>Receiver rf characteristics</u>. All receiver input amplitudes are in terms of available power in dBm from a 50-ohm source impedance signal generator.

5.4.1.1 <u>Image rejection</u>. The rejection of image signals shall be at least 70 dB for tactical HF receivers and 80 dB for all other HF receivers (DO: 100 dB).

5.4.1.2 <u>Intermediate-frequency (IF) rejection</u>. Spurious signals at the intermediate frequency (frequencies) shall be rejected by at least 70 dB for tactical HF receivers and 80 dB for all other HF receivers (DO: 100 dB).

5.4.1.3 <u>Adjacent-channel rejection</u>. The receiver shall reject any signal in the undesired sideband and adjacent channel in accordance with figure 5.

5.4.1.4 <u>Other signal-frequency external spurious responses</u>. Receiver rejection of spurious frequencies, other than IF and image, shall be at least 65 dB (55 dB for tactical application) for frequencies from +2.5 percent to +30 percent, and from -2.5 percent to -30 percent of the center frequency, and at least 80 dB (70 dB for tactical application) for frequencies beyond ±30 percent of the center frequency.

5.4.1.5 <u>Receiver protection</u>. The receiver, with primary power on or off, shall be capable of survival without damage with applied signals of up to +43 dBm (DO: +53 dBm) available power delivered from a 50-ohm source for a duration of 5 minutes for fixed site applications and 1 minute for tactical applications.

This page supersedes page 29 of 15 September 1988.
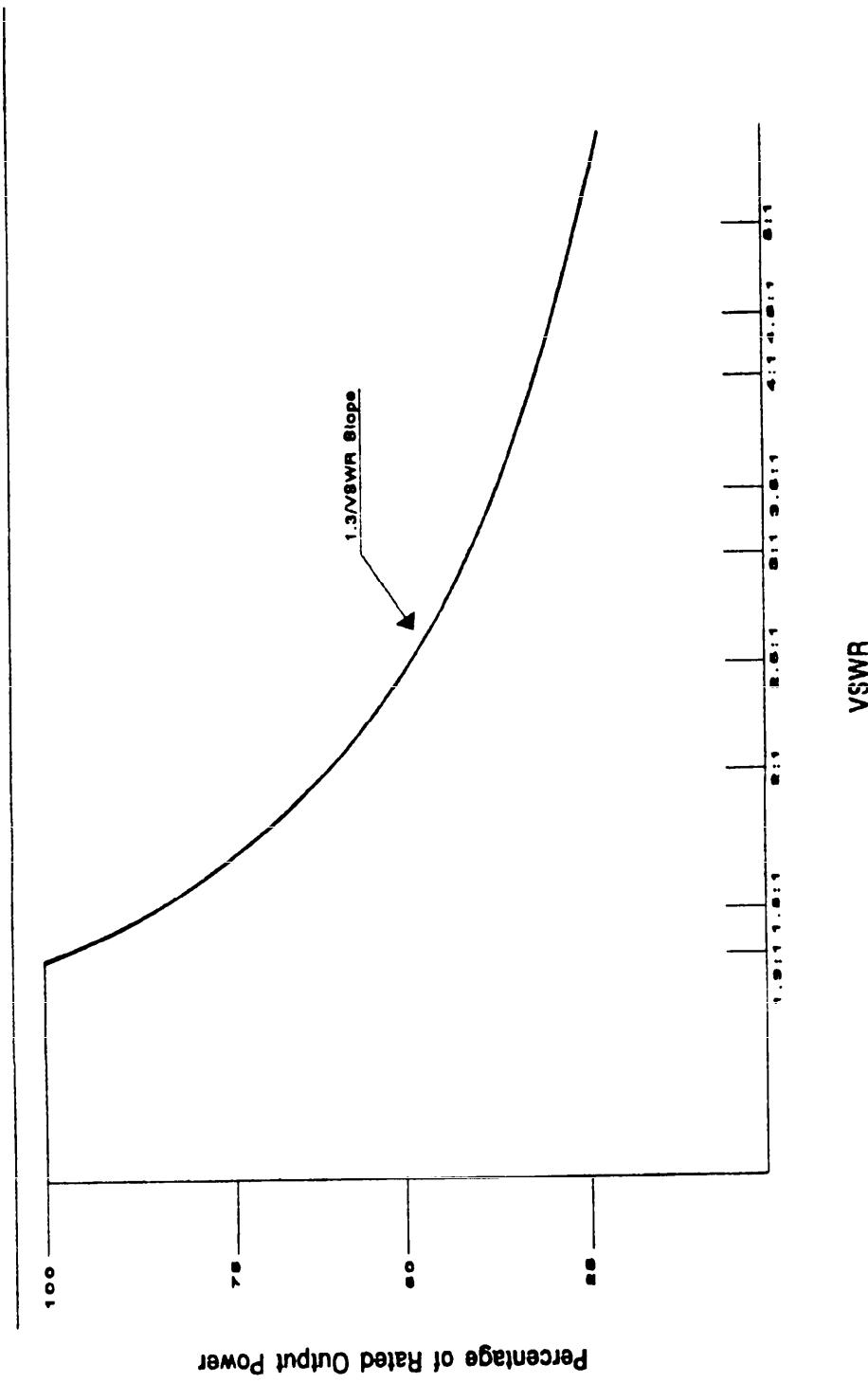
FIGURE 10. Output power vs. VSWR for transmitter with broadband output impedance networks.

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5.4.1.6 <u>Desensitization dynamic range</u>. The following requirement shall apply to the receiver in an SSB mode of operation with an IF passband setting providing at least 2750 Hz (nominal 3 kHz bandwidth) at the 2 dB points. With the receiver tuning centered on a sinusoidal input test signal and with the test signal level adjusted to produce an output SINAD of 10 dB, a single interfering sinusoidal signal, offset from the test signal by an amount equal to ±5 percent of the carrier frequency, is injected into the receiver input. The output SINAD shall not be degraded by more than 1 dB as follows:

a. For fixed site radios, the interfering signal is equal to or less than 100 dB above the test signal level.

b. For tactical radios, the interfering signal is equal to or less than 90 dB above the test signal level.

5.4.1.7 <u>Receiver sensitivity</u>. The sensitivity of the receiver over the operating frequency range, in the sideband mode of operation (3-kHz bandwidth), shall be such that a -111 dBm (DO: -121 dBm) unmodulated signal at the antenna terminal, adjusted for a 1000 Hz audio output, produces an audio output with a SINAD of at least 10 dB over the operating frequency range.

5.4.1.8 <u>Receiver out-of-band IMD</u>. Second-order and higher-order responses shall require a two-tone signal amplitude with each tone at -30 dBm or greater (-36 dBm or greater for tactical applications), to produce an output SINAD equivalent to a single -110 dBm tone. This requirement is applicable for equal-amplitude input signals with the closest signal spaced 30 kHz or more from the operating frequency.

5.4.1.9 <u>Third-order intercept point</u>. Using test signals within the first IF passband, the worst-case third-order intercept point shall not be less than +10 dBm (+1 dBm for tactical applications).

5.4.2 <u>Receiver distortion and internally generated spurious outputs</u>.

5.4.2.1 <u>Overall IMD (in-channel)</u>. The total of IMD products, with two equal-amplitude, in-channel tones spaced 110 Hz apart, present at the receiver rf input, shall meet the following requirements. However, for frequency division multiplex (FDM) service, the receiver shall meet the requirements for any tone spacing equal to or greater than the minimum between adjacent tones in any FDM library. The requirements shall be met for any rf input amplitude up to 0 dBm PEP (-6 dBm/tone) at rated audio output. All IMD products shall be at least 35 dB (DO: 45 dB) below the output level of either of the two tones.

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5.4.2.2 <u>Adjacent-channel IMD</u>. For multiple-channel equipment, the overall adjacent-channel IMD in each 3 kHz channel being measured shall not be greater than -35 dBm at the 3 kHz channel output with all other channels equally loaded with 0 dBm unweighted white noise.

5.4.2.3 <u>Audio frequency total harmonic distortion</u>. The total harmonic distortion produced by any single-frequency rf test signal, which produces a frequency within the frequency bandwidth of 300 Hz to 3050 Hz shall be at least 25 dB (DO: 35 dB) below the reference tone level with the receiver at rated output level. The rf test signal shall be at least 35 dB above the receiver noise threshold.

5.4.2.4 <u>Internally generated spurious outputs</u>. For 99 percent of the available 3 kHz channels, internally generated spurious signals shall not exceed -112 dBm. For 0.8 percent of the available 3 kHz channels, spurious signals shall not exceed -100 dBm for tactical applications and -106 dBm for fixed applications. For 0.2 percent of the available 3 kHz channels, spurious signals may exceed these levels.

5.4.3 <u>Automatic gain control (AGC) characteristic</u>. The steady-state output level of the receiver (for a single tone) shall not vary by more than 3 dB over an rf input range from -103 dBm to +13 dBm for fixed application or -103 dBm to 0 dBm for tactical application.

5.4.3.1 <u>AGC attack time (nondata modes)</u>. The receiver AGC attack time shall not exceed 30 ms.

5.4.3.2 <u>AGC release time (nondata modes)</u>. The receiver AGC release time shall be between 800 and 1200 ms for SSB voice and ICW operation. This shall be the period from rf signal downward transition until audio output is within 3 dB of the steady-state output. The final steady-state audio output is simply receiver noise being amplified in the absence of any rf input signal.

5.4.3.3 <u>AGC requirements for data service</u>. In data service, the receiver AGC attach time shall not exceed 10 ms. The AGC release time shall not exceed 25 ms.

5.4.4 <u>Receiver linearity</u>. The following shall apply with the receiver operating at maximum sensitivity, and with a reference input signal that produces a SINAD of 10 dB at the receiver output. The output SINAD shall increase monotonically and linearly within $\pm$ 1.5 dB for a linear increase in input signal level until the output SINAD is equal to at least 30 dB (DO: 40 dB). When saturation occurs, the output SINAD may vary $\pm$3 dB for additional increase in signal level. This requirement shall apply over the operating frequency range of the receiver.

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5.4.5 **Interface characteristics.**

5.4.5.1 **Input impedance.** The receiver rf input impedance shall be nominally 50 ohms, unbalanced with respect to ground. The input voltage standing wave ratio (VSWR), with respect to 50 ohms, shall not exceed 2.5:1 over the operating frequency range.

5.4.5.2 **Output impedance and power.** When a balanced output is provided the receiver output impedance shall be a nominal 600 ohms, balanced with respect to ground, capable of delivering 0 dBm to a 600-ohm load. 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 of 0 dBm to +30 dBm. As a DO, an additional interface 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 80.

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. The unclassified enhanced application level (AL-2) is the highest level of LP presently covered in appendix B. The higher levels of LP, application levels AL-3 and AL-4, will be added to appendix B as development and testing are completed as the result of the MIL-STD-187-721 Planning Standard.

This page supersedes page 33/34 of 17 June 1992.

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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 radio equipment with long-haul and tactical application 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
Leading redundant word
Lincompex
Linking protection
Link quality analysis (LQA)
LQA
Orderwire data messages
Protection interval
Radio frequency scanning
Selective calling
Slotted responses
Star net and group
Triple redundant words
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 QSTG 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.

6.5 **Changes from previous issue**. The margins of this standard are marked with vertical lines to indicate where changes from the previous issue were made. This was done as a convenience only, and the Government assumes no

This page supersedes page 35 of 17 June 1992.

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 relationship to the last previous issue.

   6.6 <u>Electromagnetic compatibility (EMC) requirements</u>. All services and agencies are responsible for their own EMC programs which are driven by their user requirements and doctrine.

   HF radio has significant inherent EMC implications that requires serious consideration by designers, users, and acquisition personnel. It is strongly recommended that all users of this standard refer to the following documents prior to design or acquisition of HF radio systems or equipment:

   a. MIL-STD-461, Requirements for the Control of Electromagnetic Interface Emissions and Susceptibility.

   b. MIL-STD-462, Measurement of Electromagnetic Interference Characteristics.

   c. MIL-HDBK-237, Electromagnetic Compatibility Management Guide for Platform, Systems and Equipment.

The applicable portions of these documents should be included in any acquisition actions for HF radio systems or equipment.

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AUTOMATIC LINK ESTABLISHMENT SYSTEM

10. GENERAL.

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

10.2 <u>Applicability</u>. 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 <u>Government documents</u>. The following document forms a part of this appendix to the extent specified:

STANDARDS

FEDERAL
    Federal Information Processing Standards

FIPS PUB 1-1
    Publication 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 <u>Non-Government publications</u>. The following documents form a part of this appendix to the extent specified:

INTERNATIONAL STANDARDIZATION DOCUMENTS

    International Telecommunications Union (ITU),
    Radio Regulations

    CCIR   Use of High Frequency Ionospheric
    Recommendation 520   Channel Simulators

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

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International Organization for Standardization (ISO)

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

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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 Introduction. The MIL-STD-188-141 data link layer contains three sublayers: a lower sublayer concerned with error correction and detection (forward error correction [FEC] sublayer), an upper sublayer containing the ALE protocol (ALE sublayer), and a linking protection sublayer (LP sublayer) in between, as shown in figure A-1. Within the FEC sublayer are redundancy and majority voting, interleaving, and Golay coding applied to the 24-bit ALE words which constitute the (FEC sublayer) service-data-unit, in terms of the International Organization for Standardization (ISO) Reference Model. The ALE sublayer specifies protocols for link establishment, data communication, and rudimentary link quality analysis (LQA) based on the capability of exchanging ALE words. The shaded area of figure A-1 indicates the contents of this appendix.

40.2 System 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 in figure A-2, using the specified ALE signal created in accordance with this appendix, shall produce a probability of linking as shown on table A-I.

TABLE A-I. Probability of linking.

Probability of Linking (Pl)	Signal-to-noise ratio (dB)		
	Gaussian Noise Channel	CCIR Good Channel	CCIR Poor Channel
$\geq$ 25%	-2.5	+0.5	+1.0
$\geq$ 50%	-1.5	+2.5	+3.0
$\geq$ 85%	-0.5	+5.5	+6.0
$\geq$ 95%	0.0	+8.5	+11.0

This page supersedes page 38 of 17 June 1992.

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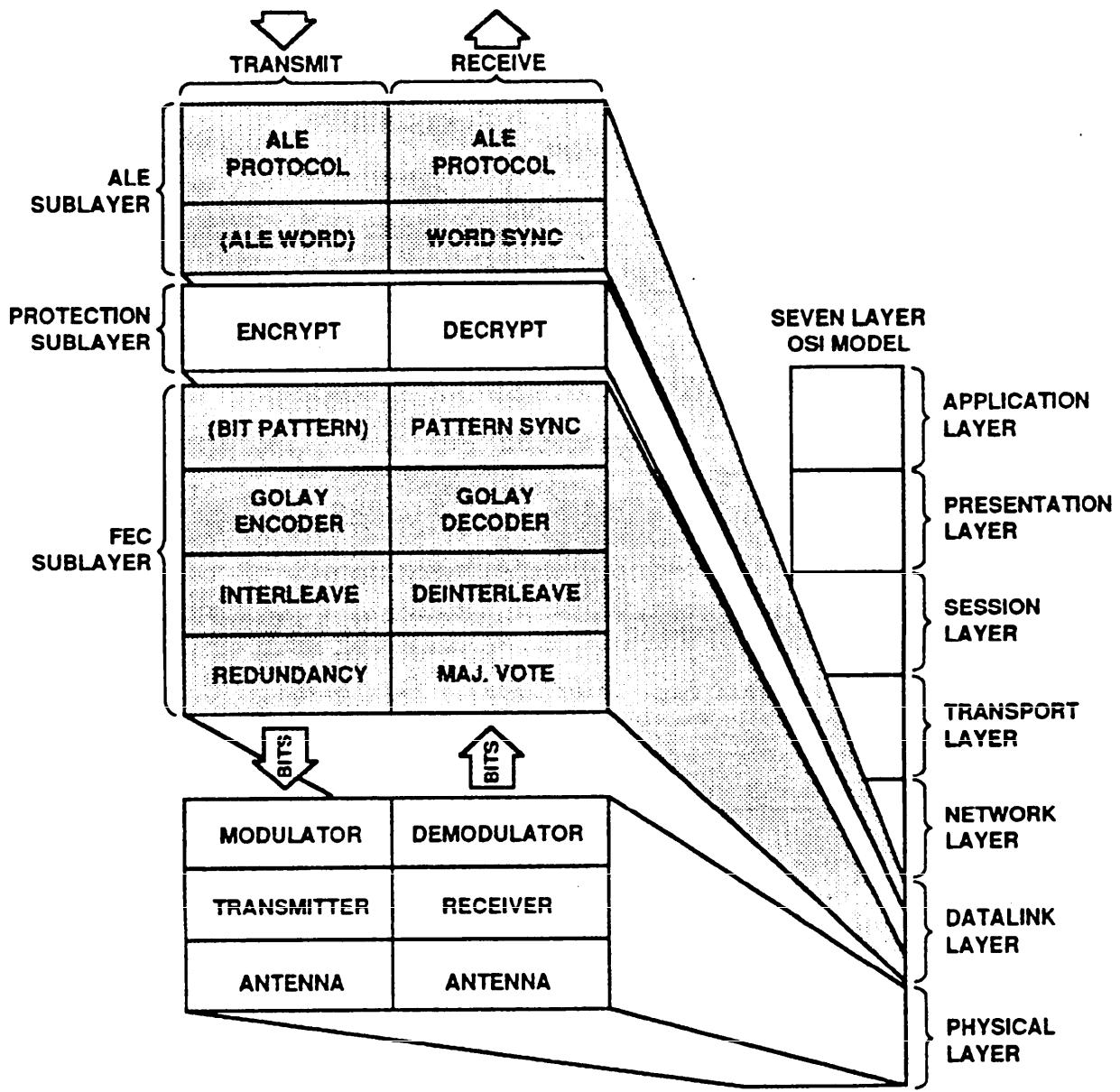
FIGURE A-1. *Data link layer with ALE and FEC sublayers.*

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FIGURE A-2. System performance measurements test setup.
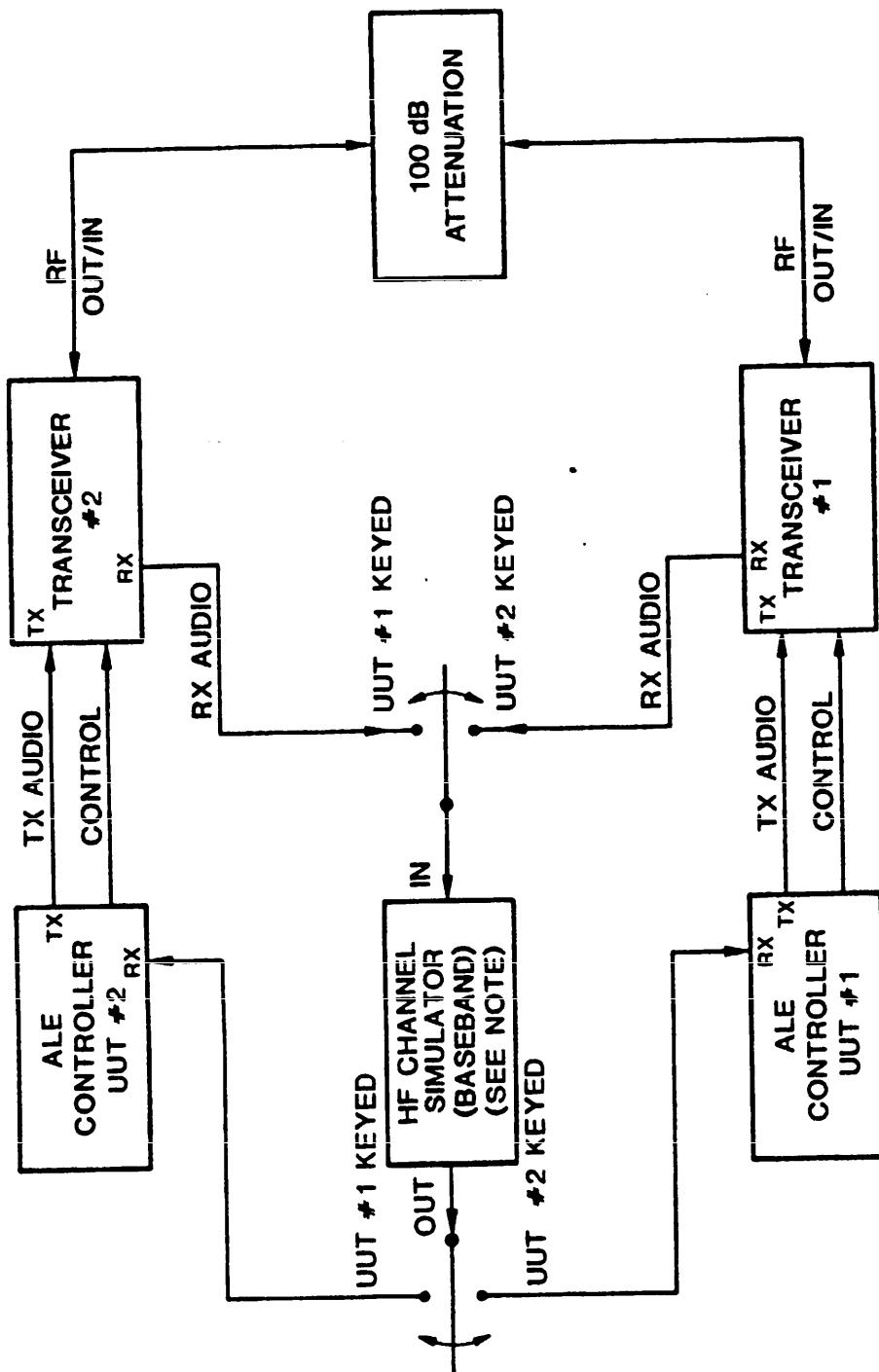
NOTE:

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.

This page supersedes page 39 of 15 September 1988.

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 0.52 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 meet or exceed the probability of linking as shown on table A-I.

40.3 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	RX	Mode TX	RX	T/R	SCAN	SCTY	(3) Next Sound	Sound Interval	* S A	* A N T	* P W R	* U S E	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 an identifiable transmission (sound or call).
4. Values shown for example only.

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The mode information normally includes:

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

40.4 <u>Scanning</u>. 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 no less than 2 per second and any higher rates that will not degrade linking performance below that shown in table A-I. The radio will stop scanning and wait on the most recent channel during the advent of any of the following selectable events:

- Automatic controller decision to stop scan (the normal mode of operation)
- Manual input of stop scan
- Activation of external stop-scan line

40.5 <u>Self address memory</u>. 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 associated 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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TABLE A-III. **Self address memory example.**

Index	Self (or Net Member) Address	Net Address	Tswt(SN)= Slot Wait Time (Tw)	(4) Valid Channels	Example Comments
SA1	SAM	--	--	All	simple individual address, 1-word, all channels
SA2	BOBBIE	--	--	C1,2,3	simple individual address, 2-word, limited channels
SA3	JIM	--	--	C7	simple individual address, 1-word, single channel
SA4	BEN	GUY	14	All	net and individual addresses, 1-word, all channels, preset slot unit time (slot 1)
SA5	CLAUDETTE	GAL	80	C3-C7	net and 3-word individual addresses, limited channels, preset slot wait-time (slot 4)
SA6	JOE	PEOPLE	17	C1-C9	2-word net and 1-word individual addresses, limited channels preset slot wait-time
.	.	.	.	.	
.	.	.	.	.	
.	.	.	.	.	
SA20	--	PARTY	--	C5-C12	2-word net only address, therefore receive only if called

NOTES:

1. The self address number "SA#" index is included for clarity. Indexes may be useful for efficient memory management.
2. If a net address is associated with a self address, the self address should be referred to as a "net member" address.
3. Addresses and values shown for example only.
4. Valid channels are the channels on which this address is planned, or permitted, to be used.

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address) within a group call shall respond in the derived slot, and with that
address, as specified in the star group scanning protocol. If a station is
called by one of its net addresses and has no associated net member address,
it shall pause and listen but shall not respond (unless subsequently called
separately with an available self or net member address), but shall enter the
linked state.

40.6 <u>Other address memory</u>. The radio shall be capable of storing,
retrieving, and employing at least 100 different sets of information
concerning the addresses of other stations and nets. The other address
information storage shall be nonvolatile. Individual addresses shall be
stored individually, and shall be associated with a specific wait for reply
time (Twr) if not the default value. Net information shall include own net
and net member associations, relative slot sequences, and own net wait for
reply times (Twrn) for use when calling. See table A-IV.

As a DO, any excess capacity which is not programmed with preplanned other
address information should be automatically filled with any addresses heard on
any of the scanned or monitored channels. When the excess capacity is filled,
it should be kept current by replacing the oldest heard addresses with the
latest ones heard. This fortuitous information should be used for calling
initiation to the those stations (if needed), and for activity evaluation.

40.7 <u>Connectivity and LQA memory</u>. The radio shall be capable of
storing, retrieving, and employing at least 4000 (DO: 10,000) sets of
connectivity and LQA information associated with the channels and the other
addresses in an LQA memory. The connectivity and LQA information storage
shall be retained in memory for not less than one hour during power down or
loss of primary power. The information in each address/channel "cell" shall
include as a minimum, the bilateral (two-way) BER values of (a) the signals
received at the station, and (b) the stations's signals received at, and
reported by, the other station. It shall also include either an indicator of
the age of the information (for discounting old data), or an algorithm for
automatically reducing the weight of data with time, to compensate for
changing propagation conditions. As a DO, the cells of the LQA memory should
also include bilateral SINAD values and MP information derived by suitably
equipped units. The information within the LQA memory shall be used to select
channels and manage networks as stated in this document. See figure A-3.

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TABLE A-IV. Other address memory example.

Other or Net Address	Individual (Net Member) Address and Slots				Valid Channels	(Net) Wait for reply time (Tw)	Example Comments
	Slot 1	Slot 2	Slot 3	Slot 4			
IRA	NA	NA	NA	NA	All	Twr	Individual Address
BAB	NA	NA	NA	NA	C1-C12	Twr	Same
GUY	BEN*	DOC	DAD	ABE	All	Twrn(5)	own net 4 members
GAL	AMY	LIZ	JANE	CLAUDETTE*	C3-C7	Twrn(5)	own net 4 members
People	JOE*	BILL	SUE	NA	C1-C9	Twrn(4)	own net 3 members
PARTY	**	NA	NA	NA	C5-C12	0	one way broadcast net, no responses
CLUSTER	ALFA	BRAVO	CHARLIE	NA	C2-C10	Twrn(4)	other net 3 members

NOTES:

1. Total number of addresses shall be at least 100.
2. *Indicates a self (net member) address in this example for the assigned slot; i.e., station is a member of listed net.
3. ** Indicates that the station is a member of the listed net, but does not respond when called.
4. Excess capacity should be filled with any other addresses heard (DO).
5. Addresses for example only.

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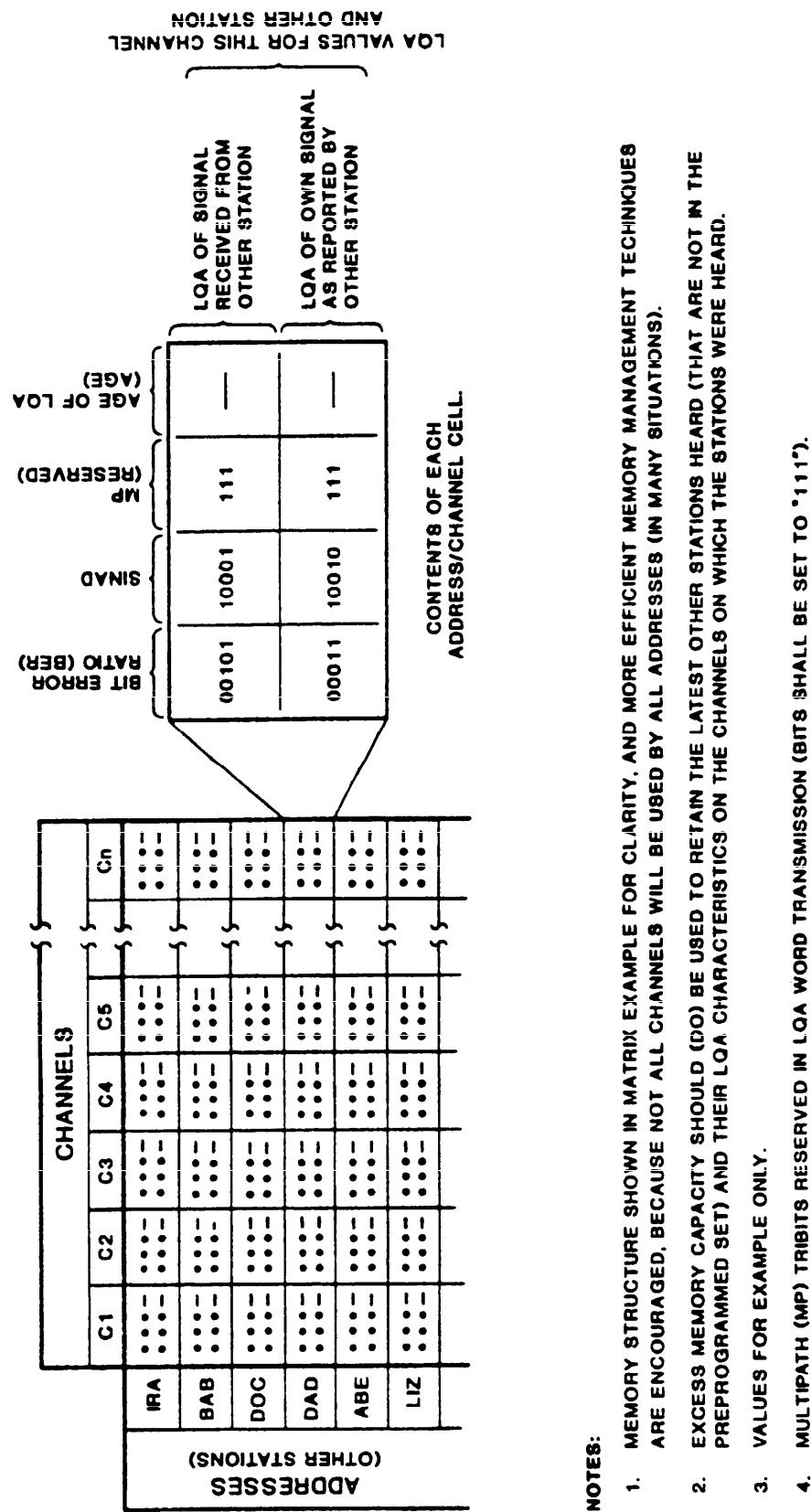
FIGURE A-3.   Connectivity and LQA memory example.

NOTES:

1.   MEMORY STRUCTURE SHOWN IN MATRIX EXAMPLE FOR CLARITY, AND MORE EFFICIENT MEMORY MANAGEMENT TECHNIQUES ARE ENCOURAGED, BECAUSE NOT ALL CHANNELS WILL BE USED BY ALL ADDRESSES (IN MANY SITUATIONS).

2.   EXCESS MEMORY CAPACITY SHOULD (DO) BE USED TO RETAIN THE LATEST OTHER STATIONS HEARD (THAT ARE NOT IN THE PREPROGRAMMED SET) AND THEIR LQA CHARACTERISTICS ON THE CHANNELS ON WHICH THE STATIONS WERE HEARD.

3.   VALUES FOR EXAMPLE ONLY.

4.   MULTIPATH (MP) TRIBITS RESERVED IN LQA WORD TRANSMISSION (BITS SHALL BE SET TO "111").

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50. WAVEFORM.

50.1 Introduction. The ALE waveform is designed to pass through the audio passband of standard SSB radio equipment. This waveform shall provide for a robust, low-speed, digital modem capability used for multiple purposes to include selective calling and data transmission. This section defines the waveform including the tones, their meanings, the timing and rates, and their accuracy.

50.2 Tones. The waveform shall be an 8-ary frequency shift-keying (FSK) modulation with eight orthogonal tones, one tone (or symbol) at a time. Each tone shall represent three bits of data as follows (least significant bit (LSB) to the right):

- 750 Hz 000
- 1000 Hz 001
- 1250 Hz 011
- 1500 Hz 010
- 1750 Hz 110
- 2000 Hz 111
- 2250 Hz 101
- 2500 Hz 100

The transmitted bits shall be encoded and interleaved data bits constituting a word, as described in 60.2 and 60.3. The transitions between tones shall be phase continuous and should be at waveform maxima or minima (slope zero).

50.3 Timing. The tones shall be transmitted at a rate of 125 tones (symbols) per second, with a resultant period of 8 ms per tone. Figure A-4 shows the frequency and time relationships. The transmitted bit rate shall be 375 bps. The transitions between adjacent redundant (tripled) transmitted words shall coincide with the transitions between tones, resulting in an integral 49 symbols (or tones) per redundant (tripled) word. The resultant single word period (Tw) shall be 130.66... ms (or 16.33... symbols), and the triple word (basic redundant format) period (3 Tw) shall be 392 ms.

50.4 Accuracy. At baseband audio, the generated tones shall be within ± 1.0 Hz. At rf, all transmitted tones shall be within the range of 2.0 dB in amplitude. Transmitted symbol timing, and therefore, the bit and word rates shall be within ten parts per million.

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FREQUENCY								
2500 Hz								
2250 Hz								
2000 Hz								
1750 Hz								
1500 Hz								
1250 Hz								
1000 Hz								
750 Hz								
DATA BITS (375 BPS)	000	001	011	010	110	111	101	100
CYCLES/SYMBOL (125 SPS)	6	8	10	12	14	16	18	20
PERIOD/SYMBOL (125 SPS)	8 ms	8 ms	8 ms	8 ms	8 ms	8 ms	8 ms	8 ms
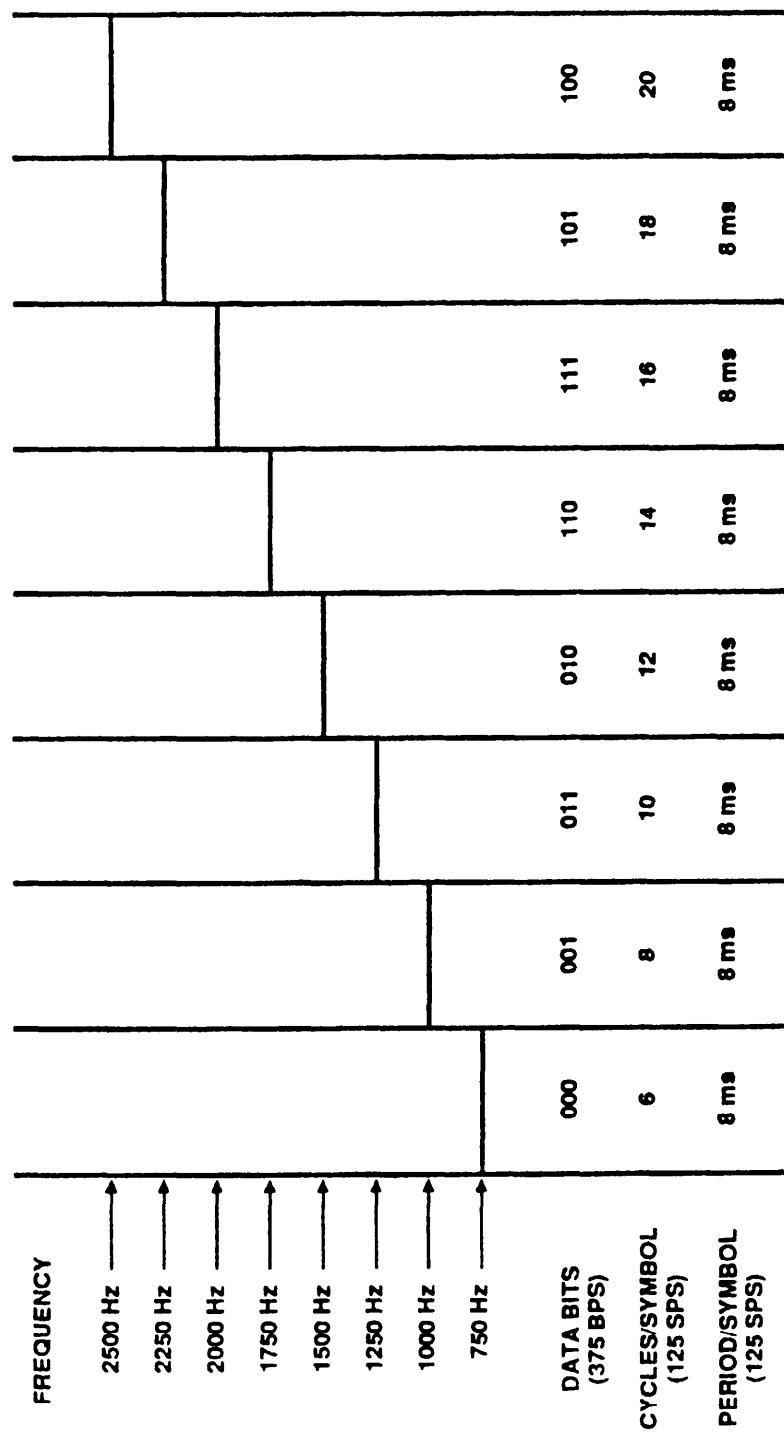
NOTE:

SYMBOL TRANSITIONS SHALL BE PHASE CONTINUOUS.

FIGURE A-4. ALE symbol library.

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60. SIGNAL STRUCTURE.

60.1 **Introduction**. This section provides definition of the ALE signal structure. Included are: bit and word format and structure; coding; forward error correction (FEC); framing; and synchronization. Also described in this section are: addressing; signal quality analysis, and the functions of the standard word preambles associated with the signal structure.

60.2 **Word format**. The basic ALE word shall consist of 24 bits of information, designated W1 (most significant bit (MSB)) through W24 (least significant bit (LSB)). The bits shall be designated as shown in figure A-5.

60.2.1 **Structure**. The word shall be divided into four parts: a 3-bit preamble and three individual 7-bit characters. The MSB for all parts, and the word, is to the left in figure A-5 and is sent earliest. Before transmission, the word shall be divided into two 12-bit halves (Golay codec A and B) for FEC encoding as described in 60.3.

60.2.2 **Word types**. The leading three bits W1 through W3 are designated preamble bits P3 through P1, respectively. These preamble bits shall be used to identify one of eight possible word types.

60.2.3 **Preambles**. The word types (and preambles) shall be as shown on table A-V and as described herein.

60.2.3.1 **THRU**. The THRU word (001) shall be used in the scanning call section of the calling cycle only with group call protocols. The THRU word shall be used alternately with REPEAT, as routing designators, to indicate the address first word of stations that are to be directly called. Each address first word shall be limited to one basic address word (3 characters) in length. A maximum of five different address first words shall be permitted in a group call. The sequence shall only be alternations of THRU, REPEAT. The THRU shall not be used for extended addresses, as it will not be used within the leading call section of the calling cycle. When the leading call starts in the group call, the entire group of called stations shall be called with their whole addresses, which shall be sent using the TO preambles and structures, as described in 60.2.3.2.

> NOTE: The THRU word is also reserved for future implementation of indirect and relay protocols, in which cases it may be used elsewhere in the ALE frame and with whole addresses and other information. Stations designed in compliance with this nonrelay standard should ignore calls to them which employ their address in a THRU word in other than the scanning call.

60.2.3.2 **TO**. The TO word (010) shall be used as a routing designator which shall indicate the address of the present destination station(s) which is (are) to directly receive the call. TO shall be used in the individual call protocols for single stations and in the net call protocols for multiple net-member stations which are called using a single net address. The TO word itself shall contain an address, one basic address word (3 characters) in length. For extended addresses, the additional address words (and characters) shall be contained in alternating DATA and REPEAT words, which

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FIGURE A-5. ALE basic word structure.
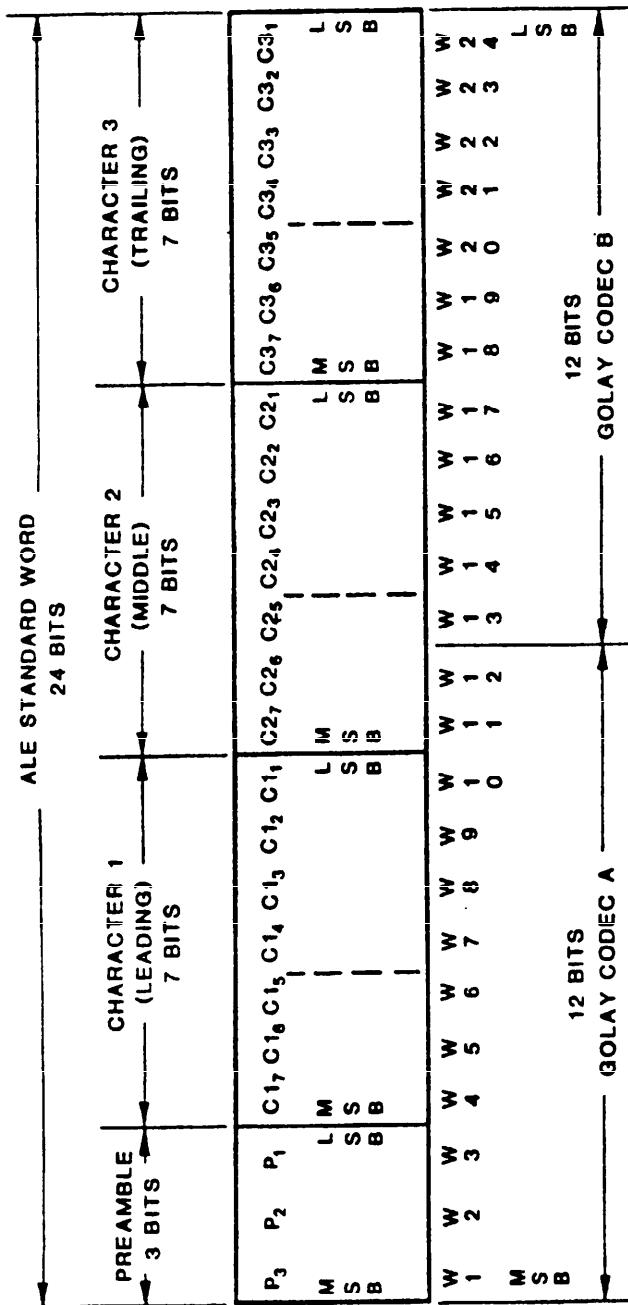
NOTE:

THREE 7-BIT ASCII CHARACTERS PER WORD IN DATA FIELD (W4-W10, W11-W17, W18-W24).
OPTIONAL 21-BIT UNFORMATTED DATA FIELD (W4-W24). MSB (W1) TRANSMITTED FIRST.

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TABLE A-V.   ALE word types (preambles).

Word type	Code bits	Functions	Significance
THRU	001	multiple (and indirect) routing	present multiple direct destinations for group calls (and future indirect relays, reserved)
TO	010	direct routing	present direct destination for individual and net calls
COMMAND	110	orderwire control and status	ALE system-wide station (and operator) orderwire for coordination, control, status, and special functions
FROM	100	identification (and indirect routing)	identification of present transmitter without termination (and past originator and relayers, reserved)
THIS IS	101	terminator and identification, continuing	identification of present transmitter, signal terminations, protocol continuation
THIS WAS	011	terminator and identification, quitting	identification of present transmitter, signal and protocol termination
DATA	000	extension and information	extension of data field of the previous ALE work, or information defined by the previous COMMAND
REPEAT	111	duplication and information	duplication of the previous preamble, or information defined by the previous COMMAND

```
         P3   P2   P1
         MSB       LSB
         W1   W2   W3
```
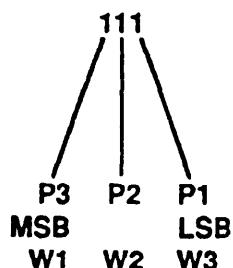
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MIL-STD-188-141A
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NOTICE 2

shall immediately follow. The sequence shall be TO, DATA, REPEAT, DATA, and
REPEAT, and shall be only long enough to contain the address, up to a maximum
capacity of five address first words (15 characters). The entire address (and
the required portion of the TO, DATA, REPEAT, DATA, REPEAT, sequence, as
necessary) shall be used in the leading call section of the ALE calling cycle.
However, in the immediately preceding scanning call section of the calling
cycle, only the first word of the destination address (and using only the TO)
shall be used, to speed scanning and linking.

60.2.3.3 COMMAND. The COMMAND word (110) is a special orderwire
designator which shall be used for system-wide coordination, command, control,
status, information, interoperation, and other special purposes. COMMAND
shall be used in any combination between ALE stations and operators, COMMAND
is an optional designator which is used only within the message section of the
ALE frame, and it shall have (at some time in the frame) a preceding call and
a following conclusion, to ensure designation of the intended receivers and
identification of the sender. The first COMMAND terminates the calling cycle
and indicates the start of the message section of the ALE frame. The
orderwire functions are directed with the COMMAND itself, or when combined
with the REPEAT and DATA words. See section 80 for orderwire messages and
functions.

60.2.3.4 FROM. The FROM word (100) is an optional designator which
shall be used to identify the transmitting station without using an ALE frame
termination, such as THIS IS or THIS WAS. It shall contain the whole address
of the transmitting station, using the FROM, and if required, the DATA and
REPEAT words, exactly as described in the TO address structure in 60.2.3.2.
It should be used only once in each ALE frame, and it shall be used only
immediately preceding a COMMAND in the message section. Under direction of
the operator or controller, it should be used to provide a "quick ID" of the
transmitting station when the normal conclusion may be delayed, such as when a
long message section is to be used in an ALE frame.

> NOTE: The FROM word is also reserved for future implementation of
> indirect and relay protocols, in which cases it may be used
> elsewhere in the ALE frame and with multiple addresses and other
> information. Stations designed in compliance with this nonrelay
> standard should ignore sections of calls to them which employ FROM
> words in any other sequence than immediately before the COMMAND
> word.

60.2.3.5 THIS IS. The THIS IS word (101) shall be used as a routing
designator which shall indicate the address of the present calling (or
sounding) station which is directly transmitting the call (or sound). Except
for the use of THIS WAS, THIS IS shall be used in all ALE protocols to
terminate the ALE frame and transmission. It shall indicate the continuation
of the protocol or handshake, and shall direct, request, or invite (depending
on the specific protocol) responses or acknowledgements from other called or
receiving stations. The THIS IS shall be used to designate the call
acceptance sound. The THIS IS word itself shall contain at least the first

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word of the calling station's address, which shall be up to one basic address word (3 characters) in length. For extended addresses, the additional address words (and characters) shall be contained in alternating DATA and REPEAT words which shall immediately follow, exactly as described for whole addresses using the TO word and sequence. The entire address (and the required portion of the THIS IS, DATA, REPEAT, DATA, REPEAT sequence, as necessary) shall be used only in the conclusion section of the ALE frame (or shall constitute an entire sound). THIS WAS shall not be used in the same frame as THIS IS, as they are mutually exclusive.

60.2.3.6 THIS WAS. The THIS WAS word (011) shall be used as a routing designator exactly as the THIS IS, with the following variations. It shall indicate the termination of the ALE protocol or handshake, and shall reject, discourage, or not invite (depending on the specific protocol) responses or acknowledgements from other called or receiving stations. The THIS WAS shall be used to designate the call rejection sound. THIS IS shall not be used in the same frame as THIS WAS, as they are mutually exclusive.

60.2.3.7 DATA. The DATA word (000) is a special designator which shall be used to extend the data field of any previous word type (except DATA itself) or to convey information in a message. When used with the routing designators TO, FROM, THIS IS, or THIS WAS, DATA shall perform address extension from the basic three characters to six, nine, or more (in multiples of three) when alternated with REPEAT words. The selected limit for address extension is a total of fifteen characters. When used with COMMAND, its function is predefined as specified in section 80.

60.2.3.8 REPEAT. The REPEAT word (111) is a special designator which shall be used to duplicate any previous preamble function or word meaning while changing the data field contents (bits W4 through W24). See table A-V. Any change of words or data field bits requires a change of preamble bits (P_3 through P_1) to preclude uncertainty and errors. If a word is to change, even if the data field is identical to that in the previous word, the preamble shall be changed, thereby clearly designating a word change. When used with the routing designator TO, REPEAT performs address expansion, which enables more than one address to be specified. See 70.6. See 60.2.3.1 for use with THRU. With DATA, REPEAT may be used to extend and expand address, message, command, and status fields. REPEAT shall be used to perform these functions, and it may directly follow any other word type except for itself, and except for THIS IS or THIS WAS, as there cannot be more than one transmitter for a specific, call at a given time.

NOTE 1. REPEAT is used in T_{BC} of group calls directed to units with different first word addresses.
NOTE 2. REPEAT is not used in T_{BC} of calls directed to groups with same first word addresses. Also REPEAT is not used in T_{BC} of calls directed to individuals and nets.

60.2.3.9 Valid sequences. The eight ALE words types which have been described shall be used to construct calls and messages only as permitted in figures A-6a, A-6b, and A-6c. The size and duration of ALE calls, and their parts, shall be limited as described on table A-VI.

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60.2.4 <u>Characters</u>.

60.2.4.1 <u>General</u>. The ALE system provides and supports three compatible
sets of characters, all of which are based on Federal Information Processing
Standard (FIPS) Pub 1-1.

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FIGURE A-6. Valid word sequences.

This page supersedes page 54 of 15 September 1988.
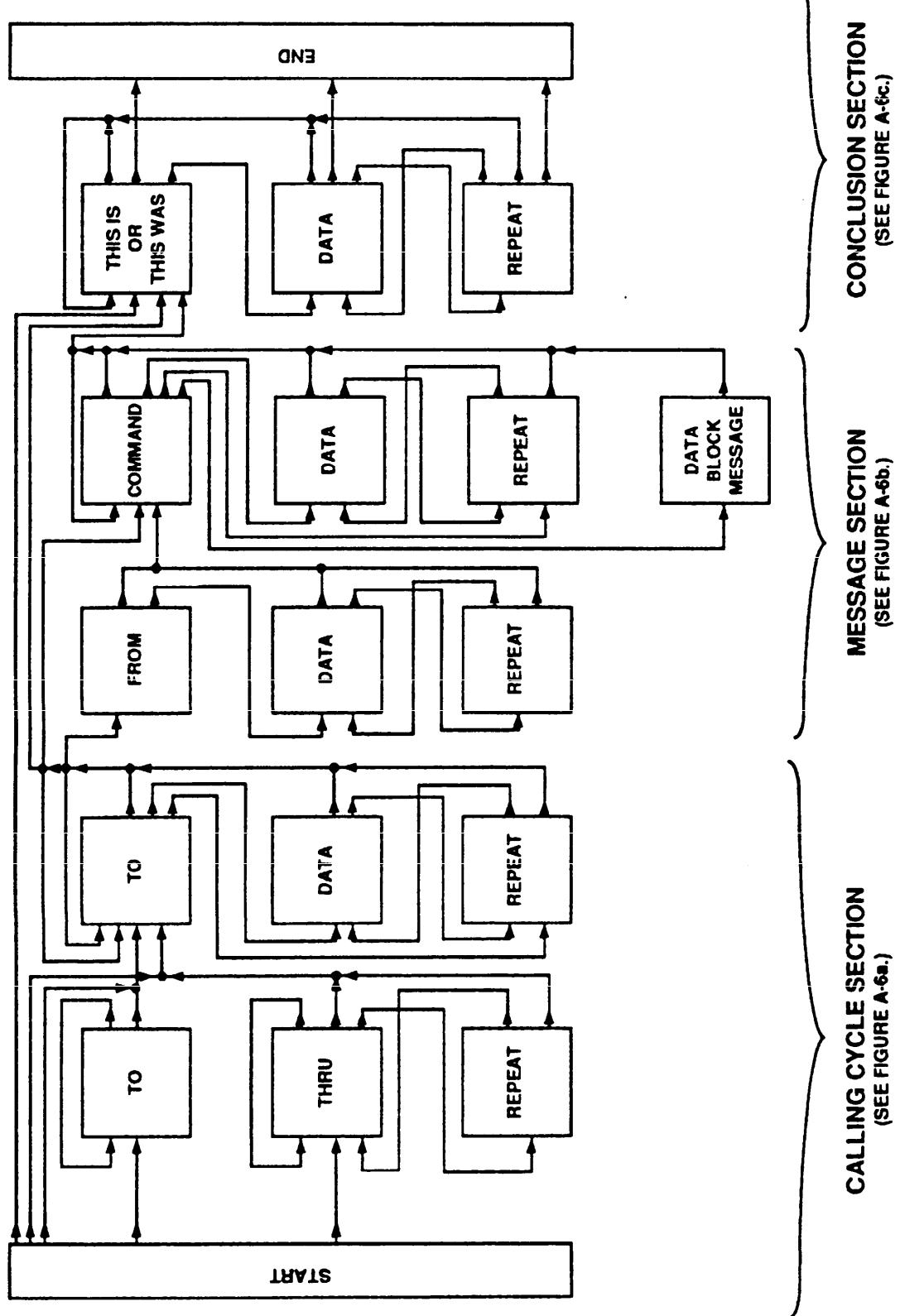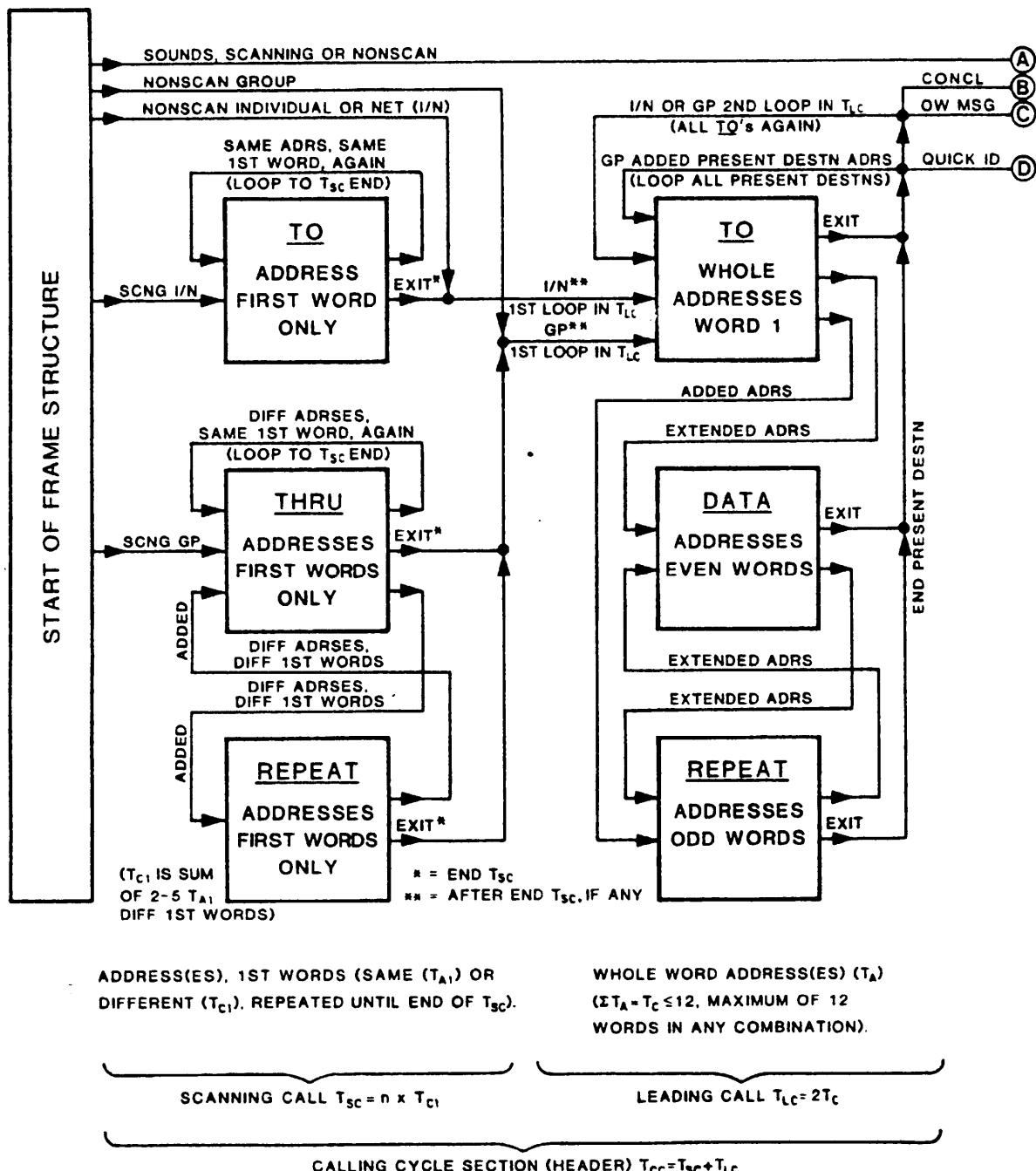
FIGURE A-6a. Valid word sequences (calling cycle section) - Continued.
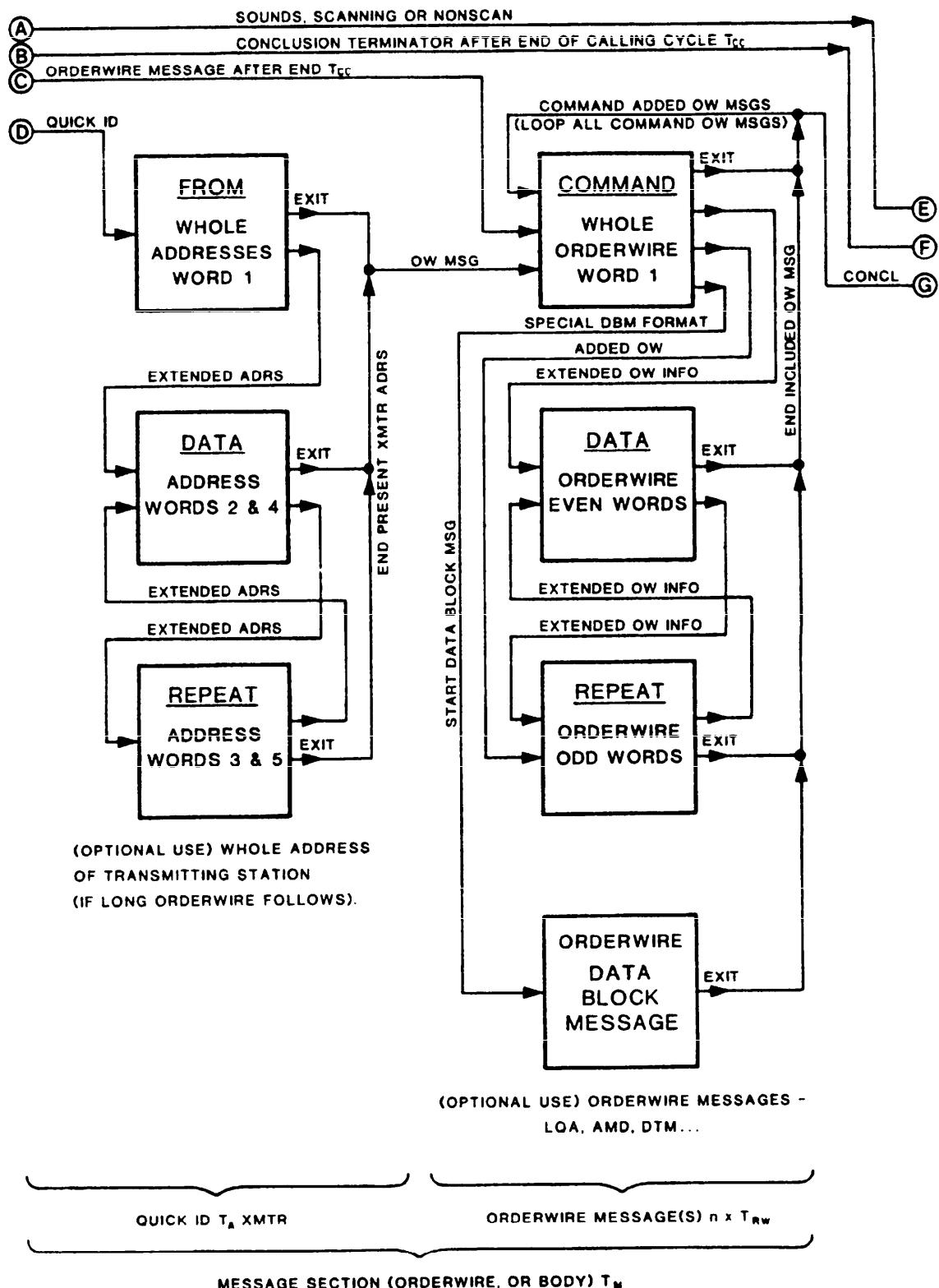
FIGURE A-6b. Valid word sequences (message section) - Continued.

This page supersedes page 56 of 15 September 1988.
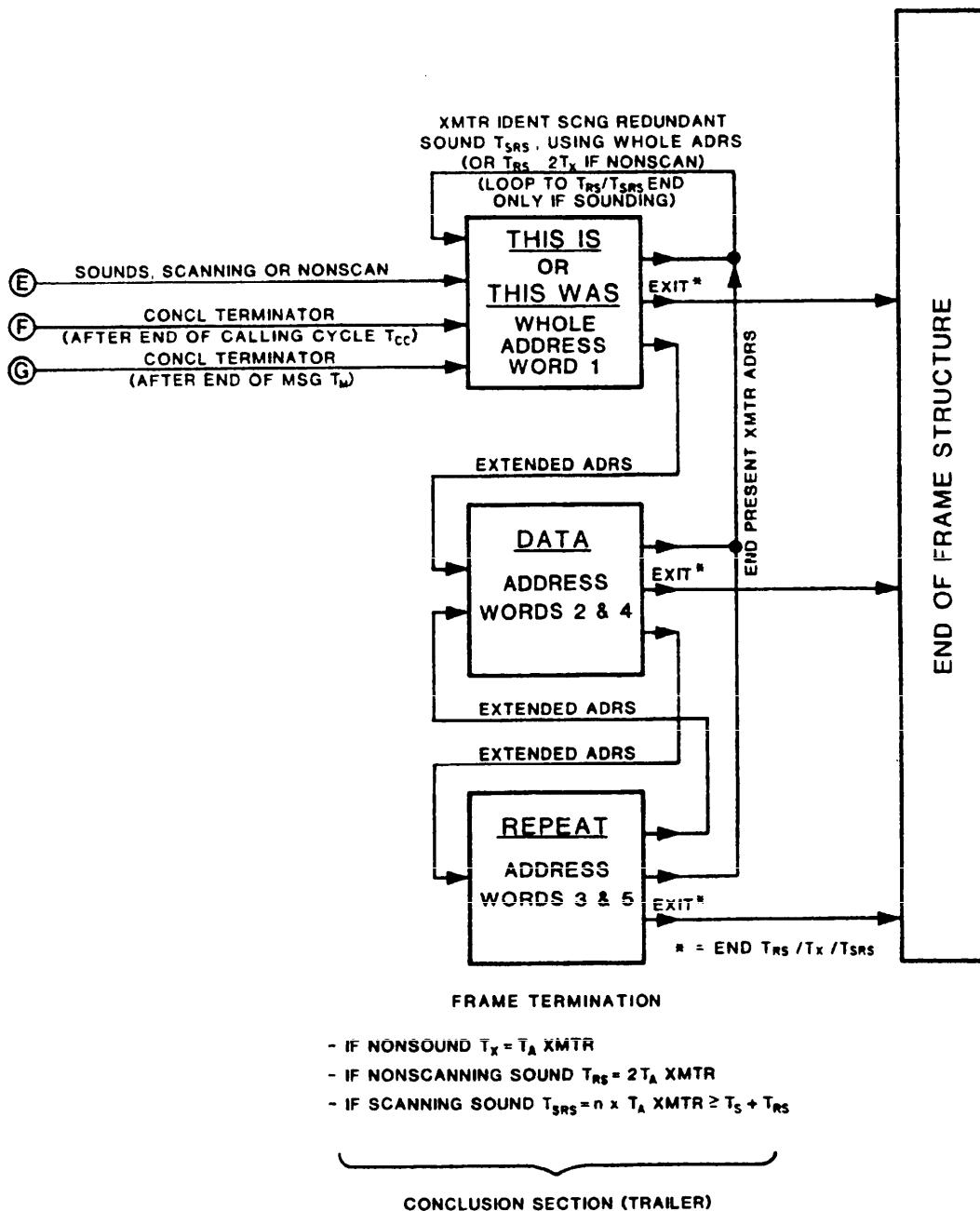
FIGURE A-6c. Valid word sequences (conclusion section) - Continued.

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TABLE A-VI. Limits to calls.

Calls	Limit
Address size (5 words) (T_a max)	1960 ms
Call time maximum T_c (one-half of T_k = 12 words max)	4704 ms
Scan period (T_s max)	50 s
Message section basic time (T_m 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) (T_m max AMD)	11.76 s
Message section time, DTM (1053 characters) (T_m max DTM)	2.29 min (entire data block)
Message section time, DBM (37377 characters) (T_m 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 in figure A-7. 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-8. 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 <u>DATA</u> (and <u>REPEAT</u>) words and shall be preceded by an associated
<u>COMMAND</u> (such as data text message). The <u>COMMAND</u> 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 <u>COMMAND</u> CRC (cyclic redundancy check), as
described in section 80.

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MIL-STD-188-141A
APPENDIX A
NOTICE 2

FIGURE A-7. Basic 38 ASCII subset.

$b_7\,b_6\,b_5$ →	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
COLUMN → / ROW ↓ $b_4\,b_3\,b_2\,b_1$	0	1	2	3	4	5	6	7
0 — 0 0 0 0	NUL	DLE	SP	0	@	P	`	p
1 — 0 0 0 1	SOH	DC1	!	1	A	Q	a	q
2 — 0 0 1 0	STX	DC2	"	2	B	R	b	r
3 — 0 0 1 1	ETX	DC3	#	3	C	S	c	s
4 — 0 1 0 0	EOT	DC4	$	4	D	T	d	t
5 — 0 1 0 1	ENQ	NAK	%	5	E	U	e	u
6 — 0 1 1 0	ACK	SYN	&	6	F	V	f	v
7 — 0 1 1 1	BEL	ETB	'	7	G	W	g	w
8 — 1 0 0 0	BS	CAN	(	8	H	X	h	x
9 — 1 0 0 1	HT	EM	)	9	I	Y	i	y
10 — 1 0 1 0	LF	SUB	*	:	J	Z	j	z
11 — 1 0 1 1	VT	ESC	+	;	K	[	k	{
12 — 1 1 0 0	FF	FS	,	<	L	\	l	|
13 — 1 1 0 1	CR	GS	-	=	M	]	m	}
14 — 1 1 1 0	SO	RS	.	>	N	^	n	~
15 — 1 1 1 1	SI	US	/	?	O	_	o	DEL

BITS

FIGURE A-8.   Expanded 64 ASCII subset.

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60.2.4.4 <u>Full 128 ASCII set and binary data</u>. The full 128 ASCII set shall include all characters, symbols, and functions available within the ASCII code. In addition, all 7-bit combinations are acceptable. See figure A-9. For digital data communications, even that using ASCII characters and binary bits, the information: (a) shall be enclosed within a sequence of <u>DATA</u> (and <u>REPEAT</u>) words; (b) shall be preceded with an associated <u>COMMAND</u> (such as data text message) which designates the usage of information which follows; and (c) shall be preceded by a valid and appropriate calling cycle using the basic 38 subset addressing. 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 <u>COMMAND</u> CRC as described in section 80.

60.3 <u>Coding</u>.

60.3.1 <u>Introduction</u>. The effective performance of stations, while communicating over adverse rf channels, relies on the combined use of forward error correction, interleaving, and redundancy. These functions shall be performed within the transmit encoder and receive decoder.

60.3.2 <u>Forward error correction (FEC)</u>. The Golay (24, 12, 3) FEC code is prescribed for this standard. The FEC code generator polynomial shall be:

$$g(x) = x^{11} + x^9 + x^7 + x^6 + x^5 + x + 1$$

The generator matrix G, derived from g(x), shall contain an identity matrix I_{12} and a parity matrix P as shown in figure A-10. The corresponding parity check matrix H shall contain a transposed matrix pT and an identity matrix I_{12} as shown in figure A-13.

60.3.2.1 <u>Encoding</u>. Encoding shall use the fundamental formula $\underline{x} = \underline{u}G$, where the code word $\underline{x}$ shall be derived from the data word $\underline{u}$ and the generator matrix G. Encoding is performed using the G matrix by summing (modulo-2) the rows of G for which the corresponding information bit is a "1". See figures A-10, A-11, and A-12A.

60.3.2.2 <u>Decoding</u>. Decoding will implement the equation

$$\underline{s} = \underline{y} H^T$$

where $\underline{y} = \underline{x} + \underline{e}$ is a received vector which is the modulo-2 sum of a code word $\underline{x}$ and an error vector $\underline{e}$, $\underline{s}$ is a vector of "n - k" bits called the syndrome. See figure A-12B. See figure A-13 for the value of H. Each correctable/detectable error vector $\underline{e}$ results in a unique vector $\underline{s}$. Because of this, $\underline{s}$ is computed according to the equation above and is used to index a look-up of the corresponding $\underline{e}$, which is then added modulo-2 to $\underline{y}$ to give the original code word $\underline{x}$. Flags are set according to the number of errors being corrected. The uses of the flags are described in 60.4. If $\underline{s}$ is not equal to 0 and $\underline{e}$ contains more ones than the number of errors being corrected by decoding mode, a detected error is indicated and the appropriate flag is set.

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ROW / COLUMN	0 (000)	1 (001)	2 (010)	3 (011)	4 (100)	5 (101)	6 (110)	7 (111)
0	NUL	DLE	SP	0	@	P	`	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
10	LF	SUB	*	:	J	Z	j	z
11	VT	ESC	+	;	K	[	k	{
12	FF	FS	,	<	L	\	l		
13	CR	GS	-	=	M	]	m	}
14	SO	RS	.	>	N	^	n	~
15	SI	US	/	?	O	_	o	DEL

FIGURE A-9. Full 128 ASCII set.

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$$
G = \begin{array}{c} \overset{\displaystyle I_{12}}{} \qquad\qquad\qquad \overset{\displaystyle P}{} \\ \left[\begin{array}{cccccccc}
100 & 000 & 000 & 000 & : & 101 & 011 & 100 & 011 \\
010 & 000 & 000 & 000 & : & 111 & 110 & 010 & 010 \\
001 & 000 & 000 & 000 & : & 110 & 100 & 101 & 011 \\
000 & 100 & 000 & 000 & : & 110 & 001 & 110 & 110 \\
000 & 010 & 000 & 000 & : & 110 & 011 & 011 & 001 \\
000 & 001 & 000 & 000 & : & 011 & 001 & 101 & 101 \\
000 & 000 & 100 & 000 & : & 001 & 100 & 110 & 111 \\
000 & 000 & 010 & 000 & : & 101 & 101 & 111 & 000 \\
000 & 000 & 001 & 000 & : & 010 & 110 & 111 & 100 \\
000 & 000 & 000 & 100 & : & 001 & 011 & 011 & 110 \\
000 & 000 & 000 & 010 & : & 101 & 110 & 001 & 101 \\
000 & 000 & 000 & 001 & : & 010 & 111 & 000 & 111
\end{array} \right]
\end{array}
$$

FIGURE A-10. Generator matrix for (24, 12) extended Golay code.

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12 BITS TO ENCODE	1	1	0	1	0	0	0	1	0	1	0	1
BIT NUMBERS	1	2	3	4	5	6	7	8	9	10	11	12

"G" MATRIX ROW NUMBERS									
1	100	000	000	000	101	011	100	011
2	010	000	000	000	111	110	010	010
4	000	100	000	000	110	001	110	110
8	000	000	010	000	101	101	111	000
10	000	000	000	100	001	011	011	110
12	000	000	000	001	010	111	000	011

110	100	010	101	010	101	100	110
ENCODED DATA BITS* $W_1 \ldots W_{12}$ (OR $W_{13} \ldots W_{24}$)				GOLAY CHECK BITS $G_1 \ldots G_{12}$ (OR $G_{13} \ldots G_{24}$)			
24 BITS CODE WORD TO SEND							

* SEE NOTE 2

NOTES:

1. THE "1" BITS TO BE ENCODED DETERMINE WHICH ROWS OF THE "G" GENERATOR MATRIX ARE TO BE "MODULO-2" SUMMED. IN THIS EXAMPLE, BITS 1, 2, 4, 8, 10, AND 12 ARE "1", SO ROWS 1, 2, 4, 8, 10, AND 12 ARE SUMMED.

2. SINCE THIS IS A "SYSTEMATIC" CODE, THE ORIGINAL 12 DATA BITS ALSO APPEAR IN THE OUTPUT ENCODED 24 BITS.

FIGURE A-11. Golay word encoding example.

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12 INPUT DATA BITS "W"

$W_1 \ W_2 \ W_3 \ . \ . \ . \ . \ . \ W_{11} \ W_{12}$

12 GOLAY CHECK BITS "G"

GOLAY ENCODE ROM

ENCODE ROM ADDRESS

$| \leftarrow W_1 \ . \ . \ . \ W_{12} \rightarrow |$

4K X 12 BITS
(NOTE 1)

ENCODE ROM
DATA OUT

$G_1 \ . . . G_{12}$

$W_1 \ W_2 \ W_3 \ . \ . \ . \ . \ . \ W_{11} \ W_{12}$ $G_1 \ G_2 \ G_3 \ . \ . \ . \ . \ . \ . G_{11} \ G_{12}$

24 OUTPUT FEC BITS TRANSMITTED
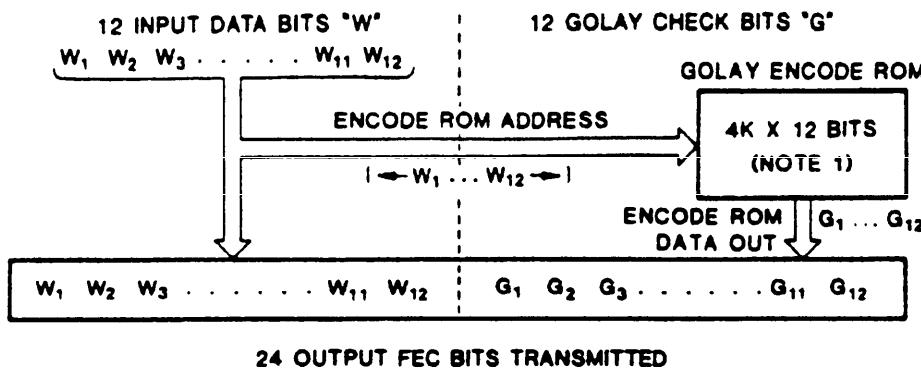
A. GOLAY FEC ENCODING EXAMPLE

24 INPUT FEC BITS RECEIVED (WITH ERRORS)

RECEIVED $W_1 \ . \ . \ W_{12}$
(PLUS ERRORS)

RECEIVED $G_1 \ . \ . G_{12}$
(PLUS ERRORS)

$W_1 \ W_2 \ W_3 \ . \ . \ . \ . \ . \ W_{11} \ W_{12}$ $G_1 \ G_2 \ G_3 \ . \ . \ . \ . \ . G_{11} \ G_{12}$

ENCODE ROM
ADDRESS
$W_1 \ . \ . \ W_{12}$
(PLUS ERRORS)

**SAME GOLAY
ENCODE ROM**

SAME
4K X 12 BITS
(NOTE 1)

$G_1 \ . \ . G_{12}$
(PLUS ERRORS)

12-BIT
"EXCLUSIVE OR"

GOLAY DECODE ROM

12-BIT
"EXCLUSIVE OR"

4K X 12 BITS
(NOTE 2)

**DATA BITS ERROR
PATTERN TO CORRECT**

"SYNDROME" USED AS
ADDRESS POINTER BASED
ON "G" ERROR PATTERN

$W_1 \ W_2 \ W_3 \ . \ . \ W_{11} \ W_{12}$
— CORRECTED DATA BITS "W"

B. GOLAY FEC DECODING EXAMPLE

NOTES:

1. ENCODE ROM CONTAINS GOLAY CHECK BITS "$G_1 \ . \ . G_{12}$" AT EACH ADDRESS, BASED ON DATA BITS "$W_1 \ . \ . W_{12}$" PREVIOUSLY COMPUTED FROM GENERATOR MATRIX "G" AND STORED.

2. DECODE ROM MAY INCLUDE ADDITIONAL BITS (OVER THE BASIC 12 TO CORRECT "W" BITS) TO INDICATE QUANTITY OF DATA ERRORS DETECTED AND CORRECTABILITY.

3. ROM "LOOK UP" HARDWARE FOR EXAMPLE ONLY. SOFTWARE IMPLEMENTATIONS MAY BE PREFERRED.

| FIGURE A-12.   Golay FEC coding examples.

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$$
H = \begin{pmatrix}
\overset{\textstyle P^T}{} & & & & & \overset{\textstyle I_{12}}{} & & & \\
111 & 110 & 010 & 010 & : & 100 & 000 & 000 & 000 \\
011 & 111 & 001 & 001 & : & 010 & 000 & 000 & 000 \\
110 & 001 & 110 & 110 & : & 001 & 000 & 000 & 000 \\
011 & 000 & 111 & 011 & : & 000 & 100 & 000 & 000 \\
110 & 010 & 001 & 111 & : & 000 & 010 & 000 & 000 \\
100 & 111 & 010 & 101 & : & 000 & 001 & 000 & 000 \\
101 & 101 & 111 & 000 & : & 000 & 000 & 100 & 000 \\
010 & 110 & 111 & 100 & : & 000 & 000 & 010 & 000 \\
001 & 011 & 011 & 110 & : & 000 & 000 & 001 & 000 \\
000 & 101 & 101 & 111 & : & 000 & 000 & 000 & 100 \\
111 & 100 & 100 & 101 & : & 000 & 000 & 000 & 010 \\
101 & 011 & 100 & 011 & : & 000 & 000 & 000 & 001
\end{pmatrix}
$$

FIGURE A-13. Parity-check matrix for (24, 12) extended Golay code.

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60.3.3 <u>Interleaving and deinterleaving</u>. 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 in figure A-14. The forty eight 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 in figure A-14 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 <u>Redundant words</u>. 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 (<u>TO</u>...), 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 <u>THRU</u> and <u>REPEAT</u> alternately), the first individual routing word (<u>THRU</u>) and all the subsequent individual routing words (<u>REPEAT</u>, <u>THRU</u>, <u>REPEAT</u>,...) 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-15. A 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 <u>Word framing and synchronization</u>.

60.4.1 <u>General</u>. 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 <u>Framing</u>. 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 in figure A-6, as limited on 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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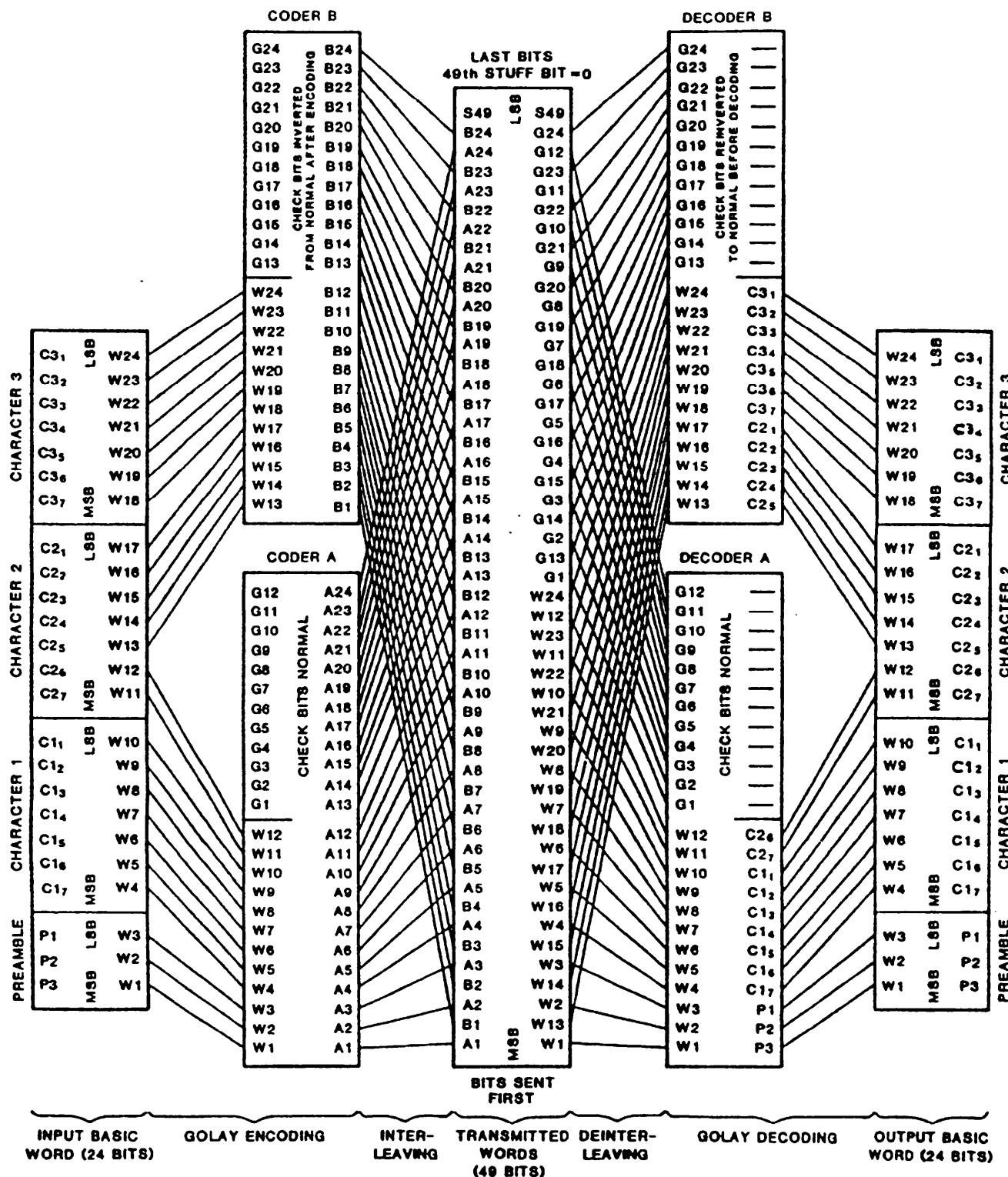
FIGURE A-14. Word bit coding and interleaving.

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FIGURE A-15. Bit and word decoding.
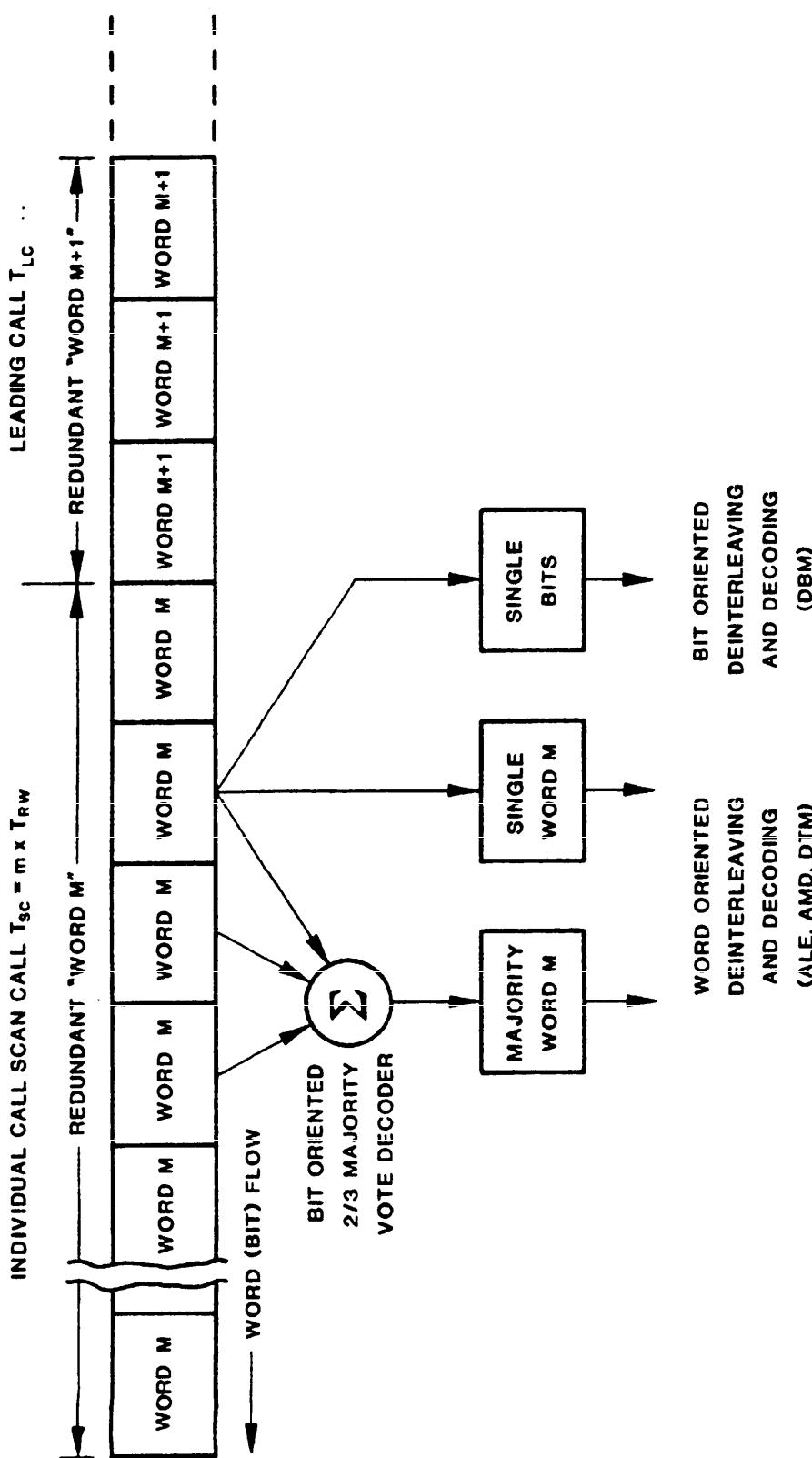
NOTES:

1. USE OF 2/3 VOTING REQUIRES EACH WORD M TO BE TRANSMITTED AT LEAST THREE ADJACENT TIMES.

2. DBM IS DATA BLOCK MESSAGE;
   AMD IS AUTOMATIC MESSAGE DISPLAY;
   DTM IS DATA TEXT MESSAGE.

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TABLE A-VII.   2/3 Majority vote decoding.

Received Bit R	Received Time	Eight Possible Bit Combinations							
R (n) (now)	T	0	0	0	0	1	1	1	1
R(n-49) (Tw old)	T-130.66... ms	0	0	1	1	0	0	1	1
R(n-98) (2 Tw old)	T-261.33... ms	0	1	0	1	0	1	0	1
Resultant majority bit M:		0	0	0	1	0	1	1	1
Possible error flag:		0	1	1	1	1	1	1	0
0 = error unlikely 1 = error likely									

TABLE A-VIII.   Majority word construction.

Relative Time	Received Bits R (Time) for 2/3 Voting			Majority Words Bit M	Used as Decoder Bits
Stuff bits Recent (LSB)	R(n)	R(n-49)	R(n-98)	M(n)	S49 ignored
	R(n-1)	R(n-50)	R(n-99)	M(n-1)	B24 (LSB)
	R(n-2)	R(n-51)	R(n-100)	M(n-2)	A24
	R(n-3)	R(n-52)	R(n-101)	M(n-3)	B23
	R(n-4)	R(n-53)	R(n-102)	M(n-4)	A23
	•	•	•	•	•
	•	•	•	•	•
	•	•	•	•	•
	R(n-46)	R(n-95)	R(n-144)	M(n-46)	A2
	R(n-47)	R(n-96)	R(n-145)	M(n-47)	B1
Older (MSB)	R(n-48)	R(n-97)	R(n-146)	M(n-48)	A1 (MSB)

NOTES:

1.   "n" indicates present bit time
2.   "n-m" indicates bit received at "m" bit times earlier

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60.4.2.1 Calling cycle. The initial section of all calls (except sounds) is termed a calling cycle (Tcc), and it is divided into two parts: a scanning call (Tsc) and a leading call (Tlc). The scanning call shall be composed of TO words if an individual or net call (or THRU and REPEAT words, alternating, if a group call), which contain only the address first word(s) of the called station(s) or net. The leading call shall be composed of TO (and possibly DATA and REPEAT) words containing the whole address(es) for the called station(s), from initiation of the leading call until the start of the message section or the conclusion (thus the end of the calling cycle). See figure A-16. The use of REPEAT and DATA is described in 60.5. The set of different address first words (Tcl) may be repeated as necessary for scanning calling (Tsc), to exceed the scan period (Ts). There is no unique "flag word" or "sync word" for frame synchronization (as discussed below). Therefore, stations may acquire and begin to read an ALE signal at any point after the start. The transmitter shall have reached at least 90 percent of the selected rf power within 2.5 ms of the first tone transmission following call initiation. The end of the calling cycle may be indicated by the start of the optional quick-ID, which occupies the first words in the message section, after the leading call and before the start of the rest of the message (or conclusion, if no message) section.

NOTE 1: The frame time may need to be delayed (equipment manufacturer dependent) to avoid loss of the leading words if the transmitter attack time is significantly long. Alternatively, the modem may transmit repeated duplicates of the scanning cycle (set of) first word(s) to be sent (not to be counted in the frame) as the transmitter rises to full power (and may even use the ALE signal momentarily instead of a tuning tone for the tuner), and then start the frame when the power is up.

NOTE 2: Non-compliance with the 90 percent of power parameter will impact the probability of linking. Compliance testing for this can be construed to be met if the probability of linking criteria is met (see table A-I).

60.4.2.2 Message. The second and optional section of all calls (except sounds) is termed a "message." Except for the quick-ID, it shall be composed of COMMAND (and possibly REPEAT and DATA) words from the end of the calling cycle until the start of the conclusion (thus the end of the message). The optional quick-ID shall be composed of FROM (and possibly REPEAT and DATA) word(s), containing the transmitter's whole address. It shall only be used once at the start of the COMMAND message section sequences. The quick-ID enables prompt transmitter identification and should be used if the message section length is a concern. It is never used without a following (COMMAND...) message(s). The message section shall always start with the first COMMAND (or FROM with later COMMAND(s)) in the call. See figure A-17. The use of REPEAT and DATA is described in section 80. The message section is not repeated within the call (although messages or information itself, within the message section, may be).

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START

IS THIS A SOUND? — YES → GO TO CONCLUSION (TERMINATOR) SEQUENCE FLOWCHART.

NO

IS THERE A SCANNING CALL? (MULTICHANNEL?) Tsc

IS THIS A GROUP CALL? (NO NET CALL?) — YES ←

CREATE GROUP SCANNING CALL (Tsc). COLLECT THE CALLED ADDRESSES FIRST WORDS ONLY. DELETE DUPLICATES. REMAINDER 5 MAXIMUM.

HAS LEADING CALL (TLc) SET OF WHOLE ADDRESS(ES) (Tc) BEEN DONE TWICE?

YES

TERMINATE CALLING CYCLE (Tcc). GO TO MESSAGE SEQUENCE FLOW CHART.

IS THERE A SINGLE WORD REMAINING?

PUT 1st WORD IN THRU NEXT IN REPEAT, NEXT IN THRU ...ALTERNATE THRU & REPEAT, & CYCLE THROUGH ADDRESS 1st WORDS, TO END OF PLANNED Tsc, TO EXCEED RECEIVERS Ts.

HAVE ALL WHOLE CALLED ADDRESS(ES) (Tc) BEEN PROCESSED? — YES

NO

USE THE TO AT XXX.

SCANNING CALL IS DONE! GO TO START LEADING CALL TLc.

PUT THE FIRST THREE CHARACTERS IN XXX. — YES — IS THIS THE FIRST FUTURE ADDRESS TO BE SENT?

NO

PUT THE ONLY FIRST WORD IN THRU, DUPLICATE TO END OF Tsc ≥ Ts.

WAS THE LAST WORD SENT AN XXX? — NO

YES

CREATE INDIVIDUAL (OR NET) SCANNING CALL (Tsc). PUT THE ADDRESS FIRST WORD IN TO, DUPLICATE TO END OF Tsc ≥ Ts.

PUT THE FIRST THREE CHARACTERS IN REPEAT.

IS THE ADDRESS GREATER THAN THREE CHARACTERS? — NO → B

YES

PUT THE SECOND THREE CHARACTERS IN DATA.

IS THE ADDRESS GREATER THAN SIX CHARACTERS? — NO → B

YES → A

(CONTINUED)

FIGURE A-16. Calling cycle sequences.

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```
                    (A)                              (B)
                     │                                ▲
                     ▼                                │
          ┌──────────────────────┐                   │
          │ PUT THE THIRD THREE   │                   │
          │ CHARACTERS IN REPEAT. │                   │
          └──────────────────────┘                   │
                     │                                │
                     ▼                                │
          ┌──────────────────────┐                   │
          │ IS THE ADDRESS GREATER│──────────────────>│
          │ THAN NINE CHARACTERS? │      NO           │
          └──────────────────────┘                    │
                     │ YES                             │
                     ▼                                 │
          ┌──────────────────────┐                    │
          │ PUT THE FOURTH THREE  │                    │
          │ CHARACTERS IN DATA.   │                    │
          └──────────────────────┘                    │
                     │                                 │
                     ▼                                 │
          ┌──────────────────────┐                    │
          │ IS THE ADDRESS GREATER│──────────────────>│
          │ THAN TWELVE CHARACTERS?│     NO            │
          └──────────────────────┘                    │
                     │ YES                             │
                     ▼                                 │
          ┌──────────────────────┐                    │
          │ PUT THE FIFTH THREE   │                    │
          │ CHARACTERS IN REPEAT. │                    │
          └──────────────────────┘                    │
                     │                                 │
                     ▼                                 │
          ┌──────────────────────┐                    │
          │ IS THE ADDRESS GREATER│──────────────────>│
          │ THAN FIFTEEN CHARACTERS?│   NO
          └──────────────────────┘
                     │ YES
                     ▼
          ┌──────────────────────┐
          │ INVALID ADDRESS SEQUENCE!│
          │ DELETE THIS ADDRESS.  │
          │ RESTART, OR ALERT OPERATOR│
          │ OR CONTROLLER.        │
          └──────────────────────┘
```

| FIGURE A-16. Calling cycle sequences - Continued.

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```
                                    ┌────────────────────────┐
                                    │   FROM CALLING CYCLE   │
                                    │ SEQUENCE FLOWCHART ONLY.│
                                    └────────────────────────┘
                                                │
┌────────────────────────┐          ┌────────────────────────┐
│  REFER TO STANDARDIZED  │   YES    │   IS THERE ANY FORM OF  │
│ MESSAGE FUNCTION FORMATS │◄────────│     MESSAGE FUNCTION    │
│  AND PROPER COMMAND     │          │   (LQA, CRC, TEXT...)?  │
│       MESSAGES.         │          └────────────────────────┘
└────────────────────────┘                      │ NO
            │                        ┌────────────────────────┐
            │                        │  GO TO THE CONCLUSION   │
            │                        │   TERMINATOR SEQUENCE   │◄──┐
            ▼                        │       FLOWCHART.        │   │
┌────────────────────────┐          └────────────────────────┘   │
│ IS THERE A QUICK-ID? (ONLY│                                     │
│  ALLOWED IF A MESSAGE    │  NO    ┌────────────────────────┐    │
│  SECTION IS TO BE SENT.) │─────►  │   HAVE ALL MESSAGE     │ YES│
└────────────────────────┘         │  FUNCTIONS (COMMANDs)  │────┘
            │ YES                   │    BEEN PROCESSED?     │
┌────────────────────────┐         └────────────────────────┘
│ PUT TRANSMITTER ADDRESS IN│                │ NO
│ FROM (& DATA & REPEAT...) │────►           ▼
└────────────────────────┘         ┌────────────────────────┐
                             YES    │  START THE NEXT MESSAGE │  NO
                          ◄─────────│ FUNCTION.IS THIS THE FIRST│────►
                                    │ MESSAGE FUNCTION TO BE SENT?│
                                    └────────────────────────┘
```

FIGURE A-17. Message sequences.

FIGURE A-17. 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-18. Sounds, and 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-19 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 the first 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,

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

where T_0 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-15. 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 should be used to discriminate and read every ALE word:

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```
┌─────────────────────────┐              ┌─────────────────────────┐
│   FROM CALLING CYCLE     │              │     FROM MESSAGE        │
│   SEQUENCE FLOWCHART.    │              │   SEQUENCE FLOWCHART.   │
└─────────────────────────┘              └─────────────────────────┘
```

FROM CALLING CYCLE SEQUENCE FLOWCHART.

FROM MESSAGE SEQUENCE FLOWCHART.

USE ONLY WHOLE TRANSMITTER ADDRESS IN SOUND. REFER TO STANDARDIZATION PROTOCOLS & PROPER TERMINATOR USAGE.

YES — ARE RESPONSES REQUESTED (OR THIS IS FORCED?) — NO

PUT FIRST THREE CHARACTERS IN THIS IS.

PUT FIRST THREE CHARACTERS IN THIS WAS.

IS THE ADDRESS GREATER THAN THREE CHARACTERS? — NO

YES

PUT THE SECOND THREE CHARACTERS IN DATA.

YES

IS THE ADDRESS GREATER THAN SIX CHARACTERS? — NO

YES

PUT THE THIRD THREE CHARACTERS IN REPEAT.

IS THE ADDRESS GREATER THAN NINE CHARACTERS? — NO

YES

(I)   (H)   (J)

FIGURE A-18. Conclusion (terminator) sequences.

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```
        ( I )                    ( H )              ( J )
          |                        |                  ^
          v                        |                  |
┌──────────────────────┐          |                  |
│ PUT THE FOURTH THREE │          |                  |
│ CHARACTERS IN DATA.  │          |                  |
└──────────────────────┘          |                  |
          |                        |                  |
          v                        |                  |
┌──────────────────────┐   NO     |                  |
│ IS THE ADDRESS GREATER├─────────>|                  |
│ THAN TWELVE CHARACTERS?│         |                  |
└──────────────────────┘          |                  |
          | YES                    |                  |
          v                        |                  |
┌──────────────────────┐          |                  |
│ PUT THE FIFTH THREE  │          |                  |
│ CHARACTERS IN REPEAT.│          |                  |
└──────────────────────┘          |                  |
          |                        |                  |
          v                        |                  |
┌──────────────────────┐   NO     |                  |
│ IS THE ADDRESS GREATER├─────────>|                  |
│ THAN FIFTEEN CHARACTERS?│        |                  |
└──────────────────────┘          |                  |
          | YES                    |                  |
          v                        |                  |
┌──────────────────────┐          |                  |
│ INVALID ADDRESS SEQUENCE!│      |                  |
│ DELETE THIS ADDRESS. │          |                  |
│ RESTART, OR ALERT OPERATOR│     |                  |
│ OR CONTROLLER.       │          |                  |
└──────────────────────┘          |                  |
```

PUT THE FOURTH THREE CHARACTERS IN DATA.

IS THE ADDRESS GREATER THAN TWELVE CHARACTERS? — NO

YES

PUT THE FIFTH THREE CHARACTERS IN REPEAT.

IS THE ADDRESS GREATER THAN FIFTEEN CHARACTERS? — NO

YES

INVALID ADDRESS SEQUENCE! DELETE THIS ADDRESS. RESTART, OR ALERT OPERATOR OR CONTROLLER.

BASIC FRAME IS CONSTRUCTED. TRIPLE EACH WORD FOR REDUNDANCY, EXCEPT THE DBM DATA BLOCK ITSELF. THE SCAN CALL HAS BEEN MULTIPLIED TO EXCEED SCAN PERIOD OF RECEIVER. LEADING CALL HAS BEEN DOUBLED. OTHER ALE WORDS JUST TRIPLED ONCE. SEND IT!

NO — WAS THIS A SOUND?

YES

BASIC FRAME IS CONSTRUCTED. TRIPLE EACH WORD FOR REDUNDANCY. THE SCANNING REDUNDANT SOUND (T_{srs}) HAS BEEN MULTIPLIED TO EXCEED SCAN PERIOD OF RECEIVER, PLUS LEADING SOUND. SEND IT!

YES — HAS THE PLANNED SCANNING REDUNDANT SOUND (T_{srs}) BEEN FILLED?

NO

REPEAT THE SOUNDED ADDRESS.

FIGURE A-18.   Conclusion (terminator) sequences - Continued.

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A. 1-CHANNEL NONSCAN, 1-WORD ADDRESSING, DIRECT, INDIVIDUAL (OR NET) CALL.
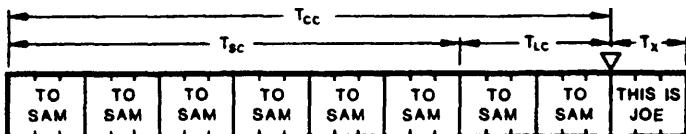
B. N-CHANNEL SCANNING, 1-WORD ADDRESSING, DIRECT, INDIVIDUAL (OR NET) CALL.
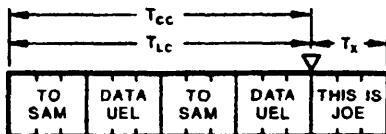
C. 1-CHANNEL NONSCAN, 2-WORD ADDRESSING, DIRECT, INDIVIDUAL (OR NET) CALL.
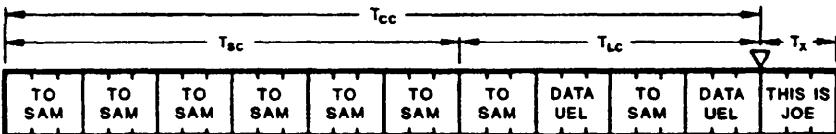
D. N-CHANNEL SCANNING, 2-WORD ADDRESSING, DIRECT, INDIVIDUAL (OR NET) CALL.
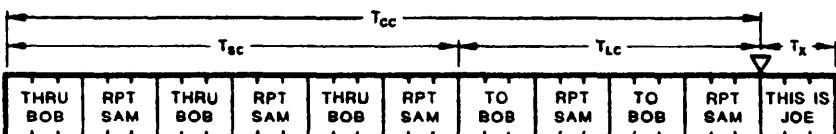
E. N-CHANNEL SCANNING, 1-WORD ADDRESSING, DIRECT, GROUP CALL.
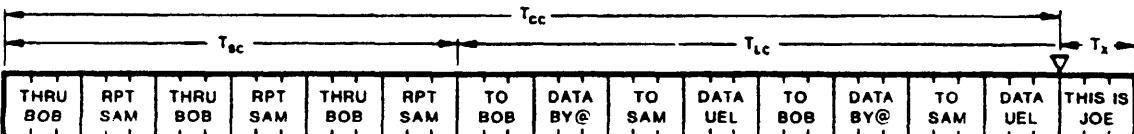
F. N-CHANNEL SCANNING, 2-WORD ADDRESSING, DIRECT, GROUP CALL.

FIGURE A-19. Basic frame structure examples.

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- Must meet or exceed a threshold of unanimous votes in the 2/3 majority voter decoder
- Successful Golay decode of "A" word bits
- Successful Golay decode of "B" word bits
- Acceptable preamble according to valid word sequences as shown in figure A-6.
- Acceptable first character bits (of basic 38 subset)
- Acceptable second character bits (of basic 38 subset)
- Acceptable third character bits (of basic 38 subset)
- History, status, expectations, and protocol
- Correct triple redundant word phase

The number of unanimous votes provides an easily adjustable BER signal quality discrimination, and the threshold should be chosen by the manufacturer to optimize performance. A successful Golay decode indicates that all detected bit errors were corrected within the power of the FEC code; that is, the errors were within correctable limits and therefore, the uncorrectable error flag(s) did not occur. The correction power (mode) of the Golay code should be chosen by the manufacturer to optimize performance using any of the four modes: (3/4, 2/5, 1/6, 0/7) where n/m indicates up to "n" errors detected and corrected, or up to "m" errors detected but not correctable. Acceptable preambles, as described here and defined in 60.2.2, refer to those preambles which are within the limits of this standard. As a DO, automatic adjustment of the unanimous vote threshold and Golay mode should be provided to optimize performance under varying conditions.

> NOTE: The application of each preamble is dependent on the recent signaling history of the stations heard, the active status of the machine, the handshake(s) expected, and the protocol being used, if any. For example, an uncommitted station, awaiting calls, would accept TO if individual or net call (and possibly THRU or REPEAT if group call) as valid preambles for calls to it. It would reject COMMAND as being irrelevant (because it missed the preceding and required calling cycle Tcc). It might also reject THIS IS or THIS WAS (unless collecting sounding information). Acceptable characters means that each character is within the appropriate ASCII subset. Note that all criteria, together, must be satisfied to accept a word. For example, all three characters would have to be within the basic 38 subset if a routing preamble, such as a TO, was decoded. Likewise, any bit combination would be conditionally acceptable if an initial REPEAT was received, but in most cases, without the necessary knowledge of the previous word, it would be considered irrelevant and should be rejected.

60.5 Addressing.

60.5.1 Introduction. The ALE system deploys a digital addressing structure based upon the standard 24-bit (three character) word and the basic 38 ASCII character subset. As described below, ALE stations have the capability and flexibility to link or network with one or many prearranged or as-needed single or multiple stations. All ALE stations shall have the

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capacity to store and use at least 20 self addresses of up to 15 characters each in any combination of individual and net calls. There are three basic addressing methods which will be presented:

- Individual station
- Multiple station
- Special modes

NOTE: Certain alphanumeric address combinations may be interpreted to have special meanings for emergency or specific functions, such as "SOS", "MAYDAY", "PANPAN", "SECURITY", "ALL", "ANY", and "NULL". These should be carefully controlled or restricted.

60.5.2 Individual station. The fundamental address element in the ALE system is the single routing word, containing three characters, which forms the basic individual station address. This basic address word, used primarily for intranet and slotted operations, may be extended to multiple words and modified to provide increased address capacity and flexibility for internet and general use. An address which is assigned to a single station (within the known or used network) shall be termed an "individual" address. If it consists of one word (that is, no longer than three characters) it shall be termed a "basic" size, and if it exceeds one word, it shall be termed an "extended" size.

60.5.2.1 Basic. The basic address word shall be composed of a routing preamble (TO, or possibly a REPEAT which follows a TO, in Tlc of group call, or a THIS IS or THIS WAS) plus three address characters, all of which shall be a alphanumeric numbers of the basic 38 ASCII subset. The use of the utility symbols "@" and "?", shall be as described in 60.5.4. The three characters in the basic individual address provide a basic 38-address capacity of 46,656, using only the 36 alphanumerics. This three-character single word is the minimum structure. Use of only one or two characters is discouraged because they provide a basic 38-address capacity of only 36 or 1296, respectively, with no significant advantages such as speed, capacity, or reliability. As examples of proper usage, a minimum three-character call directed to "JIM" would be structured "TO JIM", and a shorter (discouraged) two-character call to "ED" would be structured "TO ED@". Both would have identical size and performance characteristics. One-word addresses should be used only for abbreviated address intranet and slotted response operations, and longer two-word (or more) addresses should be used for intranet, internet, and general operations. In addition, all ALE stations shall associate specific timing and control information with all own addresses, such as prearranged delays for slotted net responses. As described in section 70, the basic individual addresses of various station(s) may be combined to implement flexible linking and networking.

NOTE: All ALE stations shall be assigned at least one (DO: several) single-word address for automatic use in one-word address protocols, such as slotted (multistation type) responses. This is a mandatory user requirement, not a design requirement. However, nothing in the design shall preclude using longer addresses.

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60.5.2.2 <u>Extended</u>. Extended addresses provide address fields which are longer than one word (three characters), up to a maximum system limit of five words (15 characters). See table A-IX. This 15-character capacity enables Integrated Services Digital Network (ISDN) address capability. Specifically, the ALE extended address word structure shall be composed of an initial basic address word, such as <u>TO</u> or <u>THIS IS</u>, as described above, plus additional words as necessary to contain the additional characters in the sequence <u>DATA</u>, <u>REPEAT</u>, <u>DATA</u>, <u>REPEAT</u>, for a maximum total of five words. All address characters shall be the alphanumeric members of the basic 38 subset. The use of the utility symbols "@" and "?" is described in 60.5.4.

> NOTE 1: All ALE stations shall be assigned at least one (DO: several) two-word address(es) for general use, plus an additional address(es) containing the station's assigned call sign(s). This is a mandatory user requirement, not a design requirement. However, nothing in the design shall preclude using longer addresses.

> NOTE 2: The recommended standard address size for intranet, internet, and general non-ISDN use is two words. Any requirement to operate with address sizes larger than six characters must be a network management decision. As examples of proper usage, a call to "EDWARD" would be "<u>TO EDW</u>", "<u>DATA ARD</u>", and a call to "MISSISSIPPI" would be "<u>TO MIS</u>", "<u>DATA SIS</u>", "<u>REPEAT SIP</u>", "<u>DATA PI@</u>".

60.5.3 <u>Multiple stations</u>. It is a critical requirement to simultaneously (or nearly simultaneously) address and interoperate with multiple stations in MF or HF networks. A prearranged collection of stations, with a commonly assigned additional address, shall be termed a "net," and the common address shall be a "net address." A nonprearranged collection of stations, without a commonly assigned additional address, shall be termed a "group."

> NOTE: Protocols for linking and networking with nets and groups are described in 70.6. It should be noted that the term "net" is also commonly used to identify any collection of stations which are, or were, interoperating, regardless of any prearrangements or the method of establishment. In this standard, the terms "net" and "group" usually specifically refer to the linking and networking methodology, not the subsequent traffic exchanges.

60.5.3.1 <u>Net</u>. As a prearranged collection of stations, a net may be organized and managed with significant prior knowledge of the member stations, including their quantities, identities, capabilities, requirements, and in most cases, their locations and necessary connectivities. Maximum advantage should be taken of this knowledge to optimize the net timing, addressing, and interchanges. The purpose of a net call is to rapidly and efficiently establish contact with multiple prearranged (net) stations (simultaneously if possible) by the use of a single net address, which is an additional address assigned to all net members in common. As described in 70.6, additional information concerning the assigned response slots (and size) must be available, and the mixing of individual, net, and group addresses and calls is restricted.

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TABLE A-IX. Basic (38) address structures.

Words		Address Characters	Types
B	1	1	Stuff-2
A			
S	1	2	Stuff-1
I			
C	1	3	Basic
	2	4	Basic + Stuff-2
	2	5	Basic + Stuff-1
	2	6	2 Basic
	3	7	2 Basic + Stuff-2
E	3	8	2 Basic + Stuff-1
X			
T	3	9	3 Basic
E			
N	4	10	3 Basic + Stuff-2
D			
E	4	11	3 Basic + Stuff-1
D			
	4	12	4 Basic
	5	13	4 Basic + Stuff-2
	5	14	4 Basic + Stuff-1
	5 (limit)	15 (limit)	5 Basic (limit)

NOTES:

1. Basic : ABC
2. Stuff-2: A@@
3. Stuff-1: AB@

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When a net address type function is required, a calling ALE station shall use an address structure identical to the individual station address, basic or extended as necessary. For each net address at a net member's station, there shall be a response slot identifier, plus a slot width modifier if directed by the specific standard protocol.

60.5.3.2 <u>Group</u>. Unlike a net, a group is nonprearranged and, 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 automated stations, essentially regardless of their individual, net, and other characteristics. The purpose of a group call is to establish contact with multiple nonprearranged (group) stations (simultaneously if possible) rapidly and efficiently by the use of a compact combination of their own addresses which are assigned individually.

When a group address type function is required, a calling ALE station shall use a sequence of the actual individual station addresses of the called stations, in the manner directed by the specific standard protocol. A stations's address shall not appear more than once in a group calling sequence, except as specifically permitted in the group calling protocols described in 70.6.

60.5.4 <u>Special modes "@" and "?"</u>.

60.5.4.1 <u>General</u>. The special modes, which use the utility symbols "@" (1000000) and "?" (0111111) include the following:

- Stuffing
- Allcalls
- Anycalls
- Wildcards
- Self address
- Null address

60.5.4.2 <u>Stuffing</u>. The ALE basic address structure is based on single words which, in themselves, provide multiples of three characters. The quantity of available addresses within the system, and the flexibility of assigning addresses, are significantly increased by the use of address character stuffing. This technique allows address lengths which are not multiples of three to be compatibly contained in the standard (multiple of three characters) address fields by "stuffing" the empty trailing positions with the utility symbol "@". See table A-X. "Stuff-1" and "stuff-2" words shall only be used in the last word of an address, and therefore should appear only in the leading call (Tlc) of the calling cycle (Tcc).

> NOTE: As an example of proper usage, a call to the address "MIAMI" would be structured "<u>TO MIA</u>". "<u>DATA MI@</u>".

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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 character "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 tracing. 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,
and 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 from 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 allcalls, 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 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 optical procedure are the same as for the sounding scanning protocol.

60.5.4.4 Anycalls. The 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, and 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
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 quite 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.

> NOTE: The caller should use a short one-word self address and shall
> not use more than two words. This is not a design criteria but a
> mandatory user requirement.

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 station (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 <u>two</u> characters that
> the desired subset of receiving stations must have to initiate a
> response. See table A-X.

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60.5.4.5 <u>Wildcards</u>. A "wildcard" is a special character which the caller uses to address multiple-station addresses with a single-call address. The receivers shall accept the wildcard character as a substitute for any alphanumeric in their self addresses in the same position or positions. Therefore, each wildcard character shall substitute for any of 36 characters (A to Z, 0 to 9) in the basic 38-character subset. The total lengths of the calling (wildcard) address, and the called addresses shall be the same. The special wildcard character shall be "?" (0111111). It shall substitute for any alphanumeric in the basic 38-character subset. It shall substitute for only a single-address character position in an address, per wildcard character. See table A-XI for examples of acceptable patterns.

Wildcard addresses shall be the exclusive members of the initial call's calling cycle, and shall not be used in any other address sequence in the ALE frame or handshake. The span (number of cases possible) of the wildcard(s) used should be minimized to only the essential needs of the user(s). The basic address wildcards, when followed with a <u>THIS WAS</u> terminator, shall cause no responses and shall be otherwise identical to the allcall protocol in 60.5.4.3. The address wildcards, when followed with a <u>THIS IS</u> terminator, shall cause responses in pseudorandomly-selected slots, and shall use the protocol otherwise identical to the anycall in 60.5.4.4. As in both the allcall and anycall, stations shall have the capability to allow the operator or controller to disable acceptance. Acceptance should normally be enabled.

60.5.4.6 <u>Self address</u>. For self test, maintenance, and other purposes, stations shall be capable of using their own self addresses in calls. When a self-addressing type function is required, ALE stations shall use the following self-addressing structures and protocols. Any ALE calling structures and protocols permissible within this standard, and containing a specifically addressed calling cycle (such as "<u>TO ABC</u>", but not allcall or anycall), shall be acceptable, except that the station may substitute (or add) any one (or several) of its own calling addresses into the calling cycle.

60.5.4.7 <u>Null address</u>. For test, maintenance, buffer times, and other purposes, the station shall use a null address which is not directed to, accepted by, or responded to by any station. When an ALE station requires a null address type function, it shall use the following null address protocol. The null address special address pattern shall be "<u>TO @@@</u>", (or "<u>REPEAT @@@</u>"), if directly after another <u>TO</u>. The null address shall only use the <u>TO</u> (or REPEAT), and only in the calling cycle (Tcc). Null addresses may be mixed with other addresses (group call), in which case they shall appear only in the leading call (Tlc), and not in the scanning call (Tsc). Nulls shall never be used in conclusion (terminator) (<u>THIS IS</u> or <u>THIS WAS</u>). If a null address appears in a group call, no station is designated to respond in the associated slot; therefore, it remains empty (and may be used as a buffer for tuneups, or overflow from the previous slot's responder, etc.).

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TABLE A-XI. Use of "?" wildcard symbol.

A B C			BASIC "STANDARD", 1 CASE EACH
A B ?	A ? C	? B C	"STANDARD" "WILD-1", 36 CASES EACH
A ? ?	? B ?	? ? C	"STANDARD" "WILD-2", 1296 CASES EACH
? ? ?			"STANDARD" "WILD-3", 46656 CASES EACH
A B @			"STUFF-1", 1 CASE EACH
A ? @	? B @		"WILD-1" "STUFF-1", 36 CASES EACH
? ? @			"WILD-2" "STUFF-1", 1296 CASES EACH
A @ @			"STUFF-2", 1 CASE EACH
? @ @			"WILD-1" "STUFF-2", 36 CASES EACH
@ A B			"DOUBLE SELECTIVE ANYCALL", ("DSA") 1/1296 CASES
@ A ?			"DSA" "WILD-1", 1/36 CASES
@ ? B			NOT PERMITTED. USE "SELECTIVE ANYCALL"
@ ? ?			NOT PERMITTED. USE "GLOBAL ANYCALL"
@ @ A			"SELECTIVE ANYCALL"
@ @ ?			"GLOBAL ANYCALL"
@ A @			"SELECTIVE ALL CALL"
@ ? @			"GLOBAL ALL CALL"

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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 necwork manager shall direct. Unless
specifically and otherwise directed by the operator or controller, all ALE
stations shall automatically insert the COMMAND LQA word (v) 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 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 normally be represented by a number
ranging between 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
should 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, should include a worst-case 48(110000) value for rejected words. For transmission in the COMMAND LQA word, the internal average value shall be converted to five-bit values as shown on table A-XII. The five-bit values, BE5 (MSB) through BE1 (LSB), shall be in 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 5-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 LQA or other such information is unavailable (or it has been exhausted and other valid channels remain available and untried) the station shall continue calling on those channels 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-20 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				LSB	Approximate BER
	BE5	BE4	BE3	BE2	BE1	
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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			CHANNELS					
			C1	C2	C3	C4	C5	C6
	A	FROM	10	4	1	0	5	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

(ADDRESSES (OTHER STATIONS))

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-20. LQA memory example.

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NOTE 1: For operator viewing, LQA values for better channels should be displayed as higher numbers, and values for poorer channels should be displayed as lower numbers.

NOTE 2: In the example shown in figure A-20, if a handshake is required with station B, channel C3 would be the best because the "round trip" (bilateral) score would be 5 (1+4), thus the lowest, channel C4 is next best with a score of 6 (3+3), the C5 with 7, C2 with 12, and C6 with 18. Linking attempts should be made in that order (C3, C4, C5, C2, and C6). C1 is left until last because of the "x" which indicates that a recent attempted handshake on that channel failed to link.

Similarly, an attempt to call A would yield the sequence C3(3), C5(12), C2(12), C1(24), C6(26), and C4(x). In this case, C5 was equal to C2 (both are 12), but C5 was chosen first because the paths were more balanced (LQA values were more equal).

If a broadcast is required (instead of a handshake), only the lower section ("to" the station) scores are used.

NOTE: In the example, to reach B, the sequence would be C4(3), C3(4), C5(5), C2(7), C6(12), and C1(x) as a last resort.

If a "listening for" or a seeking of a station is desired, only the upper section ("from" the station) scores are used.

NOTE: In the example, to listen for A, channel C4(0) would be best, and if only three channels were to be scanned, they should be C4, C3, and C2.

60.7.3 **Multiple-station channel selection**. The station shall be capable of selecting the (recent) best channel to initiate a call to, (or seek) multiple stations, based on the values in the LQA memory.

NOTE: In the example shown in figure A-20, if a star net or group handshake is required with stations B and C, C5 is the best choice as the total score is 12 (2+5+3+2), followed by C4(20) and C3(35). Next would be C2 (34+) and C6 (36+), this ranking being due to their unknown handshake capability (which had not been tried). C1(x) is the last to be tried because recent handshake attempts had failed for both B and C. To call the three stations A, B, and C, the sequence would be C5(24), C3(38), C2(46+), C6(62+), C4(one x) (recently failed attempt), and finally C1(two x).

If an additional selection factor is used, it will change the channel selection sequence.

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NOTE: In the example, to call D and E, the sequence would be C2,
C3, C4, C5, C1, and C6. If a maximum limit of LQA $\leq$ 14 is imposed
on any path (to achieve a minimum circuit quality), only C2 and C3
would be initially selected for the linking attempt. Further, if
the LQA limit was "lowered" to 10, C3 would be selected before C2
for the linking attempt.

If a broadcast to multiple stations is required, only the lower section ("to"
the station) scores are used.

NOTE: In the example, to broadcast to B and C, the sequence would
be C5(7), C4(9), C3(21), C2(7+), C6(12+), and C1(two x).

If a seeking of multiple stations is required, only the upper section ("from"
the station) scores are used.

NOTE: In the example, to listen for A and B, channel C2(2) would be
best, and if only four channels could be scanned, they should be C2,
C3, C4, and C5.

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70. PROTOCOLS.

70.1 <u>Introduction</u>. In addition to the waveform and signal structure, the ALE system provides specific protocols, or clearly defined rules for interaction among stations, to implement the necessary automated functions. This section presents the protocols for manual and automatic operation on single and multiple channels, with individual and multiple stations, and for both linking and networking.

70.2 <u>Manual operation</u>. The system is based on standard HF SSB radios, essentially all of which are manually controllable. However, these radios must also be controllable by the ALE controller if the benefits of automation are to be achieved. An ALE station consists of an ALE controller, a controllable SSB radio, and support (antennas, power, etc.). Through the ALE controller, the system enables compatible control by both operators and automation. Two specific manual operations are described below: emergency control by the operator, and push-to-talk operation.

70.2.1 <u>Operator control</u>. Each station shall be equipped with a manual control capability to permit a human operator to directly operate the basic SSB radio in emergency situations. At all other times, the radio shall be under automated control, and the human operator should operate the radio through its associated controller. In either case, the ALE controller's receiving and passive collection capabilities ("always listening"), such as monitoring for sounding signals or alerting the operator, shall not be impaired.

70.2.2 <u>Push-to-talk operation</u>. Push-to-talk (PTT) operation is the most common form of human interaction with MF/HF SSB radios, especially for tactical use by minimally trained, "noncommunicator" operators. Manual control with PTT shall be conventional; that is, the operator pushes the PTT button to talk and releases it to listen.

70.3 <u>ALE operational rules</u>. The ALE system shall incorporate the basic operational rules listed on table A-XIII. "Always listening" (rule 2) is not required during temporary periods when not technically possible, such as during transmit with a transceiver or when using a separate transmitter and receiver with a common antenna.

70.4 <u>Individual calling</u>.

70.4.1 <u>Introduction</u>. The essential element of the ALE protocols is the basic call structure, which is based on the waveform, timing, and coding structures discussed in previous sections. This basic presentation format, shown in figure A-21, is used in all the ALE protocol illustrations in this standard. Time is approximately to scale and moves from left to right. The timing symbols are defined in Annex B and their computation is described in 70.4.4. The footnotes, such as (2) for tuning time, are essentially standardized throughout, except for occasional minor variations to clarify each specific protocol. Each "box," such as "<u>THIS IS A</u>", indicates an individual, on-the-air, 130.66...ms nonredundant word (Tw), of which several duplicates (multiples of 3) are used to communicate them as redundant words

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TABLE A-XIII.   **ALE operational rules**.

1)	Independent ALE receive capability (in parallel with any others) (critical).
2)	Always listening (for ALE signals) (critical).
3)	Always will respond (unless deliberately inhibited).
4)	Always scanning (if not otherwise in use).
5)	Will not interfere with active ALE channel (unless priority or forced).
6)	Always will exchange LQA with other stations when requested (unless inhibited), and always measures the signal quality of others.
7)	Will respond in preset/derived/directed time slot (net/group/special calls).
8)	Always seek (unless inhibited) and maintain track of their connectivities with others.
9)	Linking ALE stations employ highest mutual level of capability.
10)	Minimize transmit and receive time on channel.
11)	Automatically minimize power used (if capable).

NOTE 1:   Listed in order of precedence.

NOTE 2:   Some of these rules may not be applicable in certain applications.

(Trw), as shown (usually as boxes with "tick" marks). In this example, the basic required minimum call, which is 3 Trw (1176 ms) long, is shown. The large letters, such as "A" and "B", are convenient graphic substitutes for the actual three characters of the basic address field. The delta (∇) indicates the location of the optional message section, where COMMAND (and DATA and REPEAT) may be inserted (with a consequent time increase of Trw (392 ms) per original, nonredundant word). The initiation of the outgoing frame shall always be after the transmitter is up to full power (see 60.4.2.1) and shall be word synchronized in accordance with 60.4.3.1. Described below are both single-channel and multiple-channel protocols, plus detailed timing, control, and message information for designing ALE stations. The single-channel description is also an overview of the linking. The multiple-channel description provides an in-depth analysis of the individual protocols.

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WORD TIME
$T_W = 130.66... \text{ ms}$

| TO B | TO B | TO B | TO B | TO B | TO B | TO B | TO B | TO B | THIS IS A | THIS IS A | THIS IS A |

SCANNING CALLING
(ADDRESS FIRST WORDS)
$T_{SC} = n \times T_{AI} = n \times 392 \text{ ms}$

LEADING CALL
(WHOLE ADDRESS WORDS)
$T_{LC} = 2T_A \text{ (CALLED)} \geq 2T_{RW} \geq 784 \text{ ms}$

CONCLUSION
(TERMINATOR)
$T_X = T_A \text{ (CALLER)} = n \times T_{RW} = n \times 392 \text{ ms}$

CALLING CYCLE
$T_{CC} = T_{SC} + T_{LC} \geq 784 \text{ ms}$

REDUNDANT CALL
$T_{RC} = T_{LC} + T_X \geq 1176 \text{ ms}$

SCANNING REDUNDANT CALL
$T_{SRC} = T_{SC} + T_{RC} \geq 1176 \text{ ms}$

TIME →

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 **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** PAUSES
    FOR A RESPONSE FROM **B**).

FIGURE A-21. **Basic call structure.**

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70.4.2 <u>Single channel</u>. 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-22. 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 <u>A</u> should already by 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 <u>A</u> and <u>B</u> 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 <u>A</u> shall call station <u>B</u> by transmitting a calling cycle containing <u>B</u>'s address ("<u>TO</u> <u>B</u>"), followed by a conclusion (terminator) containing his own ("<u>THIS IS</u> <u>A</u>") (7). <u>A</u> then shall wait a preset reply time (Twr, a buffer which includes anticipated propagation each way and <u>B</u>'s turnaround time) to start to receive <u>B</u>'s response (9). Upon receipt of <u>A</u>'s call and recognition of both his and <u>A</u>'s addresses, <u>B</u> shall tune up (if needed) (2), send the response, and wait his own reply time Twr. Upon receipt of <u>B</u>'s response (starting within the reply wait Twr, normally less than 2 seconds), and recognition of both his and <u>B</u>'s addresses, <u>A</u> shall sent the acknowledgement, enter the linked state (with <u>B</u>), unmute his speaker, and alert his operator. Upon receipt of the acknowledgement (starting within <u>B</u>'s reply time Twr), <u>B</u> shall also enter the linked state (with <u>A</u>), <u>B</u> shall also alert his own operator and unmute his speaker. During the linked state (<u>A</u>-<u>B</u>) 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 <u>B</u> does not start to arrive within the present wait for reply time (Twr) or wait for reply and tune time (Twrt), the handshake shall be terminated, <u>A</u> does not enter the linked state, and <u>A</u>'s operator or controller shall be notified. If the expected acknowledgement from <u>A</u> does not start to arrive within the preset wait for reply time (Twr), the handshake shall be terminated, <u>B</u> does not enter the linked state, and <u>B</u>'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 <u>B</u> is lost, <u>A</u> will be in the linked state (without <u>B</u>) 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 <u>THIS WAS</u>, 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 stations(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 (v), 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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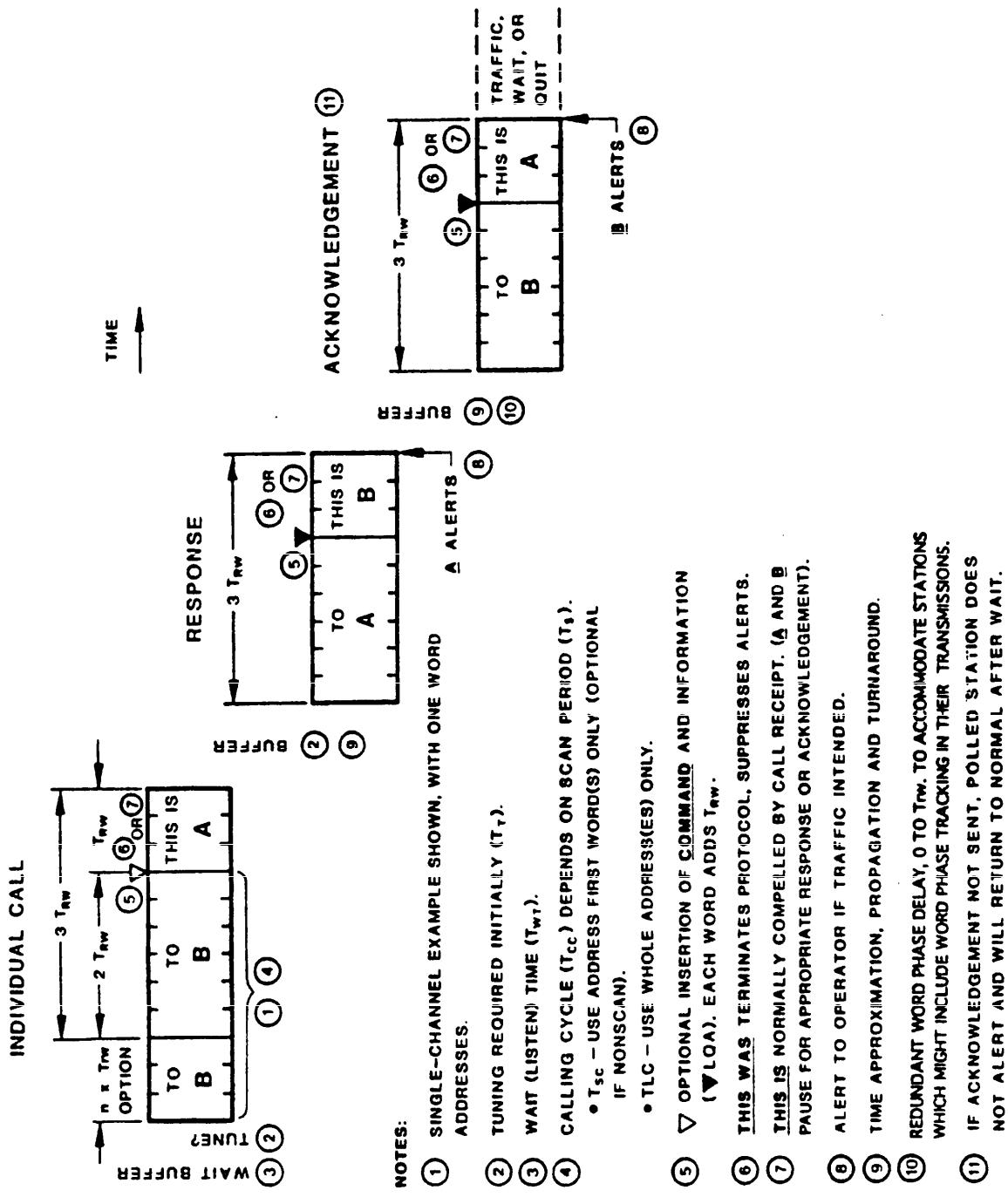
FIGURE A-22. Individual call protocol.

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).
   - TLC – 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 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.

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) or 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 preset 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 (1176 ms) 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 <u>Multiple channels</u>. All ALE stations shall be capable of performing the individual scanning calling protocol described herein, even if on a fixed frequency. See figure A-23. 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 in figure A-22, 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 ≥ 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 ≥ 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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MIL-STD-188-141A
APPENDIX A
NOTICE 2

FIGURE A-23. Individual scanning calling protocol.

INDIVIDUAL SCANNING CALL

RESPONSE

ACKNOWLEDGEMENT

TIME

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_{CC}) DEPENDS ON SCAN PERIOD (T_S).
   • T_{SC}-USE ADDRESS FIRST WORD(S) ONLY.
   • 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 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.

Within figure (Individual Scanning Call):
A ARRIVES ON CHANNEL
$T_{SC} = 13\ T_{RW}$
$T_{SC} = 10\ T_{RW} \geq 2\ T_S$
$T_{LC} = 2\ T_{RW}$
TO B / THIS IS A
⑤ ⑥ OR ⑦ T_A
① ④
② TUNE ?
③ WAIT BUFFER

CALLING CYCLE (T_{CC}) DURING WHICH B SHOULD ARRIVE ON CHANNEL, TAKE NOTICE, AND STAY TO RESPOND. ALL OTHERS TAKE NOTICE AND MAY DEPART.

Within figure (Response):
$3\ T_{RW}$
TO A / THIS IS B
⑤ ⑥ OR ⑦
⑨ BUFFER
⑩ ② TUNE

A PAUSES FOR RESPONSE

IF NO INITIAL RESPONSE, A DEPARTS CHANNEL (OR MAY TRY AGAIN)

⑧ IF FULL RESPONSE RECEIVED, A ALERTS, SENDS ACK, AND WAITS TO SEND TRAFFIC

Within figure (Acknowledgement):
$3\ T_{RW}$
TO B / THIS IS A
⑤ ⑥ OR ⑦
⑨ ⑩ BUFFER

B PAUSES FOR ACK

IF NO INITIAL ACK, B MAY DEPART CHANNEL (OR MAY PAUSE FOR A RETRY)

⑧ IF FULL ACK RECEIVED, B ALERTS AND WAITS FOR TRAFFIC

TRAFFIC, WAIT, OR QUIT

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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-23 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 scans 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 with Twrt, or if A does not later receive the appropriate terminator ("THIS IS B") starting within 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 plan to reply (acknowledge), and to complete the handshake within the time window Twr (normally less than 2 seconds).

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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 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 in figure A-23 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 on 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

- Tone rate = 125 symbols per second (sps)

- Tone period = Ttone = 8 ms

- On-air rate = 375 bps

- On-air word: Tw = 130.66... ms

- On-air redundant word: Trw = 3 Tw = 392 ms

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TABLE A-XIV.   Timing – Continued.

- On-air leading redundant words: 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 words: Ta max = 1960 ms

- Address first word limit: Tal = 392 ms

- Call time maximum: Tc = 4704 ms (one-half of Tlc = 12 words max)

- 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 = 11.76s

- Message section time limit, 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.

- Probable maximum dwell per channel, for channel, for Ts computations, let $Td = Tdrw = 784$ ms

- Number of channels: C

- Scan period: $Ts = C \times Td$

- Call time: $Tc = Ta$ (or more whole addresses as required Σ Ta) in Tlc

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TABLE A-XIV. Timing - Continued.

- Call time: $Tcl = Tal$ (or more different first words, Σ Tal) in Tsc

- Leading call time: $Tlc = 2\ Tc$

- Redundant call time: $Trc = Tlc + Tx$

- Scanning call time: $Tsc = n \times Tcl \geq Ts$

- Calling cycle time: $Tcc = Tsc + Tlc \geq Ts + Tlc$

- Scanning redundant call time: $Tsrc = Tsc + Trc$

- Last word wait delay: $Tlww = Trw = 392$ ms

- Wait for response time delay: $Twr = Ttd + Tp + Tlww + Tta + Trwp$ (if not first transmission...) $+ Tld + Tp + Trd$

- Late detect delay: $Tld = Tw = 130.66...$ms

- Redundant word phase delay: $Trwp = 0$ to Trw (0 to 392 ms)

- Turnaround time: $Tta = Trd + Tdek + Tenk + Ttc + Ttk + Ttd$

- Wait for calling cycle end time: $Twce = 2 \times$ own Ts (default)

- Tune time: Tt (as required by slowest tuner)

- Wait for reply and tune time: $Twrt = Twr + Tt$

- Detect signaling period: $Tds \leq (Td(5) = 200$ ms)

- Detect redundant word period: $Tdrw = Trw +$ spare $Trw = 784$ ms

- Detect rotating redundant word period: $Tdrrw = 2\ Trw +$ spare $Trw = 1176$ ms

Sounding

- Redundant sound time (similar to Tlc): $Trs = 2\ Ta$ (caller)

- Scanning sound time (similar to Tsc): $Tss = n \times Ta$ (caller) $\geq Ts$

- Scanning redundant sound time (similar to Tcc): $Tsrs = Tss + Trs \geq Ts + Trs$

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TABLE A-XIV. Timing -- Continued.

Star calling

- 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.

- Slot widths: Tsw = 14, 17, 9, or other Tw

- Slot number: SN

- Slot wait time: Tswt = Tsw x SN (uniform case)

- Slot wait time (delay to start reply): Tswt 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 addressed)

$$\sum_{m=1}^{m=SN-1} Ta(m) \ (called)]$$

- Number of slots: NS

- Wait for net reply (at calling station): Twrn = (Tsw x NS) for uniform slots, or generally Twrn = Tswt(NS)

- Wait for net acknowledgement (at called stations): Twan = Twrn + Tdrw

- Turnaround and tune limits: Tta + Tt $\leq$ 360, 2100, or 1500 ms, depending on whether slot 0, 1, or others

- Maximum star group wait for acknowledgement: Twan max = 107 Tw + 27 Ta (caller) + 13 Trw (optional LQA) + 13 Tm (optional message)

- 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

- Wait (listen first): Twt = 2 seconds, general uses; = 784 ms, ALE/data only channels

- Tune time: Tt = 8 Tw = 1045.33... ms (default), "blind" first call; = 20 seconds, next try

- Automatic sounding: Tps = 30 minutes

- Wait for activity: Twa = 30 seconds

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70.5 <u>Sounding</u>.

70.5.1 <u>Introduction</u>. 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. The
sounding signal is a unilateral, one-way transmission which is performed at
periodic intervals on unoccupied channels. The implementation is simple: a
timer is added to the controller to periodically initiate sounding signals (if
the channel is clear). Sounding is not an interactive, bilateral technique,
such as polling. However, the identification of connectivity from a station,
by hearing its sounding signal, does indicate a high probability (but not
guarantee) of bilateral connectivity and it may be done entirely passively at
the receiver. If propagation changes slowly, a long interval between
soundings of perhaps one or two hours may be sufficient. However, if
propagation is erratic and rapidly changing and the connectivity information
is critical, sounding may be conducted several times within each hour.

As sounding uses the standard ALE signaling, any station can receive sounding
signals. As a minimum, the signal (address) information shall be displayed to
the operator and, for stations equipped with connectivity and LQA memories,
the information shall be stored and used later for linking. If a station has
had recent transmissions on any channels which are to be sounded on, it may
not be necessary to sound on those channels again until the sounding interval,
as restarted from those last transmissions, has elapsed. In addition, if a
net (or group) of stations is polled, their responses shall serve as sounding
signals for the other net (or group) receiving stations.

All stations shall be capable of performing periodic sounding on clear
prearranged channels. The sounding capability may be selectively activated
by, and the period between sounds shall be adjustable by the operator or
controller, according to system requirements. When available, and not
otherwise committed or directed by the operator or controller, all ALE
stations shall automatically and temporarily display the addresses of all
stations heard, with an operator selectable alert.

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The structure of the sound is virtually identical to that of the basic call which was described earlier. However, the calling cycle is not needed and there is no message section. It is only necessary to send the conclusion (terminator) which identifies the transmitting station. See figure A-24. The type of word, either THIS IS or THIS WAS (but never both), indicates whether potential callers are encouraged or ignored, respectively. The minimum redundant sound time (Trs) is equal to the standard one-word address leading call time (Tlc); that is Trs = Tlc min = 2 Ta min = 2 Trw = 784 ms. Described below are both signal-channel and multiple-channel protocols, plus detailed timing and control information, for designing stations.

70.5.2 Single channel. The fundamental capability to automatically sound on a channel is provided by the sounding protocol as shown in figure A-24. As an option stations may employ this protocol for single-channel sounding, connectivity tracking, and the broadcast of their availability for calls and traffic. If this option is selected, it shall be implemented IAW this paragraph. The basic protocol consists of only one part: the sound. In this one-channel example, the sounding station A initially performs the identical steps which are followed in the individual calling protocol presented in 70.4.3. If multichannel stations are to be sounded to, A should use the totally compatible scanning sounding protocol, presented in 70.5.3. Normally, both A and all other stations, such as B, are on channel and available; that is they are "always listening" and they "always track connectivities with other stations," if they have a connectivity matrix. Starting with the sound, station A shall broadcast to station B and all other stations by transmitting the sound containing his own address ("THIS IS A"). If A is encouraging calls and receives one, A shall follow the sound with the optional handshake protocol described in 70.5.4. If A plans to ignore calls, he shall use the THIS WAS, which advises B and the others not to attempt calls, and then A shall immediately return to normal "available." As this is a single-channel example, with nowhere for A to go, A actually would still be contactable, unless otherwise directed by the operator or controller. However, in some systems it is necessary for a multichannel station A to periodically sound to a single-channel network, usually to inform them that he is active and available on that channel, although scanning. Therefore, if B, a single-channel station, needs to contact A at that time, the optional handshake may be used after the THIS IS sound. If contact is required later, the standard individual scanning calling protocol would be used even though on a single channel. Upon receipt of A's sound, B and the other stations shall display A's address as a received sound and, if they have an LQA and connectivity memory, they shall appropriately store the connectivity information. In the single-channel case, and if B or one of the other stations requires contact with A, they may attempt to link by initiating a standard individual call, by specific operator or controller direction as part of the optional handshake, despite the THIS WAS advisory.

70.5.3 Multiple channels. Sounding must be compatible with the scanning timing. All stations shall be capable of performing the scanning sounding protocols described herein, even if on a fixed frequency. See figures A-24, A-25, and A-26. These protocols establish and positively confirm unilateral connectivity between stations on any available mutually scanned channel, and they assist in establishment of links between stations which are waiting for contact. Stations shall employ these protocols for multichannel sounding, connectivity tracking, and the broadcast of their availability for calls and traffic.

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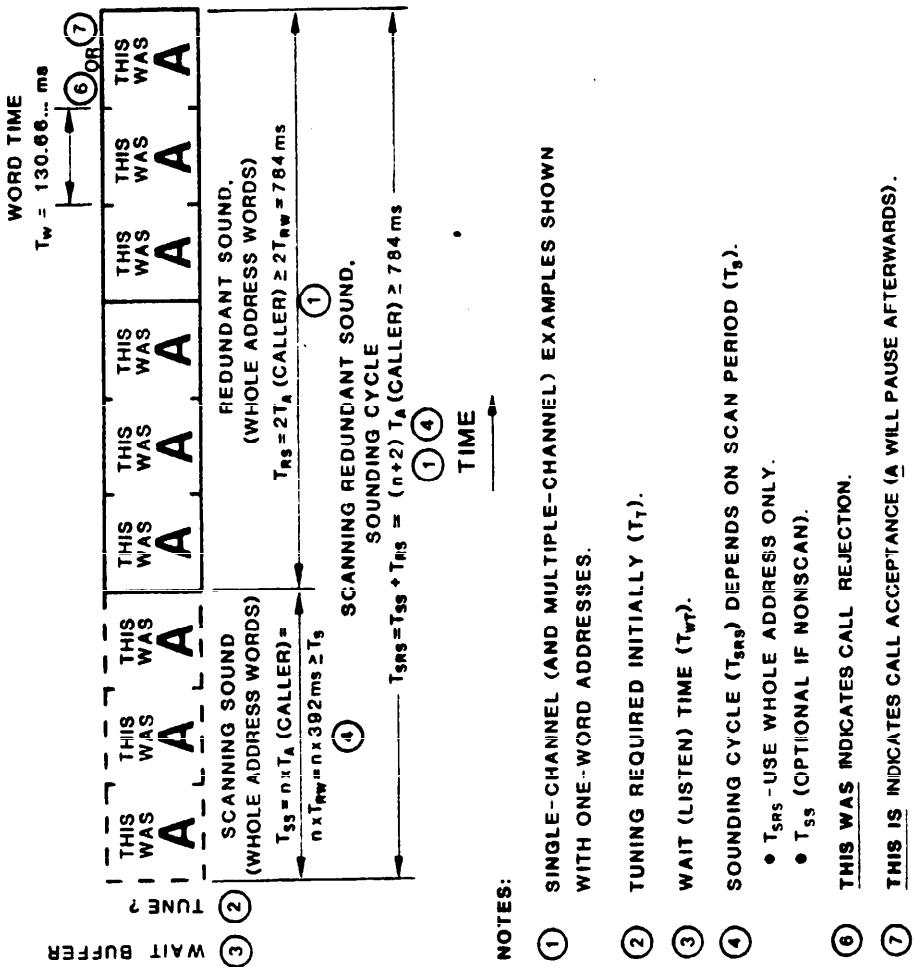
FIGURE A-24. Basic sounding structure.

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).
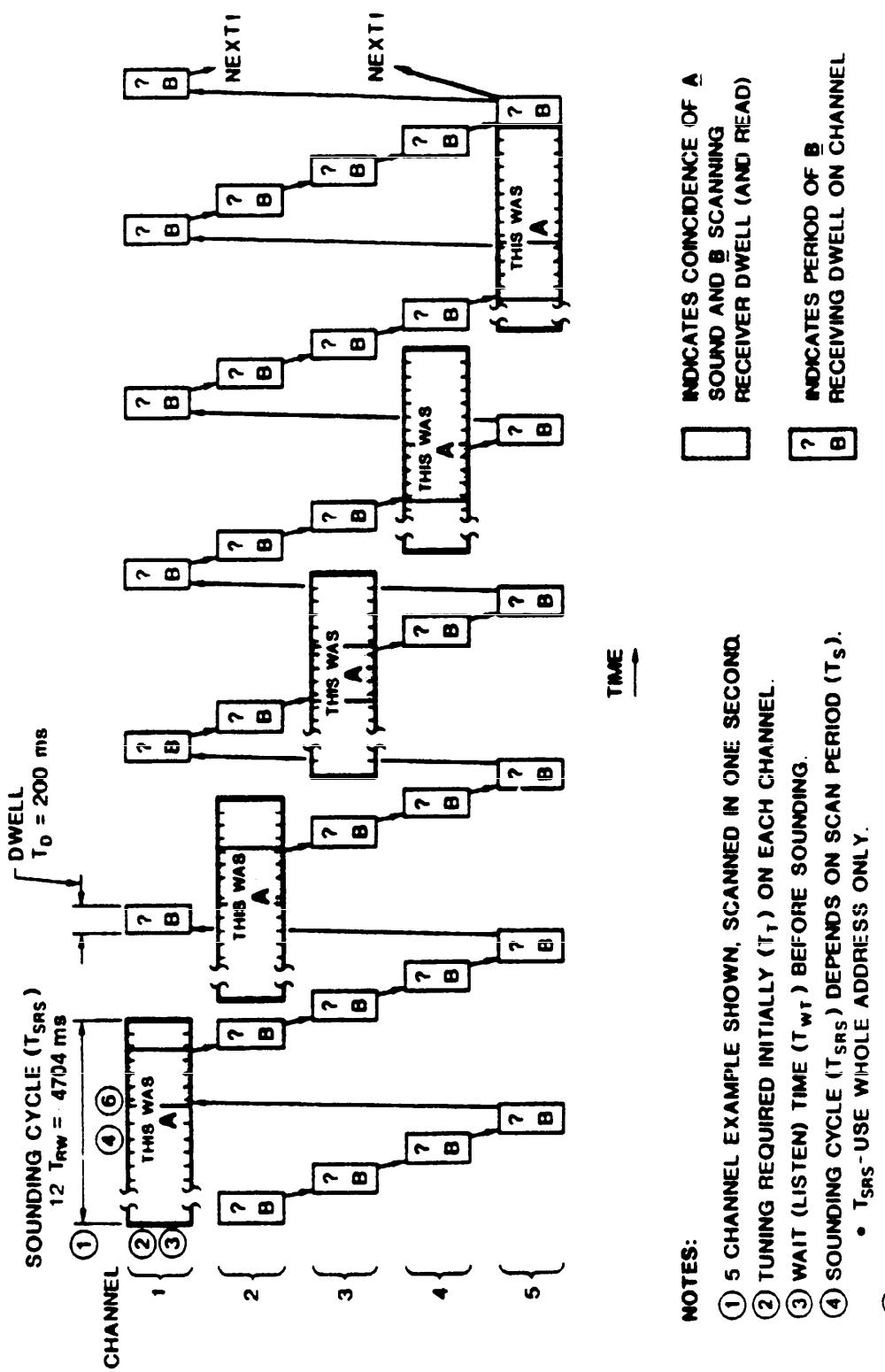
FIGURE A-25. Call rejection scanning sounding protocol.
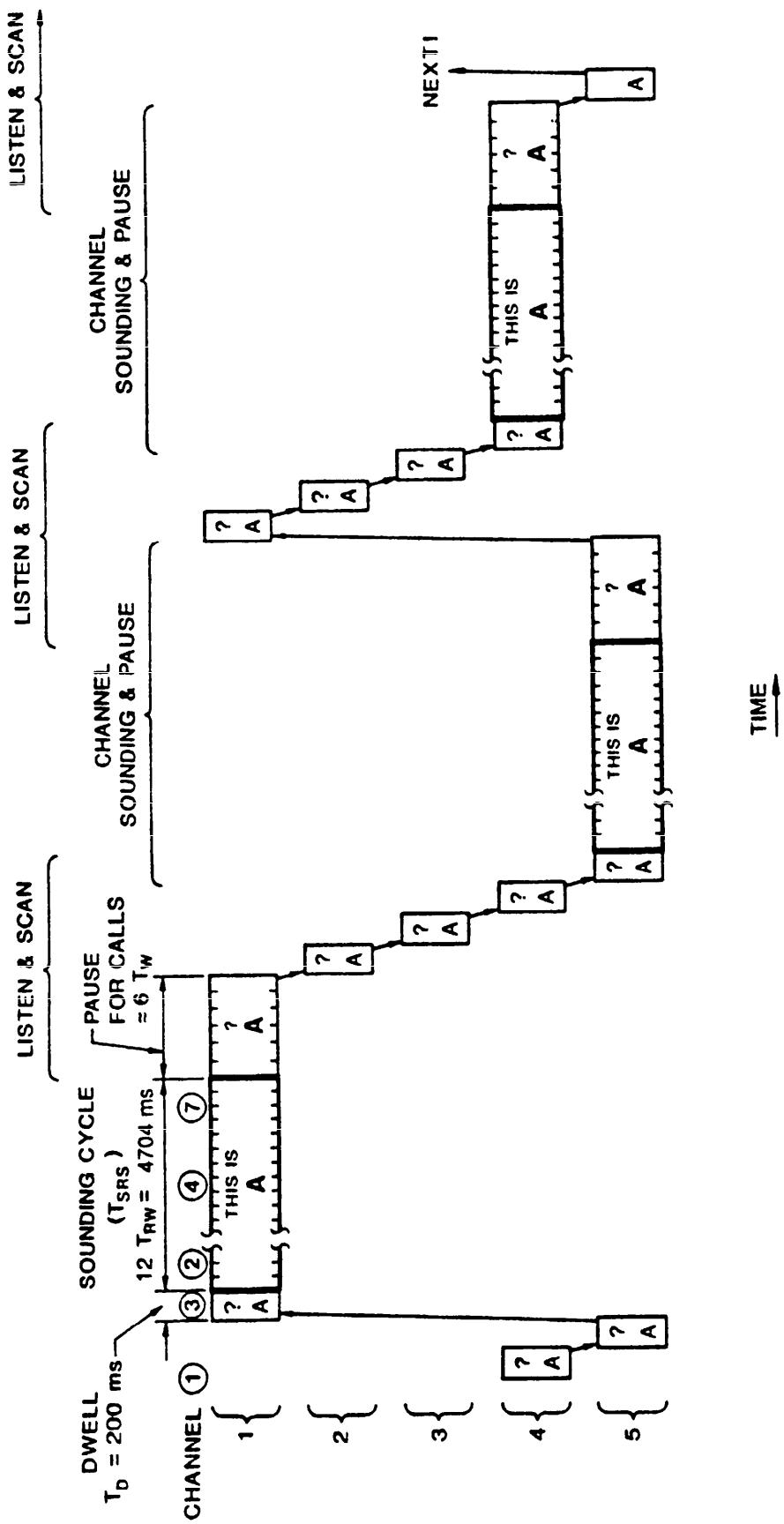
NOTES:

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_{SRS}) DEPENDS ON SCAN PERIOD (T_S).
   • T_{SRS} - USE WHOLE ADDRESS ONLY.
6. THIS WAS INDICATES CALL REJECTION.

FIGURE A-26. Call acceptance scanning sounding protocol.

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}) USES DWELL T_D.

4. SOUNDING CYCLE (T_{SRS}) DEPENDS ON SCAN PERIOD (T_S).
   - T_{SRS} —USE WHOLE ADDRESS ONLY.

7. THIS IS INDICATES CALL ACCEPTANCE (A WILL PAUSE AFTERWARDS).

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The basic protocol consists of only one part, the scanning sound. See figure A-24. 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-25. 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 times (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 use "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 figure A-25, 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-26. 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-27. 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 required 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:

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

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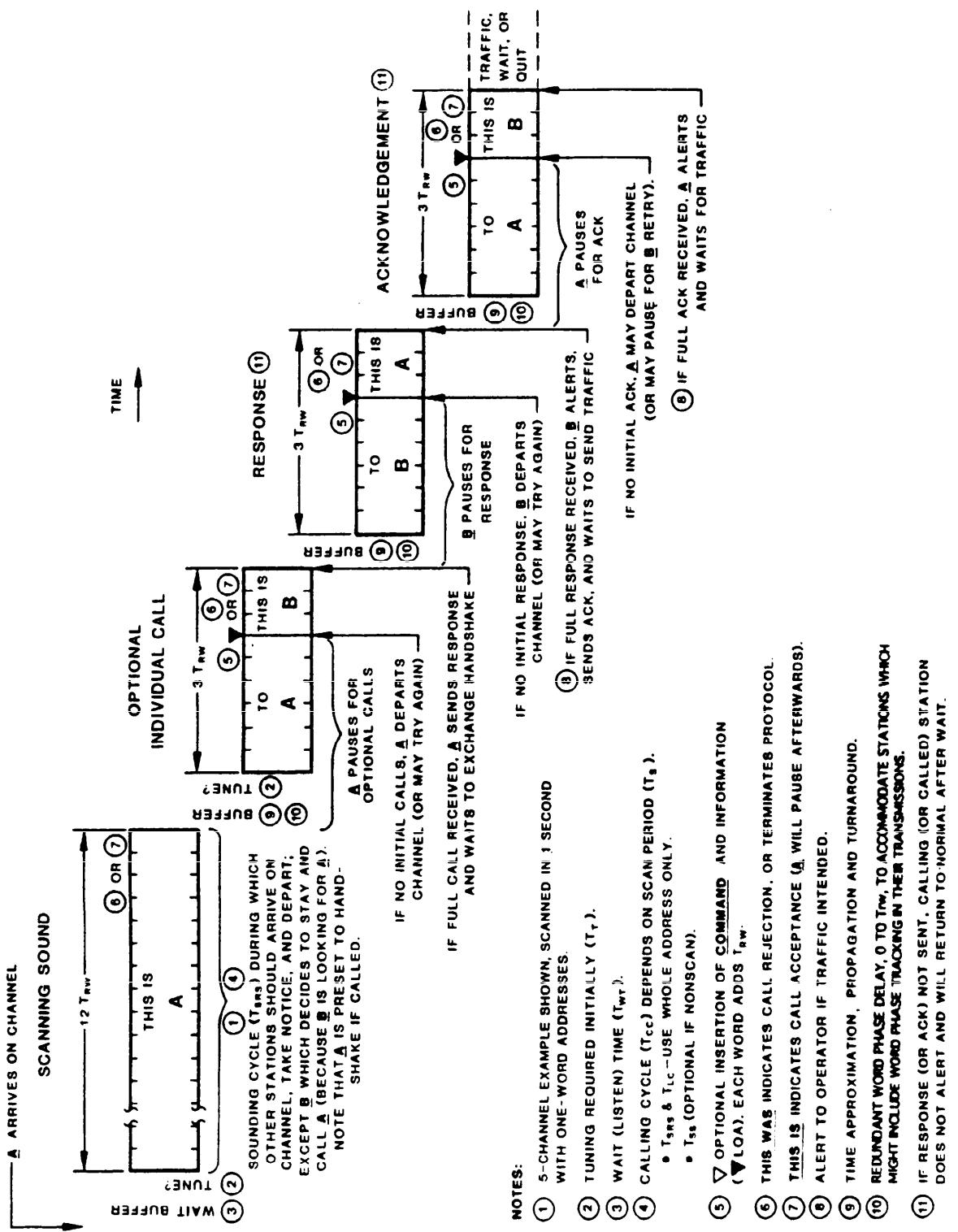
FIGURE 2. Scanning sounding with optional handshake protocol.

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_{CC}) DEPENDS ON SCAN PERIOD (T_S).
   - T_{SRS} & T_{LC}—USE WHOLE ADDRESS ONLY.
   - T_{SS} (OPTIONAL IF NONSCAN).

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

6. THIS WAS INDICATES CALL REJECTION, OR TERMINATES PROTOCOL.

7. THIS IS INDICATES CALL ACCEPTANCE (A WILL PAUSE AFTERWARDS).

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 RESPONSE (OR ACK) NOT SENT, CALLING (OR CALLED) STATION DOES NOT ALERT AND WILL RETURN TO NORMAL AFTER WAIT.

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 quantity of links. In this section, two fundamental types of multiple-station operations are described:

- Star net
- 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 40.5 and 40.6 (DO: The capability of operator selectable minimum, uniform, or variable slot widths).

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-28. 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).
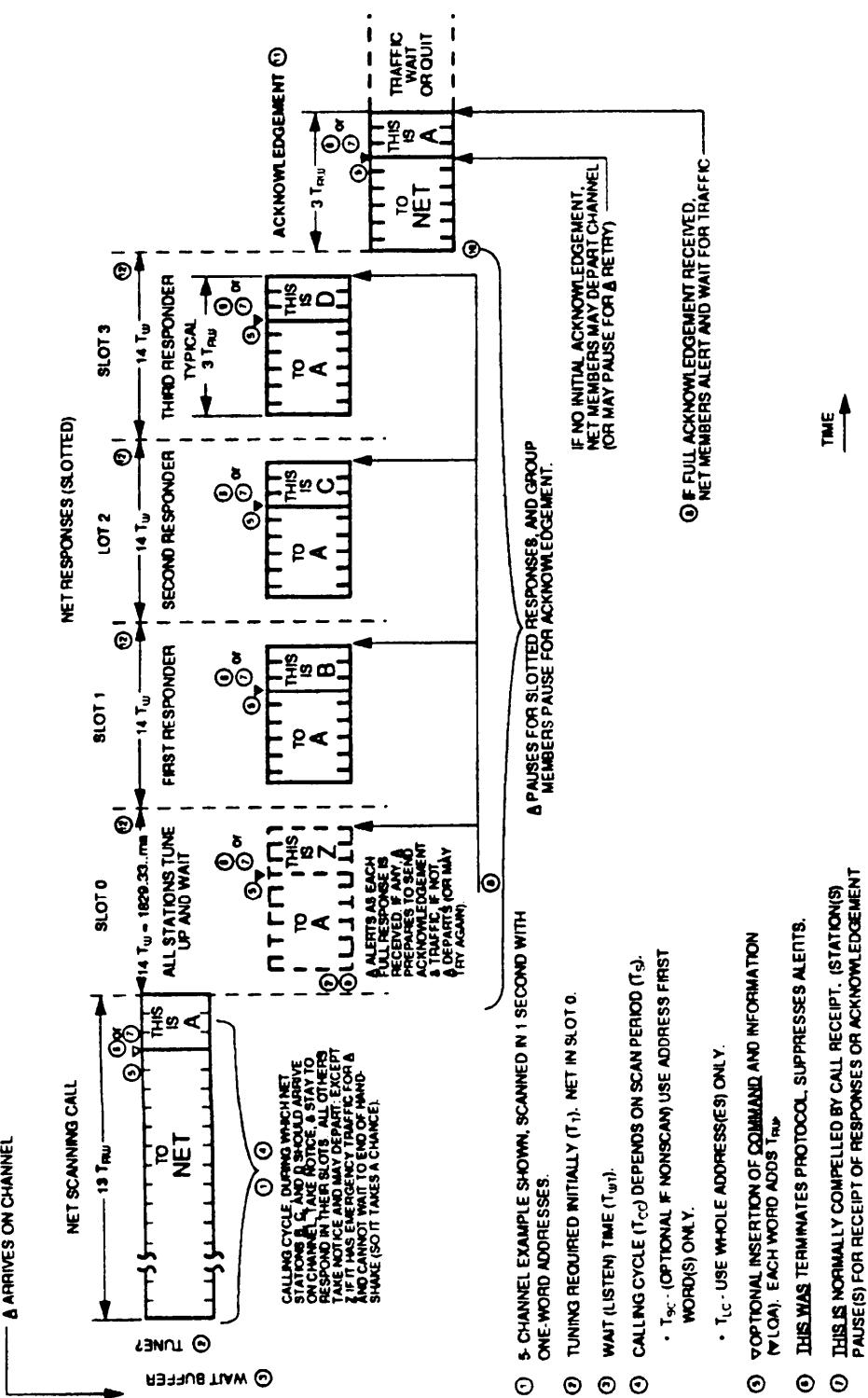
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FIGURE A-28. Starnet scanning calling protocol.

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 (see 60.4.2.1), 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 station'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).

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 and substitute an individual (or group) call acknowledgement to any selected station(s) to retain them. If the calling station sends and 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 in figure A-28, 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 and 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 stations 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 prearrangements when the net was set up. When prearranging the specific slots and sizes for a specialized network, and if the net requires more than one-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 <u>Star group</u>. 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 crate 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 multi-channel) 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-29. 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, $\underline{D}$, $\underline{C}$, and $\underline{B}$, then $\underline{D}$, $\underline{C}$,
and $\underline{B}$ again. See the acknowledgement, at the right, in figure A-29. If a
single-channel call is to be made, the first word of the standard leading call
(Tlc) would be "$\underline{TO}$ $\underline{D}$" as usual for the individual calling protocol. However,
the next address would follow immediately with the standard redundant words
(Trw) as "$\underline{REPEAT}$ $\underline{C}$" and then the next "$\underline{TO}$ $\underline{B}$" 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 of a single-channel group call, stations $\underline{D}$, $\underline{C}$, and $\underline{B}$ 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 in figure A-29, a
station such as $\underline{D}$ would hear its address ("$\underline{TO}$ $\underline{D}$") being called. It would plan
to respond immediately to whichever station is calling ($\underline{A}$), because it appears
to be (an at this point is) identical to an individual call. However, upon
reading another called address ("$\underline{REPEAT}$ $\underline{C}$"), $\underline{D}$ realizes that it is actually a
group call and slotted responses are required, so $\underline{D}$ starts to count addresses
(starting with his own) until the calling cycle ends. When the "$\underline{TO}$ $\underline{B}$"
arrives, $\underline{D}$ identifies another group-called address and counts to two. If the
call repeats, as shown for scanning cases at the left in figure A-29, when
"$\underline{REPEAT}$ $\underline{D}$" arrives, $\underline{D}$ has counted to three. $\underline{D}$ immediately knows that there
are only three stations involved in the group call ($\underline{D}$, $\underline{C}$, and $\underline{B}$). $\underline{D}$ now must
find its slot, so it resets its counter to one (itself). $\underline{D}$ continues to read
the following rotated addresses ($\underline{C}$ and $\underline{B}$ again) and continues to count, until
the calling cycle ends. Meanwhile, $\underline{C}$ and $\underline{B}$ are doing the same thing, and they
also determine that three stations ($\underline{D}$, $\underline{C}$, and $\underline{B}$) are involved. However, when
counting up to the end of the calling cycle, "$\underline{THIS}$ $\underline{IS}$ $\underline{A}$" in this case, $\underline{D}$
reaches three, $\underline{C}$ reaches two, and $\underline{B}$ reaches one. They have automatically
identified their response slots: $\underline{D}$ is slot 3, $\underline{C}$ in slot 2, and $\underline{B}$ in slot 1.
The remainder of the protocol is identical to the star net protocol. Note
that if one of the stations, such as $\underline{C}$ were to miss the earlier parts of the
calling cycle but receive its last "$\underline{TO}$ $\underline{C}$", it would still respond properly in
slot 2 because it would read the "$\underline{REPEAT}$ $\underline{B}$" which follows, realize that this
is a group call, and should have 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 addressed 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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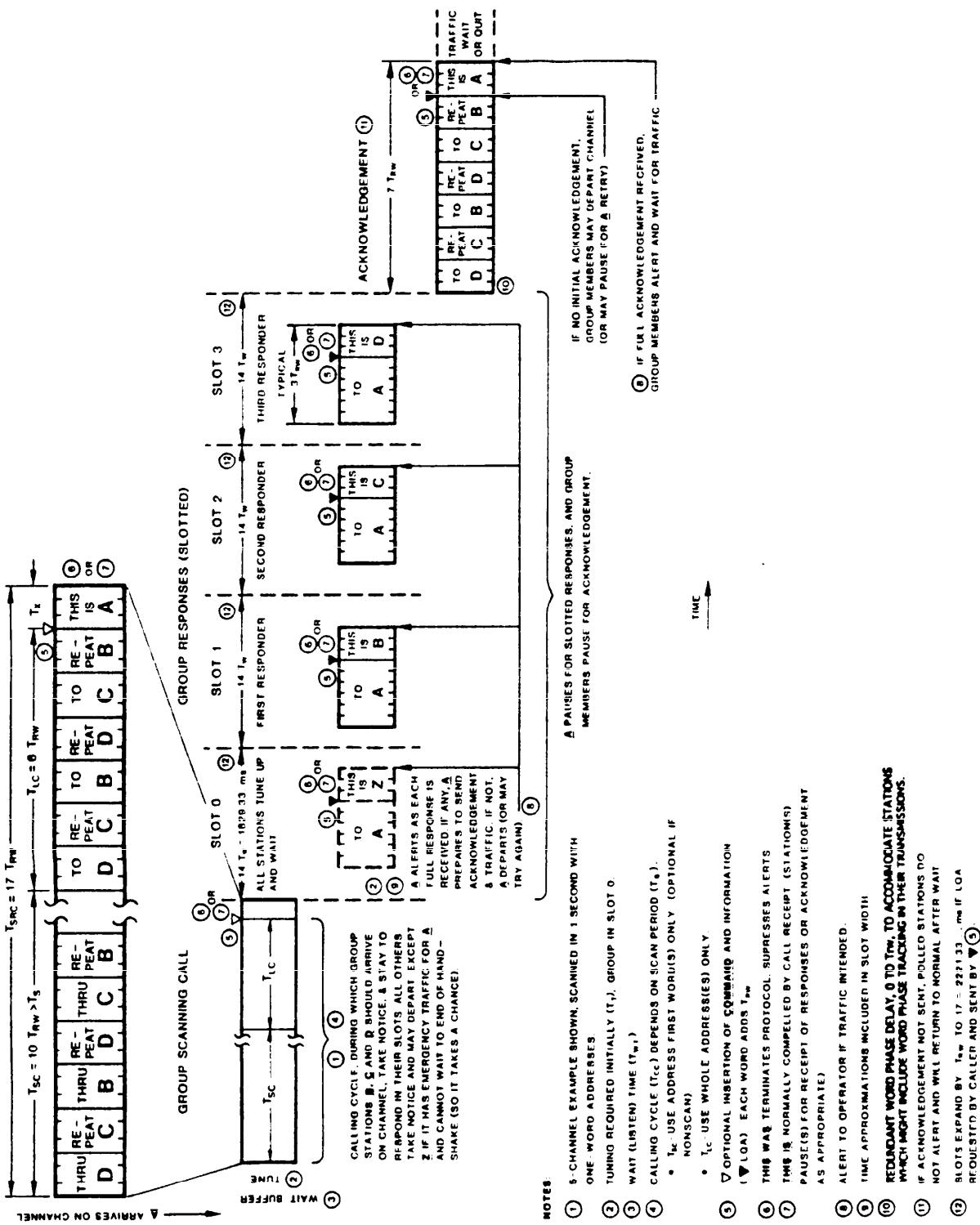
| FIGURE A-29. Stargroup scanning calling protocol.

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 $\geq$ Ts + Tlc. Similarly, the Tcc for the scanning group call must increase by a group scan call time Tsc $\geq$ Ts. In the group call, as noted above, the basic leading call, Tlc = 2Tc = 2 x (sum of all called whole addresses) 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 THRU (and alternating with REPEAT), and in Tlc, shall be in TO (and REPEAT). 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 $\geq$ 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 (NAW x Trw) + Tsc = (n + 2 NAW) x Trw, provided n $\geq$ 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 in figure A-25, Ts = 3920 ms, n $\geq$ 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 "THIS IS A" terminator of Trw increases the entire group scanning call to 17 Trw. As can be seen in figure A-25, 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 five 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 277 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 to at least one address.

> 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 station(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.

This page supersedes page 128 of 17 June 1992.

80. ORDERWIRE MESSAGES.

80.1 <u>Introduction</u>. 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 <u>COMMAND</u> functions.

> NOTE: For critical orderwire messages 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 <u>COMMAND</u> 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 <u>COMMAND</u> 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 <u>COMMAND</u> 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 <u>Link quality analysis (LQA)</u>. This mandatory function is designed to support the exchange of LQA information among ALE stations. The <u>COMMAND</u> LQA word shall be constructed as shown on table A-XVI. The preamble shall be <u>COMMAND</u> (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 an 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 <u>Bit-error-ratio (BER)</u>. 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 <u>Signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD)</u>. If the optional SINAD is analytically derived by suitable 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 <u>Multipath (MP)</u>. 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.

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

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 P2=1 P1=0	MSB	W1 W2 W3
First Character "a"	MSB LSB	C1-7=1 C1-6=1 C1-5=0 C1-4=0 C1-3=0 C1-2=0 C1-1=1		W4 W5 W6 W7 W8 W9 W10
Control	KA1			W11
Multipath Bits	MSB LSB	MP3 MP2 MP1		W12 W13 W14
SINAD Bits	MSB LSB	SN5 SN4 SN3 SN2 SN1		W15 W16 W17 W18 W19
BER Bits	MSB LSB	BE5 BE4 BE3 BE2 BE1		W20 W21 W22 W23 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 <u>Automatic message display (AMD) mode</u>. 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
<u>COMMAND</u> 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 <u>COMMAND</u> AMD word, which shall contain the first three characters of
the message. It shall be followed by a sequence of alternating <u>DATA</u> and
<u>REPEAT</u> words which shall contain the remainder of the message. The <u>COMMAND</u>,
<u>DATA</u>, and <u>REPEAT</u> 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 <u>COMMAND</u>. Multiple AMD messages may be sent within a frame,
but they each shall start with their own <u>COMMAND</u> AMD with the first three
characters.

Receipt of the <u>COMMAND</u> 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 <u>COMMAND</u> (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 and 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 the direction of the operator or 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 larger 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 on
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	

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 also 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-30 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 station 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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TABLE A-XVII. Data text message characteristics.

	WORD BITS W15--W19 (DTM CODE BITS DC10--DC6)	WORD BITS W20--W24 (DC5--DC1)	DTM CODE (DC) DECIMAL (n)	DATA WORDS (w)	BINARY BITS DATA	ASCII CHAR. DATA	DATA TIME	TOTAL DTM (T_{RW})
DTM NULL*	0 0 0 0 0	0 0 0 0 0	0	0*	0	0	0	1*
DTM EXTENDED (FULL)	0 0 0 0 0	0 0 0 0 1	1	1	21	3	392 ms	3
	0 0 0 0 0	0 0 0 1 0	2	2	42	6	784 ms	4
	▼	▼	▼	n	21n	3n	n×392 ms	n+2
	0 1 0 1 0	1 1 1 1 0	350	350	7350	1050	2.28 min	352
	0 1 0 1 0	1 1 1 1 1	351	351	7371	1053	2.29 min	353
DTM ARQ*	0 1 0 1 1	0 0 0 0 0	352	0*	0	0	0	1*
(RESERVED)*	(12≤m≤31)	0 0 0 0 0	32m	---	---	---	---	---
DTM BASIC (EXACT)	0 1 0 1 1	(01≤p≤31)	352+p	p	(21p+m−31)	3(p−1 to p)	p×392 ms	p+2
	0 1 1 0 0	(01≤p≤31)	384+p					
	▼		32m+p	▼	▼	▼	▼	▼
	1 1 1 1 1	(01≤p≤31)	960+p	p	(21p+m−31)	3(p−1 to p)	p×392 ms	p+2
	1 1 1 1 1		992+p					
	(11≤m≤31)	0 0 0 0 1	32m+1	1	1−21	0−3	392 ms	w+2
		0 0 0 1 0	32m+2	2	22−42	3−6	784 ms	
		▼	32m+p	p	(21p+m−31)	3(p−1 to p)	p×392 ms	▼
		1 1 1 1 0	32m+30	30	610−630	87−90	11.760 s	
	(11≤m≤31)	1 1 1 1 1	32m+31	31	631−651	90−93	12.152 s	w+2

NOTES:

1. * – NO COMMAND CRC USED

2. m – BINARY BITS IN LAST WORD + 10

3. p – DTM DATA WORDS

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TABLE A-XVIII.   Data text message structure.

	DTM Bits			Word Bits	
COMMAND preamble	MSB	P3=1		MSB	W1
		P2=1			W2
	LSB	P1=0			W3
First character "d"	MSB	C1 (bit-7) = 1			W4
		C1 (bit-6) = 1			W5
		C1 (bit-5) = 0			W6
		C1 (bit-4) = 0			W7
		C1 (bit-3) = 1			W8
		C1 (bit-2) = 0			W9
	LSB	C1 (bit-1) = 0			W10
Control bits	MSB	KD4			W11
		KD3			W12
		KD2			W13
	LSB	KD1			W14
DTM data code bits	MSB	DC10			W15
		DC9			W16
		DC8			W17
		DC7			W18
		DC6			W19
		DC5			W20
		DC4			W21
		DC3			W22
		DC2			W23
	LSB	DC1		LSB	W24

NOTES:

1.   COMMAND DTM and DTM ARQ first character is "d" for "data".
2.   With DTM transmission, control bit KD4 (W11) is set to "0" for no ACK request, and "1" for ACK request.
3.   If a DTM ARQ transmission, control bit KD4 (W11) is set to "0" for binary bits, and"1" for 7-bit ASCII characters.
4.   With DTM transmission, control bit KD3 (W12) is set to "0" for binary bits and "1" for 7-bit ASCII characters.
5.   If a DTM ARQ transmission, control bit KD3 (W12) is set to "0" for flow continue, and "1" for flow pause.
6.   With DTM transmissions, control bit KD2 (W13) is set (a) the same ("0" or "1") as the sequentially adjacent DTM(s) if the transmitted data field is to be reintegrated as part of a larger data text message, and (b) alternately different if independent from the prior adjacent DTM data field(s).
7.   If a DTM ARQ transmission, control bit KD2 (W13) is set the same as the referenced DTM transmission.

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TABLE A-XVIII. Data text message structure - Continued.

NOTES - Continued:

8. With DTM transmission, control bit KD1 (W14) is set alternately to "0" and "1" in any sequence of DTMs, as a sequence control.
9. If a DTM ARQ transmission, control bit KD1 (W14) is set the same as the referenced DTM transmission.
10. Data code (DC) bits are from table A-XVII.

Once a COMMAND DTM word of any type has been received by a called (addressed) or linked station, the station shall remain on channel for the entire specified DTM data block time (if any), unless forced to abandon the protocol by the operator or controller. The start of the DTM data block itself shall be exactly indicated by the end of the COMMAND DTM BASIC or EXTENDED word itself. The station shall attempt to read the entire DTM data block information in the DATA and REPEAT words, and the following COMMAND CRC, plus the expected frame continuation, which shall contain a conclusion (possible preceded by additional functions in the message section, as indicated by additional COMMAND words).

With or without ARQ, identification of each DTM data block and its associated orderwire message (if segmented into sequential DTM data blocks) shall be achieved by use of the sequence and message control bits, KD1 and KD2, (as shown n table A-XVIII) which shall alternate with each DTM transmission and message, respectively. The type of data contained within the data block (ASCII or binary bits) shall be indicated by KD3 as a data identification bit. Activation of the ARQ error control protocol shall use the ARQ control bit KD4. If no ARQ is required, such as in one-way broadcasts, multiple DTM data blocks may be sent in the same frame, but they shall be in proper sequential order if they are transferring a segmented message.

When ARQ error or flow control is required, the COMMAND DTM ARQ shall identify the acknowledged DTM data block by the use of the sequence and message control bits KD1 and KD2, which shall be set to the same values as the immediately preceding and referenced DTM data block transmission. Control bit KD3 shall be used as the DTM flow control to pause or continue (or resume) the flow of the DTM data blocks. The acknowledge (ACK) and request-for-repeat (NAK) functions shall use the ARQ control bit KD4. If no ARQ has been required by the sending station, but the receiving station needs to control the flow of the DTM data blocks, it shall use the DTM ARQ to request a pause in, and resumption of, the flow.

When data transfer ARQ error and flow control is required, the DTM data blocks shall be sent individually, in sequence, and each DTM data block shall be acknowledged before the next DTM data block is sent. Therefore, with ARQ there shall be only one DTM data block transmission in each ALE frame. If the transmitted DTM data block causes a NAK in the returned DTM ARQ, as

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ORIGINAL MESSAGE:

THE QUICK BROWN FOX!

ALE DATA TEXT TRANSMISSION:
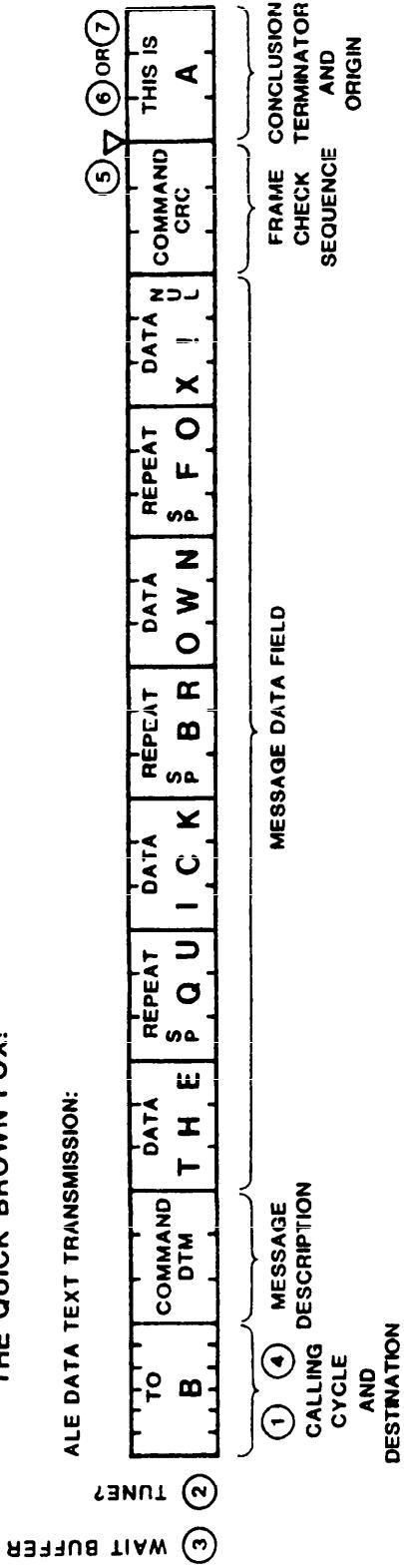
TO	COMMAND	DATA	REPEAT	DATA	REPEAT	DATA	REPEAT	DATA	COMMAND
B	DTM	T H E	$\begin{smallmatrix}S\\P\end{smallmatrix}$ Q U I C K	$\begin{smallmatrix}S\\P\end{smallmatrix}$ B R O W N	$\begin{smallmatrix}S\\P\end{smallmatrix}$ F O X !	$\begin{smallmatrix}U\\L\end{smallmatrix}$			CRC

① ④ MESSAGE
CALLING DESCRIPTION
CYCLE
AND
DESTINATION

MESSAGE DATA FIELD

FRAME CONCLUSION
CHECK TERMINATOR
SEQUENCE AND
ORIGIN

⑤ ▽ ⑥ OR ⑦

THIS IS
A

② TUNE?

③ WAIT BUFFER

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_{CC}) DEPENDS ON SCAN PERIOD (T_S).

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

⑥ <u>THIS WAS</u> TERMINATES PROTOCOL. SUPRESSES ALERTS.

⑦ <u>THIS IS</u> NORMALLY COMPELLED BY CALL RECEIPT (A PAUSES
FOR AN APPROPRIATE RESPONSE FROM B).

GENERAL NOTES:

1. <u>COMMAND</u> DTM IS USED TO INDICATE THE NUMBER OF WORDS IN THE
MESSAGE, WHETHER ASCII OR BINARY DATA, AND THE NUMBER OF
STUFF BITS IN THE LAST WORD.

2. <u>COMMAND</u> CRC CONTAINS FOUR HEXADECIMAL CHARACTERS CONSTITUTING
THE 16-BIT FRAME CHECK SEQUENCE.

| FIGURE A-30. Data text message structure example.

described below, or if ACK or DTM ARQ is detected in the returned frame, or if
no ALE frame is detected at all, the sending station shall resend and exact
duplicate of the unacknowledged DTM data block. It shall send and continue to
resend duplicates (which should be up to at least seven) one at a time and
with appropriate pauses for responses, until the involved DTM data block is
specifically acknowledged by a correct DTM ARQ. Only then shall the next DTM
data block in the sequence be sent. If the sending station is frequently or
totally unable to detect ALE frame or DTM ARQ responses, it should abort the
DTM transfer protocol, terminate the link, and relink and reinitiate the DTM
protocol on a better channel, under operator or controller direction.

Before initiation of the DTM data transfer protocols, the sending stations
should confirm the existence of the DTM capability in the intended receiving
stations, if not already known. When a DTM interrogation function is
required, the following protocol shall be used. Within any standard protocol
frame (using THIS IS), the sending station shall transmit a COMMAND DTM NULL,
with ARQ required, to the intended station(s). These receiving stations shall
respond with the appropriate standard frame and protocol, with the following
variations. They shall include a COMMAND DTM ARQ if they are DTM capable, and
they shall omit it if they are not DTM capable. The sending station shall
examine the ALE and DTM ARQ responses for existence, correctness, and the
status of the DTM KD control bits, as described herein. The transmitted
COMMAND DTM NULL shall have its control bits set as follows: KD1 and KD2 set
opposite of any subsequent and sequential COMMAND DTM BASIC or EXTENDED data
blocks which will be transmitted next; KD3 set to indicate the intended type
of traffic: and KD4 set to require ARQ. The returned COMMAND DTM ARQ shall
have its control bits set as follows: KD1 and KD2 set to match the
interrogating DTM NULL; KD3 set to indicate if the station is ready for DTM
data exchanges, or if a pause is requested; and KD4 set to ACK if the station
is ready to accept DTM data transmissions with the specified traffic type, and
NAK if it cannot or will not participate, or it failed to read the DTM NULL.

The sending (interrogating) station shall handle any and all stations which
return a NAK, or do not return a DTM ARQ at all, or do not respond at all, in
any combination of the following three ways, and for any combination of these
stations. The specific actions and stations shall be selected by the operator
or controller. The sending station shall: (a) terminate the link with them,
using an appropriate and specific call and the THIS WAS terminator; or (b)
direct them to remain and stay linked during the transmissions, using the
COMMAND STAY protocol in each frame immediately before each COMMAND DTM word
and data block sent; or (c) redirect them to do anything else which is
controllable using the COMMAND functions described within this standard.

Each received DTM data block shall be examined using the CRC data integrity
test which is included within the mandatory associated COMMAND CRC which
immediately follows the DTM data block structure. If the data block passes
the CRC test, the data shall be passed through to the appropriate DCE port

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(or normal output as directed by the operator or controller). If the data
block is part of a larger message which was segmented before DTM transfer, it
shall be recombined before output. If any DTM data blocks are received and do
not pass the CRC data integrity test, any detectable but uncorrectable errors
or areas likely to contain errors, should be tagged for further analysis,
error control, or inspection by the operator or controller.

If ARQ is required, the received by unacceptable data block shall be
temporarily stored, and a DTM ARQ NAK shall be returned to sender, who shall
retransmit an exact duplicate DTM data block. Upon receipt of the duplicate,
the receiving station shall again test the CRC. If the CRC is successful, the
data block shall be passed through as described before, the previously
unacceptable data block should be deleted, and a DTM ARQ ACK shall be
returned. If the CRC fails again, both the duplicate and the previously
stored data blocks shall be used to correct, as possible, errors and to create
an "improved" data block. See figure A-31 for an example of data block
reconstruction. The "improved" data block shall then be CRC tested. If the
CRC is successful, the "improved" data block is passed through, the previously
unacceptable data blocks should be deleted, and a DTM ARQ ACK shall be
returned. If the CRC test fails, the "improved" data block shall be stored
and a DTM ARQ NAK shall be returned. This process shall be repeated until:
(a) a received duplicate, or an "improved" data block passes the CRC test (the
data block is passed through, and a DTM ARQ ACK is returned); (b) the maximum
number of duplicates (such as seven or more) have been sent without success
(with actions by the sender as described above); or (c) the operators or
controllers terminate or redirect the DTM protocol.

During reception of ALE frames and DTM data blocks, it is expected that fades,
interferences, and collisions will occur. The receiving station shall have
the capability to maintain synchronization with the frame and the DTM data
block transmission, once initiated. It shall also have the capability to read
and process any colliding and significantly stronger (that is, readable) ALE
signals without confusing them with the DTM signal (basic ALE reception in
parallel, and always listening). Therefore, useful information which may be
derived from readable collisions of ALE signals should not be arbitrarily
rejected or wasted. The DTM structures, especially the DTM EXTENDED, can
tolerate weak signals, short fades, and short noise bursts. For these cases
and for collisions, the DTM protocol can detect DTM words which have been
damaged and "tag" them for error correction or repeats.

The DTM constructions are described herein. Within the DTM data block
structure, the **COMMAND** DTM word shall be placed ahead of the DTM data block
itself. The DTM word shall alert the receiving station that a DTM data block
is arriving, how long it is, what type of traffic it contains, what its
message and block sequence is, and if ARQ is required. It shall also indicate
the exact start of the data block (the end of the **COMMAND** DTM word), and shall
initiate the reception, tracking, decoding, reading, and checking of the
message data contained within the data block, which itself is within the **DATA**
and **REPEAT** words. The message data itself shall be either one of two types,
binary bits or ASCII. The ASCII characters (typically used for text) shall be
the standard 7-bit length, and the start, stop, and parity bits shall be
removed at the sending (and restored at the receiving) station. The binary
bits (typically used for other character formats,

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MIL-STD-188-141A
APPENDIX A
NOTICE 2

- ORIGINAL MESSAGE:

  THE QUICK BROWN FOX!

- EACH ALE DATA TRANSMISSION:

TO	COMMAND DTM	DATA	REPEAT	DATA	REPEAT	DATA	REPEAT	DATA	COMMAND CRC	THIS IS
B		THE	ꜱP QUICK	ꜱP BROWN	FO	WN	FO	X!ꜱL		A

- FIRST TRY – BROKEN MESSAGE (SEND NAK):

  COMMAND DTM
  7A7 THE ꜱP QUICK ꜱP BROWN ꜱP FOX!ꜱL

  COMMAND CRC
  9602 (CRC 9602 REJECT)

- SECOND TRY – BROKEN MESSAGE (SEND NAK):

  COMMAND DTM
  7A7 THE ꜱP QꜱB BR ꜱB W

  COMMAND CRC
  51E4 (CRC 51E4 REJECT)

- THIRD TRY – BROKEN MESSAGE (SEND ACK, SEE COMBINED OVERLAYS):

  COMMAND DTM
  7A7 ꜱB QUICK ꜱB ꜱB X!ꜱL

  COMMAND CRC
  A712 (CRC A712 REJECT)

- COMBINED OVERLAYS ON WORD BASIS, THREE TRIES:

  COMMAND DTM
  7A7 THE ꜱP QUICK ꜱP BROWN ꜱP FOX!ꜱL

  COMMAND CRC
  2C5B (CRC 2C5B GOOD)

- FINALLY RECEIVED MESSAGE

  THE QUICK BROWN FOX!

NOTES:

1. **COMMAND** DTM IN THIS EXAMPLE INDICATES SEVEN WORDS WITH ASCII CHARACTERS AND SEVEN STUFF BITS IN THE LAST WORD. ꜱ

2. ꜱB INDICATES SUBSTITUTE CHARACTERS WHEN BAD AND REJECTED.

3. ꜱP INDICATES SPACE FUNCTION

4. **COMMAND** CRC CONTAINS FOUR HEXADECIMAL CHARACTERS CONSTITUTING THE 16-BIT FRAME CHECK SEQUENCE.

FIGURE A-31. Data text message reconstruction (overlay).

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computer files, and cryptographic devices) may have any (or no) pattern or
format, and they shall be transferred transparently (that is, exactly as they
were input to the sending station) with the same length and without
modification. The size of the DTM BASIC or EXTENDED data block shall be the
smallest multiple of DATA and REPEAT words which will accommodate the quantity
of the ASCII or binary bits message data to be transferred in the DTM data
block. If the message data to be transferred does not exactly fit the
unencoded data field of the DTM block size selected, the available empty
positions shall be "stuffed" with ASCII "DEL" (1111111) characters or all "1"
bits. The combined message and "stuff" data in the uncoded DTM data field
shall then be checked by the CRC for error control in the DTM protocol. The
resulting 16-bit CRC word shall always be inserted into the COMMAND CRC word
which immediately follows the DTM data block words themselves. All the bits
in the data filed shall then be inserted into standard DATA and REPEAT words,
on a 21-bit or 3-character basis, and Golay FEC encoded, interleaved, and
tripled for redundancy. Immediately after the COMMAND DTM word, the DTM DATA
and REPEAT words shall follow standard word format, and the COMMAND CRC shall
be at the end.

The DTM BASIC data block has a relatively compact range of sizes from 0 to 31
words and shall be used to transfer any quantity of message data between zero
and the maximum limits for the DTM BASIC structure, which is up to 651 bits
or 93 ASCII characters. It is capable of counting the exact quantity of
message data which it contains, on a bit-by-bit basis. It should be used as a
single DTM for any message data within this range. It shall also be used to
transfer any message data in this size range which is an "overflow" from the
larger size (and increments) DTM EXTENDED data blocks (which shall immediately
precede the DTM BASIC in the DTM sequence of sending).

The DTM EXTENDED data blocks are also variable in size in increments of single
ALE words up to 351. They should be used as a single, large DTM to maximize
the advantages of DTM throughput. The size of the data block should be
selected to provide the largest data field size which can be totally filled by
the message data to be transferred. Any "overflow" shall be in a message data
segment sent within an immediately following and appropriately sized DTM
EXTENDED or BASIC data block. Under operator or controller direction,
multiple DTM EXTENDED data blocks, with smaller than the maximum appropriate
ID sizes, should be selected if they will optimize DTM data transfer
throughput and reliability. However, these multiple data blocks will require
that the message data be divided into multiple segments at the sending
station, that they shall be sent only in the exact order of the segments in
the message, and that the receiving stations must recombine the segments into
a complete received message. When binary bits are being transferred, the
EXTENDED data field shall be filled exactly to the last bit. When ASCII
characters are being transferred, there are no stuff bits as the 7-bit
characters fit the ALE word 21-bit data field exactly.

If stations are exchanging DTM data blocks and DTM ARQ's, they may combine
both functions in the same frames, and they shall discriminate based on the
direction of transmission and the sending and destination addressing. If ARQ
is required in a given direction, only one DTM data block shall be allowed
within any frame in that direction, and only on DTM ARQ shall be allowed in

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each frame in the return direction. If no ARQ is required in a given direction, multiple DTM data blocks may be included in frames in that direction, and multiple DTM ARQ's may be included in the return direction.

As always throughout the DTM protocol, any sequence of DTM data blocks to be transferred shall have the KD1 sequence control bits alternating with the preceding and following DTM data blocks (except duplicates for ARQ, which shall be exactly the same as the originally transmitted DTM data block).

Also, all multiple DTM data blocks transferring multiple segments of a larger data message shall all have their KD2 message control bits set to the same value, and opposite of the preceding and following messages. If a sequence of multiple but unrelated DTM data blocks are sent (such as several independent and short messages within several DTM BASIC data blocks), they may be sent in any sequence. However, the KD1 or KD2 sequence and message control bits shall alternate with those in the adjacent DTM data blocks.

The COMMAND DTM words shall be constructed as shown on table A-XVIII. The preamble shall be COMMAND (110) in bits P3 through P1 (W1 through W3). The first character shall be "d" (1100100) in bits C1-7 through C1-1) (W4 through W10), which shall identify the DTM "data" function.

For DTM BASIC, EXTENDED, and NULL, when the "ARQ" control bit KD4 (W11) is set to "0", no correct data receipt acknowledgement is required; and when set to "1", it is required. For DTM ARQ, "ARQ" control bit KD4 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 DTM ARQ responding to a DTM NULL interrogation, KD4 "0" indicates nonparticipation in the DTM protocol or traffic type, and KD4 "1" indicates affirmative participation in both the DTM protocol and traffic type.

For DTM BASIC, EXTENDED, and NULL, when the "data type" control bit KD3 (W12) is set to "0", the message data contained within the DTM data block shall be binary bits with no required format or pattern; and when KD3 is set to "1" the message data is 7-bit ASCII characters. For DTM ARQ, "flow control bit KD3 is set to indicate that the DTM transfer flow should continue, or resume; and when KD3 is set to "1" it indicates that the sending station should pause (until another and identical DTM ARQ is returned, except that KD3 shall be "0").

For DTM BASIC, EXTENDED, and NULL, when the "message" control bit KD2 (W13) is set to the same value as the KD2 in any sequentially adjacent DTM data block, the message data contained within those adjacent blocks (after individual error control) shall be recombined with the message data within the present DTM data block to segment-by-segment reconstitute the original whole message; and when KD2 is set opposite to any sequentially adjacent DTM data blocks, those data blocks contain separate message data and shall not be combined. For DTM ARQ, "message" control bit KD2 shall be set to match the referenced DTM data block KD2 value to provide message confirmation.

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For DTM BASIC, EXTENDED, and NULL, the "sequence" control bit KD1 (W14) shall be set opposite to the KD1 value in the sequentially adjacent DTM BASIC, EXTENDED, or NULLs to be sent (the KD1 values therefore alternate, regardless of their message dependencies). When KD1 is set to the same value as any sequentially adjacent DTM sent, it indicates that it is a duplicate (which shall be exactly the same). For DTM ARQ, "sequence" control bit KD1 shall be set to match the referenced DTM data block or NULL KD1 value to provide sequence confirmation.

When used for the DTM protocols, the ten DTM data code (DC) bits DC10 through DC1 (W15 through W24) shall indicate the DTM mode (BASIC, EXTENDED, ARQ, or NULL). They shall also indicate the size of the message data and the length of the data block. The DTM NULL DC value shall be "0" (0000000000), and it shall designate the single COMMAND DTM NULL word. The DTM EXTENDED DC values shall range from "1" (0000000001) to "351" (0101011111), and they designate the COMMAND DTM EXTENDED word and the data block multiple of DATA and REPEAT words which define the variable data block sizes. The EXTENDED sizes shall range from 1 to 351 words, with a range of 21 to 7371 binary bits, in increments of 21, or 3 to 1053 ASCII characters, in increments of 3. The DTM BASIC DC values shall range for "353" (0101100001) to "1023" (1111111111), and they shall designate the COMMAND DTM BASIC word and the exact size of the message data in compact and variable size data blocks, with up to 651 binary bits or 93 ASCII characters. The DTM ARQ DC value shall be "352" (0101100000), and it shall designate the single COMMAND DTM ARQ word. The DC values "384" (0110000000) and all higher multiples of "32m" (m x 100000) shall be reserved until standardized. See table A-XVII for DC values and DTM block sizes and other characteristics.

80.5 Data block message (DBM) mode. The DBM orderwire message mode enables ALE stations to communicate either full ASCII, or unformatted binary bit messages to and from any selected ALE station(s) for direct output to and input from associated data terminal or other DTE devices through their standard DCE ports. This DBM data transfer function is a high-speed mode (relative to DTM and AMD) with improved robustness, especially against long fades and noise bursts. When used over MF/HF by the ALE system, DBM orderwire messages may be unilateral or bilateral, and broadcast or acknowledged. As the DBM data blocks can be very large, this special orderwire message function enables exploitation of deep interleaving and FEC techniques to penetrate HF-channel long fades and large noise bursts.

The DBM 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 the direction of the operator or controller, the stations should have the capability of using the DBM data traffic mode (ASCII or binary bits) to control switching of the DBM 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 DBM 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 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 on table A-XIX, and they are
summarized below:

COMMAND DTM Mode	BASIC	EXTENDED	ARQ	NULL
Maximum Size, Bits	588	262836	0	
Cyclic Redundancy Check	16 Bits	16 Bits	0	
Data Capacity, ASCII	0-81	81-37377, by 84	0	
Data Capacity, Bits	0-572	572-262820, by 588	0	
ALE Word Redundancy	49 Fixed	49-21903, by 49	0	
Data Transmission	3.136 Sec	3.136 Sec -		
		Increments	23.26 Min, by	

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-32 shows an example of an exchange using
the DBM orderwire to transfer and acknowledge messages. Figure A-33 shows an
example of a DBM data interleaver, and figure A-34 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 in 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 (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_w)
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	ID×64ms	8n+1
	0 1 1 1 0 1 1 1 0 0	444	21756	261066	37293	23.21min	3553
	0 1 1 1 0 1 1 1 0 1	445	21805	261644	37377	23.26min	3561
(RESERVED)	0 1 1 1 0 1 1 1 1 0	446	---	---	---	---	---
	0 1 1 1 0 1 1 1 1 1	447	---	---	---	---	---
DBM BASIC (EXACT)	0 1 1 1 1 0 0 0 0 0	448	49	0	0	3.136s	9
	0 1 1 1 1 0 0 0 0 1	449		1	0		
	0 1 1 1 1 0 0 0 1 0	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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FIGURE A-32. Data block message structure and ARQ example.
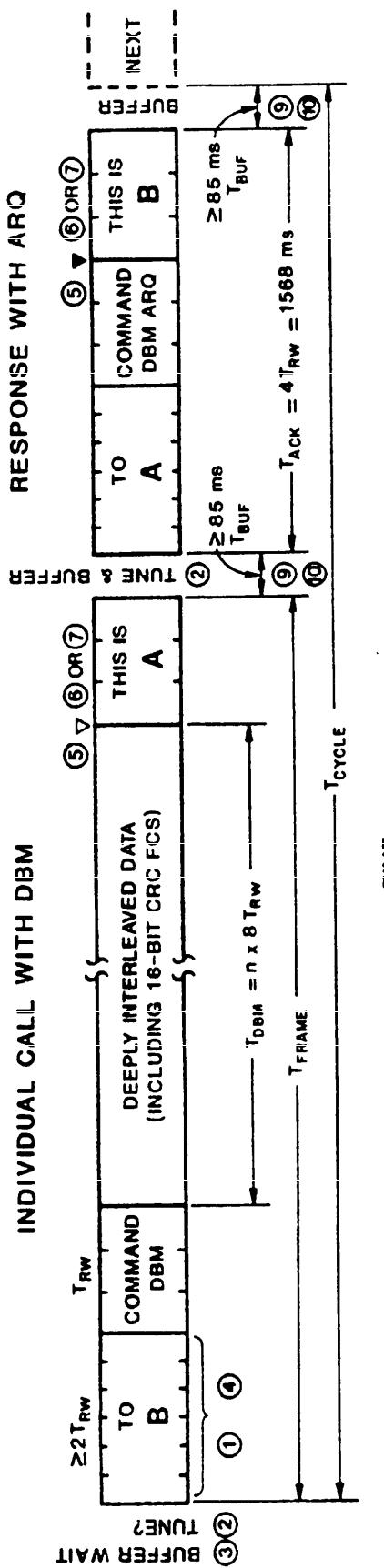
NOTES:

① 1-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).

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 AN APPROPRIATE RESPONSE FROM THE OTHER STATION).

⑨ TIME APPROXIMATION, PROPAGATION AND TURNAROUND.

⑩ REDUNDANT WORD PHASE DELAY, 0 TO T_{RW}, FOR ALL
STATION TRANSMISSIONS AFTER THE FIRST.

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MIL-STD-188-141A
APPENDIX A
NOTICE 2

QUANTITY OF ROWS = INTERLEAVING DEPTH (ID)

READ DATA INTO MATRIX LEFT TO RIGHT ROW BY ROW (D_x TO D_{x+11}, WITH ASSOCIATED G_x TO G_{x+11}). FIRST CHARACTER (OR BIT) FIRST, MSB OF CHARACTERS FIRST.

FIRST TONE SENT

DATA BITS "D"

GOLAY CHECK BITS "G"

NEXT TO LAST TONE SENT

LAST TONE SENT

START OF SECOND TONE SENT

EXAMPLE STUFF BITS "SB"

CRC FCS BITS "X" (ALWAYS LAST)

DATA TRANSMITTED OUT OF MATRIX, COLUMN BY COLUMN, TOP TO BOTTOM (DX, $DX+12$, $DX+24$ .....)

FIGURE A-33. Data block message interleaver and deinterleaver.
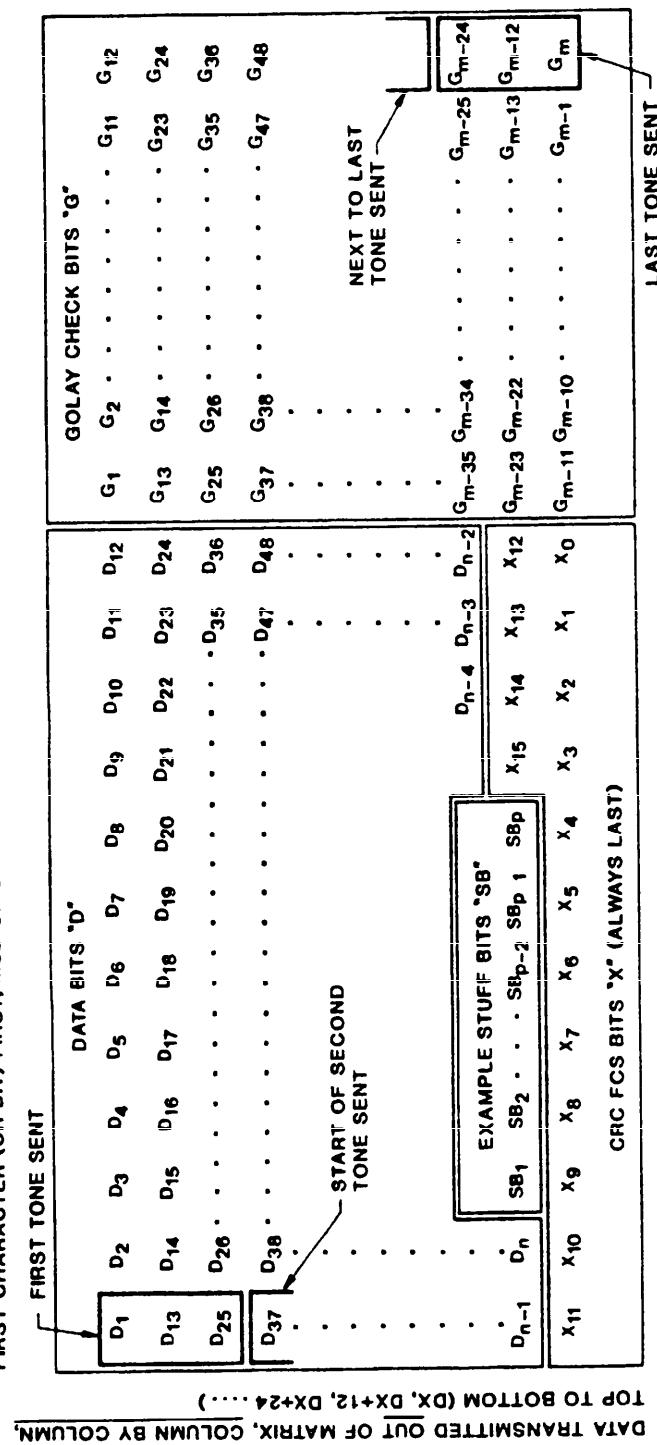
NOTES:

1. QUANTITY OF CRC FSC BITS (x) = 16.

2. STUFF BITS (SB) SET TO "1".

3. ID IS ALWAYS A MULTIPLE OF 49 TO PRESERVE WORD PHASE.

4. QUANTITY OF DATA FIELD OR GOLAY CHECK BITS = m = ID x 12.

5. SIZE OF DATA BLOCK MESSAGE, TOTAL = DATA FIELD BITS & GOLAY CHECK BITS = $2m$.

6. QUANTITY OF DATA BITS = n.
   - IN DBM BASIC: $0 \leq n \leq 572$.
   - IN DBM EXTENDED: n = ID x 12 FOR BINARY; n = (ID x 12)-P FOR ASCII.

7. QUANTITY OF STUFF BITS: $P = m - n - 16$.
   - IN DBM BASIC: $0 \leq P \leq 572$.
   - IN DBM EXTENDED: P = 0 FOR BINARY; $0 \leq P \leq 6$ FOR ASCII.
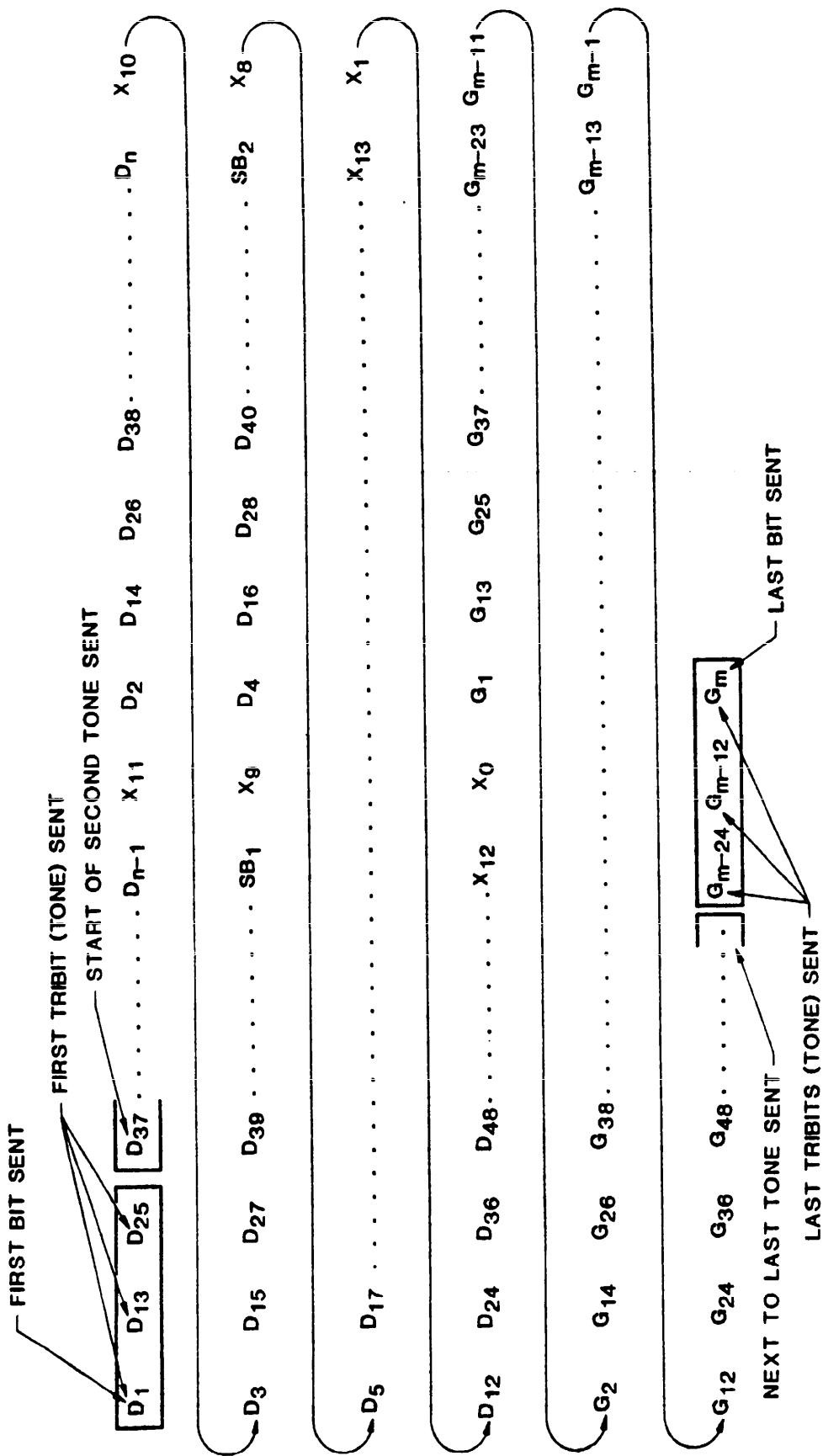
FIGURE A-34. Data block message example.

NOTES:

1. QUANTITY OF TONES SENT = $2m+3 = (2 \times 12 \times ID) + 3 = ID \times 8$

2. TIME OF BLOCK SENT = $ID \times 8 \times 8 \text{ ms} = ID \times 64 \text{ ms}$.

until all the DBM 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.

Once a COMMAND DBM word of any type has been received by a called (addressed)
or linked station, the station shall remain on channel for the entire
specified DBM data block time (if any), unless forced to abandon the protocol
by the operator or controller. The start of the DBM data block itself shall
be exactly indicated by the end of the COMMAND DBM BASIC or EXTENDED word
itself. The station shall attempt to read the entire DBM data block
information, plus the expected frame continuation, which shall contain a
conclusion (possible preceded by additional functions in the message section,
as indicated by additional COMMAND words).

With or without ARQ, identification of each DBM data block and its associated
orderwire message (if segmented into sequential DBM data blocks) shall be
achieved by use of the sequence and message control bits, KB1 and KB2, (see
table A-XX) which shall alternate with each DBM transmission and message,
respectively. The type of data contained within the data block (ASCII or
binary bits) shall be indicated by KB3 as a data identification bit.
Activation of the ARQ error-control protocol shall use the ARQ control bit
KB4. If no ARQ is required, such as in one-way broadcasts, multiple DBM data
blocks may be sent in the same frame, but they shall be in proper sequence if
they are transferring a segmented message.

When ARQ error or flow control is required, the COMMAND DBM ARQ shall identify
the acknowledged DBM data block by the use of the sequence and message control
bits KB1 and KB2, which shall be set to the same values as the immediately
preceding and referenced DBM data block transmission. Control bit KB3 shall
be used as the DBM flow control to pause or continue (or resume) the flow of
the DBM data blocks. The ACK and NAK functions shall use the ARQ control bit
KB4. If no ARQ has been required by the sending station, but the receiving
station needs to control the flow of the DBM data blocks, it shall use the DBM
ARQ to request a pause in, and resumption of, the flow.

When data transfer ARQ error and flow control is required, the DBM data blocks
shall be sent individually and in sequence. Each DBM data block shall be
individually acknowledged before the next DBM data block is sent. Therefore,
with ARQ there shall be only one DBM data block transmission in each frame.
If the transmitted DBM data block causes a NAK in the returned DBM ARQ, as
described below, or if no ACK or DBM ARQ is detected in the returned frame, or
if no frame is detected at all, the sending station shall resend an exact
duplicate of the unacknowledged DBM data block. It shall continue to resend
duplicates (which should be at least seven), one at a time and with
appropriate pauses for responses, until the involved DBM data block is
specifically acknowledged by a correct DBM ARQ. Only then shall the next DBM
data block in the sequence be sent. If the sending station is frequently or
totally unable to detect frame or DBM ARQ responses, it should abort the DBM
transfer protocol, terminate the link and relink and reinitiate the DBM
protocol on a better channel (under operator or controller direction).

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MIL-STD-188-141A
APPENDIX A
NOTICE 2

TABLE A-XX. <u>Data block message structures</u>.

	DBM Bits			Word Bits	
COMMAND preamble	MSB LSB	P3 = 1 P2 = 1 P1 = 0		MSB	W1 W2 W3
First character "d"	MSB LSB	C1 (bit-7) = 1 C1 (bit-6) = 1 C1 (bit-5) = 0 C1 (bit-4) = 0 C1 (bit-3) = 0 C1 (bit-2) = 1 C1 (bit-1) = 0			W4 W5 W6 W7 W8 W9 W10
Control bits	MSB LSB	KB4 KB3 KB2 KB1			W11 W12 W13 W14
DTM data code bits	MSB LSB	BC10 BC9 BC8 BC7 BC6 BC5 BC4 BC3 BC2 BC1		 LSB	W15 W16 W17 W18 W19 W20 W21 W22 W23 W24

NOTES:

1. COMMAND DBM and DBM ARQ first character is "b" for "block".
2. With DBM transmission, control bit KB4 (W11) is set to "0" for no ACK request, and "1" for ACK request.
3. If a DBM ARQ transmission, control bit KB4 (W11) is set to "0" for ACK, and "1" for NAK.
4. With DBM transmissions, control bit KB3 (W12) is set to "0" for binary bits and "1" for 7-bit ASCII characters.
5. If a DBM ARQ transmission, control bit KB3 (W12) is set to "0" for flow continue, and "1" for flow pause.
6. With DBM transmissions, control bit KB2 (W13) is set: (a) the same ("0" or "1") as the sequentially adjacent DBM(s) if the transmitted data field is to be reintegrated as part of a larger data block message, and (b) alternately different if independent from the prior adjacent DBM data field(s).
7. If a DBM ARQ transmission, control bit KB2 (W13) is set the same as the referenced DBM transmission.
8. With DBM transmissions, control bit KB1 (W14) is set alternately to "0" and "1" in any sequence of DBMs as a sequence control.
9. If a DBM ARQ transmission, control bit KB1 (W14) is set the same as the referenced DBM transmission.
10. Block code (BC) bits are from table A-XIX.

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Before initiation of the DBM data transfer protocols, the sending stations
should confirm the existence of the DBM capability in the intended receiving
stations, if not already known. When a DBM interrogation function is
required, the following protocol shall be used. Within any standard protocol
frame (using THIS IS), the sending station shall transmit a COMMAND DBM NULL,
with ARQ required, to the intended station(s). These receiving stations shall
respond with the appropriate standard frame and protocol, with the following
variations. They shall include a COMMAND DBM ARQ if they are DBM capable, and
they shall omit it if they are not DBM capable. The sending station shall
examine the ALE and DBM ARQ responses for existence, correctness, and the
status of the DBM KB control bits, as described herein. The transmitted
COMMAND DBM NULL shall have its control bits set as follows: KB1 and KB2 set
opposite of any subsequent and sequential COMMAND DBM BASIC or EXTENDED data
blocks which will be transmitted next; KB3 set to indicate the intended type
of traffic; and KB4 set to require ARQ. The returned COMMAND DBM ARQ shall
have its control bits set as follows: KB1 and KB2 set to match the
interrogating DBM NULL; KB3 set to indicate if the station is ready for DBM
data exchanges, or if a pause is requested; and KB4 set to ACK if the station
is ready to accept DBM data transmissions with the specified traffic type, and
NAK if it cannot or will not participate, or if it failed to read the DBM
NULL.

The sending (interrogating) station shall handle any stations which return a
NAK, or do not return a DBM ARQ, or do not respond, in any combination of the
following, and for any combination of these stations. The specific actions
and stations shall be selected by the operator or controller. The sending
station shall: (a) terminate the link with these stations, using an
appropriate and specific call and the THIS WAS terminator; (b) direct the
stations to remain and stay linked during the transmissions, using the COMMAND
STAY protocol in each frame immediately before each COMMAND DBM word and data
block sent; or (c) redirect them to do anything else which is controllable
using the COMMAND functions described within this standard.

Each received DBM data block shall be examined using the CRC data integrity
test which is embedded within the DBM structure and protocol. If the data
block passes the CRC test, the data shall be passed through to the appropriate
DCE port (or normal output as directed by the operator or controller). If the
data block is part of a larger message which was segmented before DBM
transfer, it shall be recombined before output. If any DBM data blocks are
received and do not pass the CRC data integrity test, any detectable but
uncorrectable errors; or areas likely to contain errors, should be tagged for
further analysis, error control, or inspection by the operator or controller.

If ARQ is required, the received but unacceptable data block shall be
temporarily stored, and a DBM ARQ NAK shall be returned to the sender, who
shall retransmit an exact duplicate DBM data block. Upon receipt of the
duplicate, the receiving station shall again test the CRC. If the CRC is
successful, the data block shall be passed through as described before, the
previously unacceptable data block should be deleted, and a DBM ARQ ACK shall
be returned. If the CRC fails again, both the duplicate and the previously
stored data blocks shall be used to correct, as possible, errors and to create
an "improved" data block. See figure A-31 for an example of data

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block reconstruction. The "improved" data block shall then be CRC tested. If the CRC is successful, the "improved" data block is passed through, the previously unacceptable data blocks should be deleted, and a DBM ARQ ACK shall be returned. If the CRC test fails, the "improved" data block shall also be stored and a DBM ARQ NAK shall be returned. This process shall be repeated until: (a) a received duplicate, or an "improved" data block passes the CRC test (and the data block is passed through, and a DBM ARQ ACK is returned); (b) the maximum number of duplicates (such as seven or more) have been sent without success (with actions by the sender as described above); or (c) the operators or controllers terminate or redirect the DBM protocol.

During reception of frames and DBM data blocks, it is expected that fades, interferences, and collisions will occur. The receiving station shall have the capability to maintain synchronization with the frame and the DBM data block transmission, once initiated. It shall also have the capability to read and process any colliding and significantly stronger (that is, readable) ALE signals without confusing them with the DBM signal (basic ALE reception in parallel, and always listening). The DBM structures, especially the DBM EXTENDED, can tolerate significant fades, noise bursts, and collisions. Therefore, useful information which may be derived from readable collisions of ALE signals should not be arbitrarily rejected or wasted.

The DBM constructions shall be as described herein. Within the DBM data block structure, a COMMAND DBM word shall be placed ahead of the encoded and interleaved data block itself. The DBM word shall alert the receiving station that a DBM data block is arriving, how long it is, what type of traffic it contains, what its ID is, what its message and block sequence is, and if ARQ is required. It shall also indicate the exact start of the data block itself (the end of the COMMAND DBM word itself) and shall initiate the reception, tracking, deinterleaving, decoding, and checking of the data contained within the block. The message data itself shall be either one of two types, binary bits or ASCII. The ASCII characters (typically used for text) shall be the standard 7-bit length, and the start, stop, and parity bits shall be removed at the sending (and restored at the receiving) station. The binary bits (typically used for other character formats, computer files, and cryptographic devices) may have any (or no) pattern or format, and they shall be transferred transparently, that is, exactly as they were input to the sending station, with the same length and without modification. The value of the ID shall be the smallest (multiple of 49) which will accommodate the quantity of ASCII or binary bits message data to be transferred in the DBM data block. If the message data to be transferred does not exactly fit the uncoded data field of the DBM block size selected (except for the last 16 bits, which are reserved for the CRC), the available empty positions shall be "stuffed" with ASCII "DEL" characters or all "1" bits. The combined message and "stuff" data in the uncoded DBM data field shall then be checked by the CRC for error control in the DBM protocol. The resulting 16-bit CRC word shall always occupy the last 16 bits in the data field. All the bits in the field shall then be Golay FEC encoded, on a 12-bit basis, to produce rows of 24-bit code words, arranged from top to bottom in the interleaver matrix (or equivalent), as shown in figure A-33. The bits in the matrix are then read out by columns (of length equal to the ID) for transmission. Immediately after the COMMAND DBM word, the encoded and interleaved data blocks bits shall follow in bit format, three bits per symbol (tone).

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The DBM BASIC data block has a fixed size (ID 49) and shall be used to transfer any quantity of message data between zero and the maximum limits for the DBM BASIC structure, which is up to 572 bits or 81 ASCII characters. It is capable of counting the exact quantity of message data which it contains, on a bit-by-bit basis. It should be used as a single DBM for any message data within this range. It shall also be used to transfer any message data in this size range which is an "overflow" from the larger size (and increments) DBM EXTENDED data blocks (which shall immediately precede the DBM BASIC in the DBM sequence of sending).

The DBM EXTENDED data blocks are variable in size, in increments of 49 times the ID. They should be used as a single, large DBM to maximize the advantages of DBM deep interleaving, FEC techniques, and higher speed (than DTM or AMD) transfer of data. The ID of the EXTENDED data block should be selected to provide the largest data field size which can be totally filled by the message data to be transferred. Any "overflow" shall be in a message data segment sent within an immediately following DBM EXTENDED or BASIC data block. Under operator or controller direction, multiple DBM EXTENDED data blocks, with smaller than the maximum appropriate ID sizes, should be selected if they will optimize DBM data transfer throughput and reliability. However, these multiple data blocks will require that the message data be divided into multiple segments at the sending station and sent only in the exact order of the segments in the message. The receiving stations must recombine the segments into a complete received message. When binary bits are being transferred, the EXTENDED data field shall be filled exactly to the last bit. When ASCII characters are being transferred, the EXTENDED data field may have 0 to 6 "stuff" bits inserted. Individual ASCII characters shall not be split between DBM data blocks and the receiving station shall read the decoded data field on a 7-bit basis, and it shall discard any remaining "stuff" bits (modulo-7 remainder).

If stations are exchanging DBM data blocks and DBM ARQs, they may combine both functions in the same frames. They shall discriminate based on the direction of transmission and the sending and destination addressing. If ARQ is required in a given direction, only one DBM data block shall be allowed within any frame in that direction, and only one DBM ARQ shall be allowed in each frame in the return direction. If no ARQ is required in a given direction, multiple DBM data blocks may be included in frames in that direction, and multiple DBM ARQs may be included in the return direction.

As always throughout the DBM protocol, any sequence of DBM data blocks to be transferred shall have their KB1 sequence control bits alternating with the preceding and following DBM data blocks (except duplicates for ARQ, which shall be exactly the same as their originally transmitted DBM data block). Also, all multiple DBM data blocks transferring multiple segments of a large data message shall all have their KB2 message control bits set to the same value, and opposite of the preceding and following messages. If a sequence of multiple but unrelated DBM data blocks are sent (such as several independent and short messages within several DBM BASIC data blocks), they may be sent in any sequence. However, when sent, the associated KB1 and KB2 sequence and message control bits shall alternate with those in the adjacent DBM data blocks.

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The COMMAND DBM words shall be constructed as shown on 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 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 data 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 <u>Cyclic redundancy check (CRC)</u>. 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

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

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 on 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 on 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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TABLE A-XXI. Cyclic redundancy check structure.

	CRC bits		Word bits
COMMAND preamble	MSB	P3=1	MSB W1
		P2=1	W2
	LSB	P1=0	W3
(c) MSB		C1-7=1	W4
		C1-6=1	W5
First character(s)		C1-5=1	W6
"x,y,z,{"		C1-4=1	W7
		C1-3=0	W8
(x) MSB		C1-2=X^{15}	W9
(c) LSB		C1-1=X^{14}	W10
		X^{13}	W11
		X^{12}	W12
		X^{11}	W13
		X^{10}	W14
		X^{9}	W15
		X^{8}	W16
		X^{7}	W17
		X^{5}	W18
		X^{5}	W19
		X^{4}	W20
		X^{3}	W21
		X^{2}	W22
		X^{1}	W23
(x) LSB		X^{0}	LSB W24

NOTES:

1. **COMMAND** CRC first character is one of four, "x" (1111000),
    "y" (1111001), "z" (1111010), or "{" (1111011), depending on
    CRC bits X^{15} and X^{14}, which are also C1-2 and C1-1, respectively.

2. "X^{n}" indicates FCS bits.

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checked ALE words, including their preambles. If it is necessary to check the ALE words in the calling cycle (TO) preceding the message section, an optional calling cycle COMMAND CRC shall be used as the calling cycle terminator (first FROM or COMMAND), shall therefore appear first in the message section, and shall analyze the calling cycle words in their simplest (Tc), nonredundant and nonrotated form. If it is necessary to check the words in a conclusion (THIS IS or THIS WAS), an optional conclusion CRC shall directly precede the conclusion portion of the call, shall be at the end of the message section, and shall itself be directly preceded by a separate COMMAND CRC (which may be used to check the message section or calling cycle, as described herein). Stations shall perform CRC analysis on all received ALE transmissions and shall be prepared to compare analytical FCS values with any COMMAND CRC words which may be received. If a CRC FCS comparison fails, an automatic (or operator initiated) retransmission request (ARQ) or other appropriate procedure may be used to correct the message, as may be defined in this standard.

80.7 Tune and wait. The COMMAND tune and wait special control function directs the receiving station(s) to perform the initial parts of the handshake, up through tuneup, and wait on channel for further instructions during the specified time limit. The time limit timer is essentially the WRTT wait for response and tune timer, as used in net slotted responses where its value Twrn is set by the timing information in the special control instruction, and it starts from the detected end of the call. The COMMAND tune and wait instruction shall suppress any normal or preset responses. Except for the tuneup itself, the receiving station(s) shall make no additional emissions, and they shall quit the channel and resume scan if no further instructions are received.

> NOTE: This special control function enables very slow tuning
> stations, or stations which must wait for manual operator
> interaction, to effectively interface with automated networks.

The COMMAND tune and wait shall be constructed as follows and as shown on table A-XXII. The preamble shall be COMMAND (110) in bits P3 through P1 (W1 through W3). The first character (C1) shall be "t" (1110100) in bits C1-7 through C1-1 (W4 through W10) and "t" (1110100) in bits C2-7 through C2-1 (W11 through W17), for "time, tuneup." The "T" time bits TB7 through TB1 (W18 through W24) shall be values selected from table A-XXIII, and limited as shown on table A-XXIV. The lowest value (00000) shall cause the tuning to be performed immediately, with zero waiting time, resulting in immediate return to normal scan after tuning.

80.8 Time-related special functions for all COMMANDs. These special control functions permit the manipulation of timing in the ALE system. They are based on the standard "T" time values, presented on table A-XXIII, which have the following ranges bases on exact multiples of Tw (130.66...ms) or Trw (392 ms).

- 0 to 4 seconds in 1/8 second (Tw) increments
- 0 to 36 seconds in 1 second (3 Trw) increments
- 0 to 31 minutes in 1 minute (153 Trw) increments
- 0 to 29 hours in 1 hour (9184 Trw) increments

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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 on table A-XXIV. The basic
structure is the same as on table A-XXII.

TABLE A-XXII. Tune and wait structure.

	Tune and Wait Bits		Word Bits	
COMMAND Preamble	MSB LSB	P3 = 1 P2 = 1 P1 = 0	MSB	W1 W2 W3
First Character "t"	MSB LSB	C1-7 = 1 C1-6 = 1 C1-5 = 1 C1-4 = 0 C1-3 = 1 C1-2 = 0 C1-1 = 0		W4 W5 W6 W7 W8 W9 W10
Second Character "t"	MSB LSB	C2-7 = 1 C2-6 = 1 C2-5 = 1 C2-4 = 0 C2-3 = 1 C2-2 = 0 C2-1 = 0		W11 W12 W13 W14 W15 W16 W17
Time Bits	MSB LSB	TB7 TB6 TB5 TB4 TB3 TB2 TB1	 LSB	W18 W19 W20 W21 W22 W23 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)	LBS 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	392.0ms	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"	"a" ($\leq$0011111) (See Note 5)	Wait on channel for time T and stay linked, don't transmit unless commanded, and ignore all signals during T if not understood; except ALE frame reacquisition by T (must be in correct redundant word phase). T in multiples of Trw, as indicated by binary value of last 14 bits ($\leq$0011111 1111111 = 4095s), 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 standard 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 employees 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 on 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	U12-7		W18
		U12-6		W19
		U12-5		W20
		U12-4		W21
		U12-3		W22
		U12-2		W23
	LSB	U12-1	LSB	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.

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Characters per message (DTM)	0 to 1053 full ASCII characters per block
Characters per message (DTM)	0 to 37377 full ASCII characters per block
Character rate (DTM, AMD, basic ALE)	7.653
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 (Trw) or 392 ms per triple redundant word (Trw)
Message period (DBM)	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-188-141 whenever linking protection (LP) is a requirement for the HF radio implementation. The functional capability herein described includes linking protection, linking protection application levels, 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 Robbins 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, U.S. 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 <u>Introduction</u>. Linking protection (LP) refers to the protection of the linking function required to establish, control, maintain, and terminate the radio link. Because this protection is applied to the link establishment function, linking protection is a data link layer function in terms of International Standard 7498 (ISO 7498-1984), the Open Systems Interconnection (OSI) Reference Model. Figure B-1 shows a conceptual model of the MIL-STD-188-141 data link layer functions, showing the placement within the data link layer at which linking protection shall be implemented. 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 application levels and their corresponding protection interval (PI) are defined in 40.2.1 through 40.2.1.5.

40.2 <u>Linking protection</u>. 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 in figure B-2. 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.

40.2.1 <u>Linking protection application levels</u>. The following application levels of LP are defined herein, with the unclassified enhanced application level (AL-2) currently providing the highest degree of protection. The classified AL-4 (offering the highest degree of protection) and unclassified but sensitive AL-3 are not yet standardized, but, are included herein as design objectives. All protected radios shall be capable of operation at the AL-1 level. A means shall be provided to disable automatic linking at linking protection application levels less secure than the application level in use by the station being called. For example, a station which is operating at AL-2 shall be able to disable the receiver from listening for linking attempts at AL-0 and AL-1. (DO: alert the operator but do not link automatically when a valid call is received from a transmitter with a lower linking protection application level.) This mechanism shall not preclude the operator from manually initiating ALE using a disabled application level. This manual override is required for interoperability.

40.2.1.1 <u>Unprotected application level AL-0</u>. Assignment of the unprotected application level (AL-0) indicates that no linking protection is being employed. No protection is provided against interfering, unintentional, or malicious linking attempts. All protected HF radios shall be capable of operation in the AL-0 mode.

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TRANSMIT RECEIVE

ALE SUBLAYER	ALE PROTOCOL	ALE PROTOCOL
	(ALE WORD)	WORD SYNC

PROTECTION SUBLAYER	ENCRYPT	DECRYPT

FEC SUBLAYER	(BIT PATTERN)	PATTERN SYNC
	GOLAY ENCODER	GOLAY DECODER
	INTERLEAVE	DEINTERLEAVE
	REDUNDANCY	MAJ. VOTE

BITS BITS

MODULATOR	DEMODULATOR
TRANSMITTER	RECEIVER
ANTENNA	ANTENNA

SEVEN LAYER OSI MODEL

- APPLICATION LAYER
- PRESENTATION LAYER
- SESSION LAYER
- TRANSPORT LAYER
- NETWORK LAYER
- DATALINK LAYER
- PHYSICAL LAYER

FIGURE B-1. Data link layer with linking protection sublayer.

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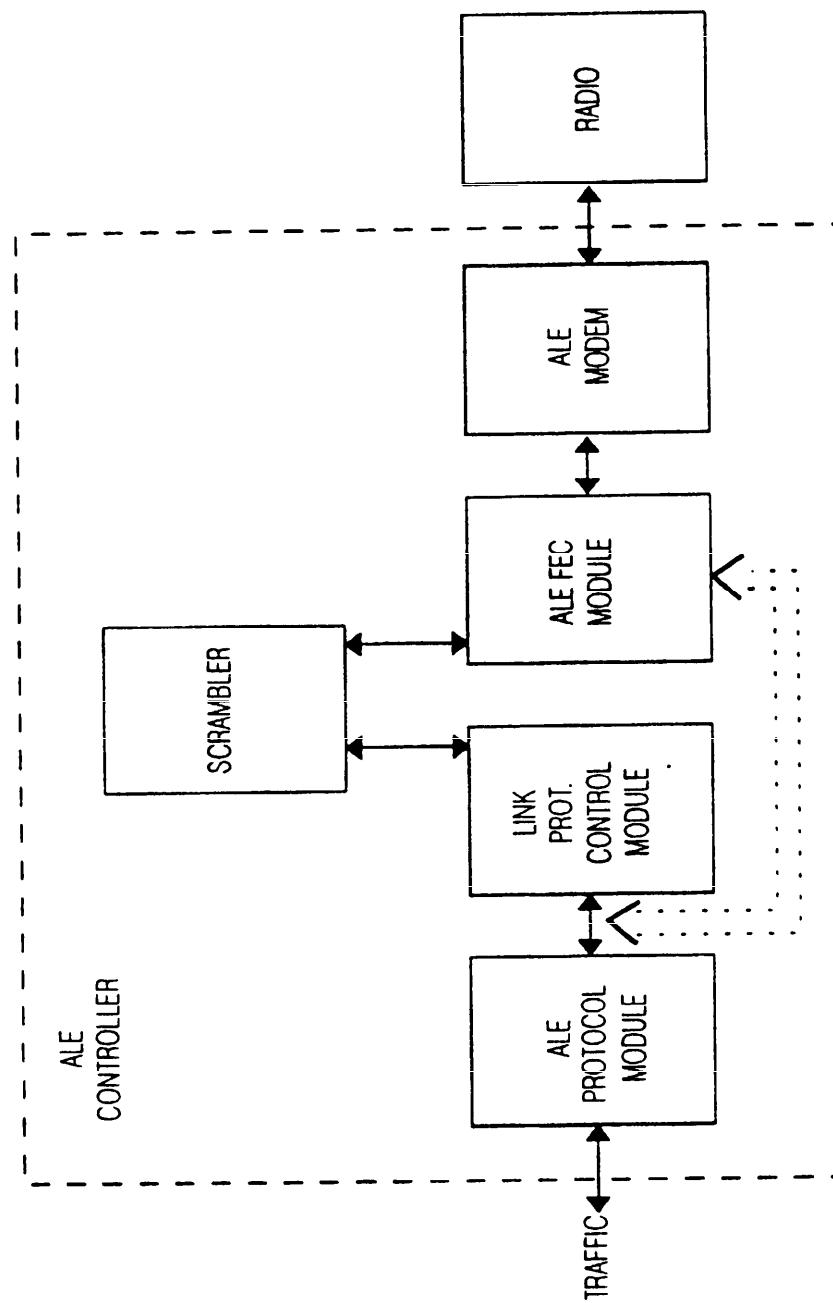
NOTE: the double dashed line (===) indicates unprotected mode.

FIGURE B-2. Data flow in a protected radio.

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40.2.1.2 <u>Unclassified application level AL-1</u>. The AL-1 unclassified
application level is mandatory for all protected radio systems, and therefore,
provides protected interoperability within the U.S. Government. All protected
radios shall be capable of operation in the AL-1 mode even if they also
provide application levels with greater protection. The AL-1 scrambler shall
employ the lattice encryption algorithm as specified and documented 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. The AL-1 protection interval (PI)
is 60 seconds, which provides slightly lower protection than any of the other
available protected modes, but which permits for relaxed synchronization
requirements.

40.2.1.3 <u>Unclassified enhanced application level AL-2</u>. The AL-2
scrambler shall employ the same algorithm as specified for the AL-1, and may
be implemented in hardware or software, with manufacturer-specific interfaces.
This scrambler is for general U.S. Government and commercial use. The AL-2 PI
is 2 seconds.

40.2.1.4 <u>Unclassified but sensitive application level AL-3</u>. (DO: AL-3
shall use distinct hardware scramblers and shall employ the algorithm and
interface control document (ICD) developed by the National Security Agency
(NSA). Systems employing the AL-3 LP must meet NSA security requirements.
The AL-3 PI is a maximum of 2 seconds.) Technical parameters are not yet
standardized.

40.2.1.5 <u>Classified application level AL-4</u>. (DO: AL-4 shall use
distinct hardware scramblers and shall employ the algorithm and ICD developed
by NSA. An AL-4 scrambler may be used to protect classified orderwire
traffic. Systems employing classified application level LP must meet NSA
security requirements. The AL-4 PI is a minimum of 1 second.) Technical
parameters are not yet standardized.

40.2.2 <u>Linking protection control module</u>. The LPCM shall execute the LP
procedure specified in 40.2.2.4 and control the attached scrambler(s) as
specified below.

40.2.2.1 <u>Scrambler interfaces</u>. 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 40.2.1.2 and
40.2.1.3). For the unclassified application level the ICD is prepared and
controlled by the manufacturer.

40.2.2.2 <u>Time of day (TOD)</u>. 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.

40.2.2.2.1 <u>TOD entry</u>. A means shall be provided for entry of TOD (date
and time) via either an operator interface or an electronic fill port or 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 within ± 15 seconds is
suggested.

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40.2.2.2.2 <u>Time exchange protocols</u>. 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 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.

40.2.3 <u>Seed format</u>. 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 data, and a word number in the format shown in figure B-3A, where the most significant bits of the seed and of each field are on the left. The TOD portion of the seed shall be monotonically non-decreasing. The remaining bits are not so constrained. The <u>date</u> field shall be formatted IAW figure B-3B. The <u>month</u> field shall contain a 4-bit integer for the current month (1 for January through 12 for December). The <u>day</u> 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 <u>PI</u> field shall be formatted IAW figure B-3C. The <u>course time</u> field shall contain an 11-bit integer which counts minutes since midnight (except that temporary discrepancies may occur as discussed in 40.2.3.1). The 6-bit <u>fine time</u> 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 <u>fine time</u> field shall be set to the time obtained using this protocol and incremented as described in 40.2.3.1. The <u>fine time</u> 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 <u>word</u> field shall be used to count words within a PI, as specified in 40.2.3.1. The <u>frequency</u> field shall be formatted IAW figure B-3D. 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 all 1's for the unclassified application level of LP.

40.2.3.1 <u>Procedure</u>. The procedure to be employed in protecting transmissions consisting entirely of 24-bit ALE words is presented in 40.2.3.1.1 and 40.2.3.1.2. When a radio is neither transmitting or receiving, the PI number shall be incremented as follows. When using linking protection level AL-2 and local time quality (see 40.2.4.2) is 5 or better, the <u>fine time</u> field shall be incremented at the end of each PI by the length of the PI, modulo 60. When the <u>fine time</u> field rolls over to 0, the <u>course time</u> field shall be incremented, modulo 1440. At midnight, the <u>course</u> and <u>fine time</u> fields shall be set to 0, and the <u>data</u> and <u>month</u> fields updated. When using linking protection level AL-1, or when the local time quality (see 40.2.4.2) is 6 or 7, the <u>fine time</u> field shall contain all 1's and the <u>course time</u> field shall be incremented once per minute, modulo 1440. At midnight, the <u>coarse time</u> field shall be set to 0, and the <u>date</u> and <u>month</u> fields updated. Whenever the local time uncertainty is greater than the PI, the system shall:

a.   Present an alarm to the operator.

b.   Optionally, also attempt resynchronization (if enabled). The first attempt at resynchronization shall use the current fine seed. If this fails, the system shall use a coarse seed for subsequent attempts.

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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 01010000

1   9   10   26   27   34   37   64

TOD

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-3.   **Seed formats.**

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40.2.3.1.1 <u>Transmitting station</u>. 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 be allowed to persist until the conclusion of each transmission, whereupon the TOD fields of the seed shall be corrected. The <u>word number</u> field w shall be as follows:

a. During the scanning call phase (T_{sc}) 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 T_{sc} shall begin with w = 0 or w = 1, as required, such that the last word of T_{sc} is encrypted using w = 1. The TOD used during T_{sc} shall change as required to keep pace with real time, except that TOD shall only change when w = 0. Words encrypted with w = 1 shall use the same TOD as the preceding word.

b. At the beginning of the leading call phase (T_{lc}) of a call (which is the beginning of a single-channel), 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 = w_{max}. For the word following a word encrypted with w = w_{max}, the TOD shall be incremented and w shall be reset to 0.

(1) W_{max} = 2 for a 1-second PI.
(2) w_{max} = 5 for a 2-second PI.
(3) w_{max} = 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-4 illustrates the permissible TOD/w combinations for a transmitting station using a 60 second (w_{max}=153) and a 2-second PI (w_{max} = 5), and the permissible sequences of these combinations. Sounds are protected in the same fashion with Trs in place of T_{lc}.

40.2.3.1.2 <u>Receiving station</u>. 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. Figures B-4C and D illustrate the permissible TOD/w sequences for a receiving station using a 60-second PI and a 2-second PI respectively, after word sync is achieved. Note that, unlike the transmitter the receiving station state machine may be non-deterministic. For example, when in T_{sc} and in state N/1, a received word may yield valid preambles and ASCII when decrypted using all of the valid combinations: T/0, (T + 1)/0, and T/2 (the latter implying that T_{lc} started two words previously), and will

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

Page added.

A <u>Transmitting station state diagram (60 second PI)</u>

B <u>Transmitting station state diagram (2 second PI)</u>

C <u>Transmitting and receiving station state diagram (60 second PI)</u>

D <u>Transmitting and receiving station state diagram (2 second PI)</u>
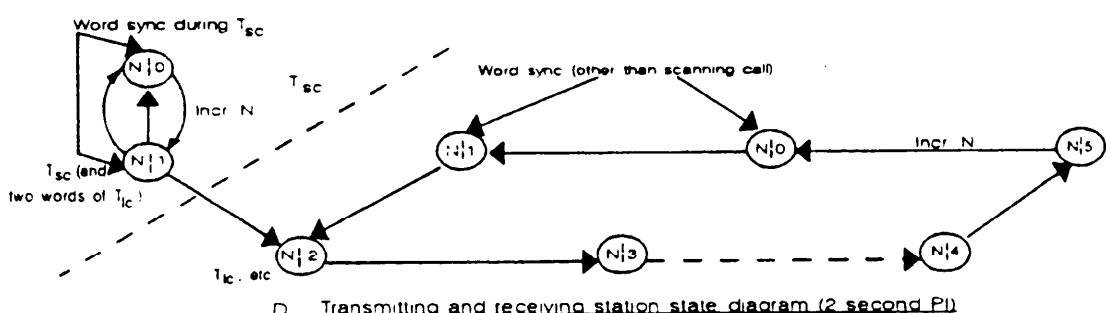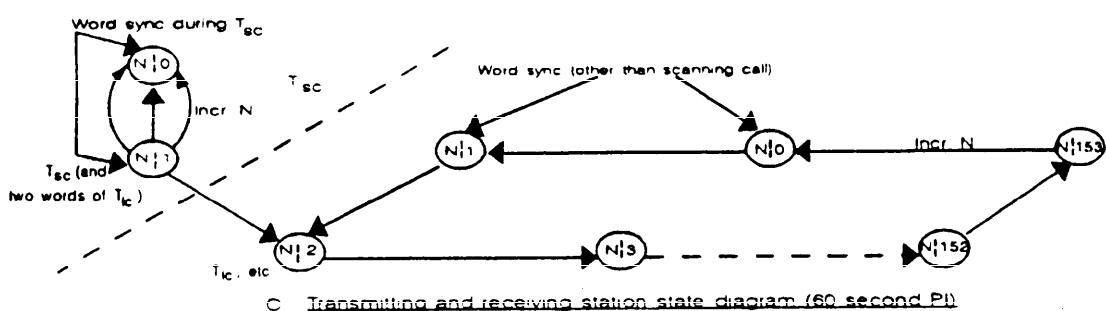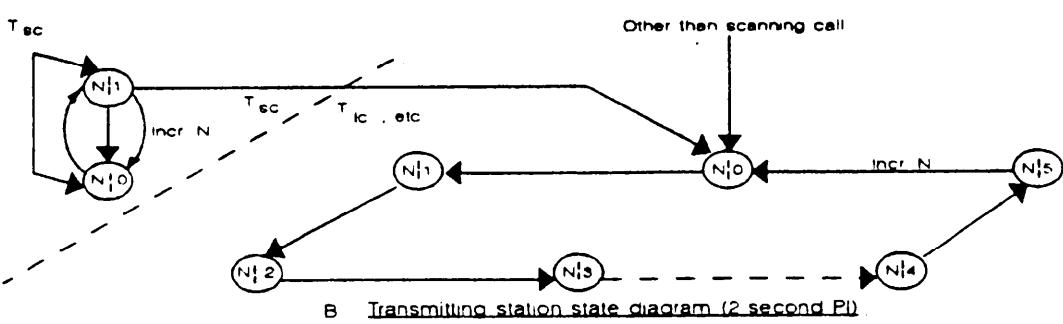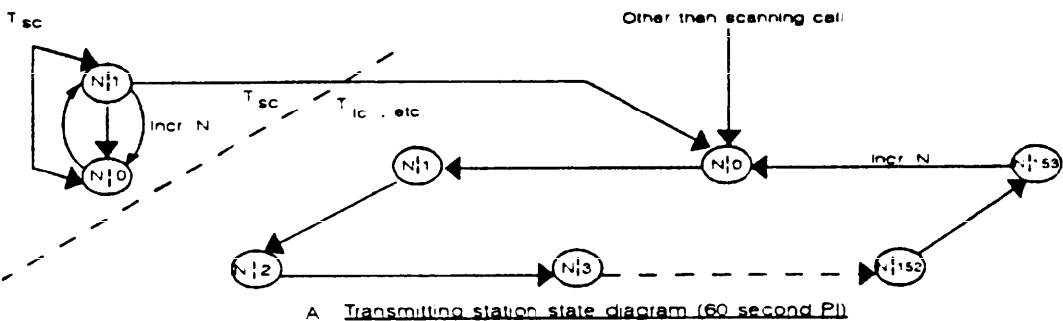
FIGURE B-4. <u>Transmitting and receiving stations state diagrams (60-second PI)</u>.

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40.2.3.1.3 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 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 words. Time exchange command words, Time Is and Time Request, that are used to request and to provide TOD data, shall be formatted as shown in figure B-5. The three most-significant bits (W1-3) shall contain the standard CMD preamble (110). The next seven bits (W4-10) shall contain the ASCII character '~'(1111110), indicating 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 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 no 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).

40.2.3.1.1.3 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 in figure B-6, 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

3	7	3	6	5
CMD	Time Exchange	Time Quality	Seconds	40 ms ticks
110	1111110	100	100010	00011

1   3 4   10 11   13 14   19 20   24

"Time Is" Command

| FIGURE B-5. Time exchange command word.

40.2.4.1.3 Authentication word. Authentication words, formatted as shown in figure B-6, 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: "Exclusive or" is the condition that exists when each resulting bit is a 1 if the two input bits do not match, or the resulting is a 0 when the two input bits match.)

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 on table B-I shall be employed for this purpose. The time uncertainty windows on 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

DATA	0	Month	Day	Minute
3	1	4	5	11
000	0	0101	01000	011101111101

1   3   4   5   8 9   13 14   24

Coarse Time Word

REP	Authenticator
3	21
111	110101110011111111110

1   3 4   24

Authenticator Word
(over Command and Coarse Time Words)

| FIGURE B-6. Coarse time and authentication words.

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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 data and time to within one minute may attempt to actively acquire time from any station with which it can communicate in protected mode by

This page reprinted without change.

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 data 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 <u>Time Request call</u>. A station requiring fine time shall request the current value of the network time by transmitting a <u>Time Request</u> 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 <u>Time Is</u> <time> DATA <coarse time>
> REP <authenticator> THIS IS <requester>.

The <u>Time Is</u> 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 <u>Time Request</u> call transmission shall be protected using the procedure specified in 40.2.3.1.1 and 40.2.3.1.2. When acquiring time synchronization, the coarse seed (<u>fine time</u> 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 <u>Time Service response</u>. A station which receives and accepts a <u>Time Request</u> call shall respond with a <u>Time Service</u> response formatted as follows:

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

The <u>Time Is</u> 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 <u>Time Service</u> response shall be protected as specified in 40.2.3.1.1 and 40.2.3.1.2 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 <u>Time Service</u> response may differ from that used in the request which caused that response. A time server shall respond only to the first <u>Time Request</u> call using each fine or coarse seed; i.e., one coarse request per minute and one fine request per fine PI. Acceptance of time request may be disabled by the operator. Stations which are prepared to accept coarse <u>Time Request</u> 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 <u>Time Server request</u>. A time server may request authenticated time from the original requestor by returning a <u>Time Server</u> request, which is identical to the <u>Time Service</u> response as given above except that the <u>THIS WAS</u> termination is replaced by <u>THIS IS</u>. 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 <u>Time Service</u> response and the authentication word (including the REP preamble) from the <u>Time Server</u> request, as specified in 40.2.4.1.3.

40.2.4.3.4 <u>Authentication and adjustment</u>. A station awaiting a <u>Time Service</u> 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, 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 <u>Time Service</u> 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 <u>Time Is</u> command and <u>coarse time</u> word, and the time uncertainty shall be set IAW 40.2.4.2.

40.2.4.4 <u>Active time acquisition (non-protected)</u>. A station which does not know the correct data 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 decryption.

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

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

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

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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 21-bit 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 AL-1 and AL-2 algorithm and a seed containing the time sent and w = all 1's. The least-significant 21 bits of this encryption shall be used as the Authenticator. 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>.
```

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The <u>Time Is</u> 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 <u>Advanced time exchange protocols</u>. Advanced timing exchange protocols for application levels 3 and 4 will be addressed as required with future upgrades of MIL-STD-188-141.

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CONCLUDING MATERIAL

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

Review activities:
  Army--CR   (Project TCSS-1413)
  Navy--MC
  DoD--DC, NS, DI

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STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.

2. The submitter of this form must complete blocks 4, 5, 6, and 7.

3. The preparing activity must provide a reply within 30 days from receipt of the form.

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I RECOMMEND A CHANGE:	1. DOCUMENT NUMBER MIL-STD-188-141A	2. DOCUMENT DATE (YYMMDD) 880915

3. DOCUMENT TITLE
INTEROPERABILITY AND PERFORMANCE STANDARDS FOR MEDIUM AND HIGH FREQUENCY RADIO EQUIPMENT

4. NATURE OF CHANGE (Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME (Last, First, Middle Initial)	b. ORGANIZATION	
c. ADDRESS (Include Zip Code)	d. TELEPHONE (Include Area Code) (1) Commercial (2) AUTOVON (If applicable)	7. DATE SUBMITTED (YYMMDD)

8. PREPARING ACTIVITY

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c. ADDRESS (Include Zip Code) ENGINEERING COMMAND ATTN: ASQB-OSE-TT FORT HUACHUCA, ARIZONA 85613-5000	IF YOU DO NOT RECEIVE A REPLY WITHIN 45 DAYS, CONTACT: Defense Quality and Standardization Office 5203 Leesburg Pike, Suite 1403, Falls Church, VA 22041-3466 Telephone (703) 756-2340 AUTOVON 289-2340	

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