FEDERAL STANDARD 1045A

TELECOMMUNICATIONS: HF RADIO AUTOMATIC LINK ESTABLISHMENT

Prepared By:

National Communications System
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FS-1045A: Letter of Promulgation

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General Services Administration
Information Resources Management Service
Letter of Promulgation
Federal Standard 1045A, Telecommunications:
HF Radio Automatic Link Establishment

1. SCOPE. The terms and accompanying definitions contained in this standard are drawn from authoritative non-Government sources such as the International Telecommunication Union, the International Organization for Standardization, the Telecommunications Industry Association, and the American National Standards Institute, as well as from numerous authoritative U.S. Government publications. The Federal Telecommunications Standards Committee (FTSC) HF Radio Subcommittee (HFRS) Standards Development Working Group (SDWG) developed a family of High Frequency Automatic Link Establishment (ALE) specifications that defines the necessary technical parameters for automatic link establishment for HF radio connections. Federal Standard 1045A is one of the family of standards to be used in conjunction with the interoperability criteria for HF radio automatic link establishment operation.

1.1 Applicability. All Federal departments and agencies shall use Federal Standard 1045A as the authoritative source of definitions for terms and functions used in the preparation of all telecommunications documentation. The use of this standard by all Federal departments and agencies is mandatory.

1.2 Purpose. The purpose of this standard is to improve the Federal acquisition process by providing Federal departments and agencies with a comprehensive, authoritative source for automatic link establishment in HF radio.

2. Requirements and Applicable Documents. The HF radio terms and definitions constitute this standard, and are to be applied to the design and procurement of ALE automated radio equipment. There are a family of Federal Telecommunications Standards and proposed HF radio automatic link establishment standards that may be applicable to implementation of this standard and these are listed in the standard.

3. Use. All Federal departments and agencies shall use this standard in the design and procurement of ALE automated radio equipment. Only after determining that a requirement is not included in this document may other sources be used.

4. Effective Date. The use of this approved standard by U.S. Government departments and agencies is mandatory, effective 180 days following the publication date of this standard.

5. Changes. When a Federal department or agency considers that this standard does not provide for its essential needs, a statement citing inadequacies shall be sent in duplicate to the General Services Administration (KMR), Washington, DC 20405, in accordance with the provisions of the Federal Information Resources Management Regulation, Subpart 201-20.3. The General Services Administration will determine the appropriate action to be taken and will notify the agency.

Federal departments and agencies are encouraged to submit updates and corrections to this standard, which will be considered for the next revision of this standard. The General Services Administration has delegated the compilation of suggested changes to the National Communications System whose address is given below:

Office of the Manager,
National Communications System,
Office of Technology and Standards,
Washington, DC 20305-2010

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FS-1045A: Foreword

This standard is issued by the General Services Administration pursuant to the Federal Property and Administrative Services Act of 1949, as amended.

This document provides Federal departments and agencies with a comprehensive description of the performance and interoperability criteria for automatic link establishment (ALE) in high frequency (HF) radio. This standard provides the waveform, coding, and protocols to support ALE and is the foundation for the adaptive and automated radio features that are being defined in a family of Federal HF radio telecommunications standards:

- FED-STD-1046, HF Radio Automatic Networking
- FED-STD-1047, HF Radio Automatic Store-and-Forward
- FED-STD-1048, HF Radio Automatic Networking to Multiple-media
- FED-STD-1049, HF Radio Automatic Operation in Stressed Environments
- FED-STD-1050, HF Radio Baseline Parameters
- FED-STD-1051, HF Radio System Controller Interface
- FED-STD-1052, HF Radio Modems

This standard was developed with extensive cooperation among the Federal departments and agencies working within the Federal Telecommunications Standards Committee (FTSC). Standards development was based on the requirements contained in the Statement of Requirements (SOR) for the Development of a Family of Federal Standards for Automated High Frequency Radio. Test results of equipment conforming to the standard are contained in three documents: (1) Automated HF Radio Proof-of-Concept for Automated Link Establishment (ALE), Phase A HF Channel Simulator Test Report; (2) Automated HF Radio Proof-of-Concept for Automatic Link Establishment (ALE) HF Channel Simulator Test and On-the-Air Test Final Report, and (3) High Frequency (HF) Automatic Link Establishment (ALE) Equipment Test Report. The impact of this standard on industry and Federal departments and agencies was evaluated in the Economic and Technological Impact Assessment.

This standard shall be used by all Federal departments and agencies in the design and procurement of ALE automated radio equipment.

Neither this nor any other standard in a high technology field such as telecommunications can be considered complete and ageless. Periodic revisions will be made as required. The recommendations of Federal departments and agencies on improving the content or relevance of this document should be forwarded to the FTSC.

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FED-STD-1045A
<u>October 18, 1993</u>
SUPERSEDING
FED-STD-1045
January 24, 1990

FEDERAL STANDARD
Telecommunications: HF RADIO AUTOMATIC LINK ESTABLISHMENT

1. <u>SCOPE</u>. The purpose of this standard is to facilitate interoperability between telecommunication facilities and systems of the Federal Government, and compatibility of these facilities and systems at the high frequency (HF) radio over-the-air interface with data processing equipment (systems) of the Federal Government.

This standard specifies automated HF radio features such as frequency scanning, selective calling, automatic link establishment (ALE), link quality analysis (LQA), and sounding. The criteria contained herein are considered to be the minimum essential requirements for acquisition of ALE in Federal radios.

1.1 <u>Limitations</u>. Companion standards specify additional automated HF radio features.

- FED-STD-1046 HF Radio Automatic Networking, includes polling, connectivity exchange, and enhanced LQA.
- FED-STD-1047 HF Radio Automatic Store-and-Forward, includes message store-and-forward and network coordination and management.
- FED-STD-1048 HF Radio Automatic Networking to Multiple-Media, includes features to interface with other types of communications systems.
- FED-STD-1049 HF Radio Automatic Operation in Stressed Environments, includes linking protection which relates to link authentication, address protection, antispoofing, encryption, and anti-interference.
- FED-STD-1050 HF Radio Baseline Parameters, defines the minimum performance requirements to enable the radio to support automated operations.
- FED-STD-1051 HF Radio System Controller Interface, defines the functional interfaces both for radio control and for higher level functions.
- FED-STD-1052 HF Radio Modems, includes high performance modems, minimum mandatory interoperability modes, and an automatic error-free message delivery system.

1.2 <u>Applicability</u>. This standard shall be used by all Federal departments and agencies in the design and procurement of medium frequency (MF) and HF radio systems employing ALE. This standard is mandatory only for those MF and HF radio systems which require ALE. This standard is intended to assure interoperability among Federal MF and HF radio systems employing ALE. This standard shall specify equipment that shall be interoperable with equipment currently existing in the Federal inventory. The standard shall be used in the planning, design, and procurement, including lease and purchase, of all new data communications systems that utilize the HF radio media.

All Federal departments and agencies shall use the mandatory requirements contained herein. Appendix A is a nonmandatory section that contains technical criteria for basic MF and HF radio equipment and is provided as a suggested minimum quality radio to support the ALE and future automated radio features.

This standard is mandatory within the Federal Government in the design and development of new MF and HF ALE 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.

1.3 Purpose. The purpose of this standard is to improve the Federal acquisition process by providing Federal departments and agencies a comprehensive, authoritative source for ALE in HF radio. This document establishes 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 MF band and in the HF band. This document was developed in accordance with the "Statement of Requirements (SOR) for the Development of a Family of Federal Standards for Automated High Frequency Radio" to provide communications interoperability and to satisfy the requirements of Federal departments and agencies. It is also the purpose of this document to establish a level of performance of new radio equipment considered necessary to satisfy the requirements of a majority of users. These technical parameters represent minimum 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.

1.4 System standard and design objective (DO). 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.

FS-1045A: Applicable Documents

2 APPLICABLE DOCUMENTS. The issues of the following documents in effect on the date of invitation for bids or request for proposal form a part of this standard to the extent specified herein.

2.1 Government documents relating to standards development.

- Statement of Requirements (SOR) for the Development of a Family of Federal Standards for Automated High Frequency Radio (Dated 20 November 1987, Approved by Federal Telecommunications Standards Committee on 14 January 1988.)
- Automated HF Radio Proof-of-Concept for Automatic Link Establishment (ALE) Phase A HF Channel Simulator Test Report, Federal Emergency Management Agency, 25 March 1988.
- High Frequency (HF) Automatic Link Establishment (ALE) Equipment Performance Test Report, 88-DCA-T002, Defense Communications Agency, Joint Tactical Command, Control, and Communications Agency, August 1988.
- Automated HF Radio Proof-of-Concept for Automatic Link Establishment (ALE) HF Channel Simulator Test and On-the-Air Test Final Report, Federal Emergency Management Agency, 10 August 1988.
- Impact Assessment of Proposed Federal Standard 1045, U.S. Department of Commerce, National Telecommunications and Information Administration, Institute for Telecommunication Sciences (NTIA/ITS), 6 December 1988.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DODISS) and supplement thereto, cited in the solicitation (see Appendix A, par. 30.2).

STANDARDS

FEDERAL

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

FEDERAL INFORMATION PROCESSING STANDARDS

- FIPS PUB 1-1 Publication Code: for Information Interchange

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-188-141 Interoperability and Performance Standards for Medium and High Frequency Radio Equipment
- 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 19120-5899.)

Note: Copies of Federal Information Processing Standards (FIPS) are available to Department of Defense activities from the Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120-5099. Others must request copies of FIPS from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161-2171.

2.2.2 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

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

2.3 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 Government adopted, are those listed in the issue of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see Appendix A, 30.2).

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
- STANAG 4285 (C) Characteristics of 1200/2400/3600 Bits per Second Single Tone Modulators/ Demodulators for HF Radio Links (U)

Quadripartite Standardization Agreements (QSTAGs)

- QSTAG 733 Technical Standards for Single Channel High Frequency Radio Equipment

International Telecommunication Union (ITU), Radio Regulations.

- CCIR Recommendation 455-1 Improved Transmission System for HF Radiotelephone Circuits
- CCIR Recommendation 520 Use of High Frequency Ionospheric Channel Simulators

(Application for copies should be addressed to the General Secretariat, International Telecommunication 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 information services.)

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

FS-1045A: Definitions

3 DEFINITIONS. Definitions needed for the technical understanding of this standard are found in the current version of FED-STD-1037.

3.1 Terms.

The following definitions are provided for the convenience of the reader.

- **Automatic link establishment (ALE):** The capability of an HF radio station to make contact, or initiate a circuit, between itself and another specified radio station, without operator assistance and usually under processor control. ALE techniques include automatic signaling, selective calling, and automatic handshaking. Other automatic techniques that are related to ALE are channel scanning and selection, link quality analysis (LQA), polling, sounding, message store and forward, address protection, and anti-spoofing.
- **Automatic sounding:** Sounding is the ability to empirically test selected channels (and propagation paths) by providing a very brief beacon-like identifying broadcast which may be utilized by other stations to evaluate connectivity, propagation, and availability and to select known working channels for possible later use for communications or calling. Such soundings are primarily intended to increase the efficiency of the ALE function, thereby increasing system throughput. Sounding information shall be used for reducing the set of assigned channels to be used for a particular ALE connectivity attempt.
- **Compatibility:** Capability of two or more items or components of equipment or material to exist or function in the same system or environment without mutual interference.
- **High performance HF data modem:** High speed (capable of 1200 bps or greater) data modems which incorporate sophisticated techniques for correcting or reducing the number of raw (over the air induced) errors.
- **Interoperability:** The condition achieved among communications-electronics systems or items of communications-electronics equipment when information or services can be exchanged directly and satisfactorily between them and/or their users.
- **Linked compressor and expander (Lincompex):** A speech processing system comprised of a compressor and expander linked by a control channel separate from the audio (speech) channel.
- **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 bit error ratio (BER), the ratio of signal-plus-noise-plus-distortion to noise-plus-distortion (SINAD), and multipath (MP). Such assessments may be stored and exchanged between stations for ALE decision use.
- **Multipath (MP):** The propagation phenomenon that results in radio signals reaching the receiving antenna by two or more paths.

- **Multiple-media communications:** Multiple-media communications systems can switch from one medium to another through the same node thereby providing the user with substantial flexibility as to the employment of various transmission subsystems. A multiple-media communications network allows traffic to be carried by one of several types of subsystems, connecting one node to another. Multiple-media communications include HF radio, landlines, microwave radio, satellite communication, meteor burst, ultra-high frequency (UHF) radio, and HF packet radio. User equipment includes telephone, data terminals, facsimile, and slow scan television (narrow band video). A multiple-media network includes point-to-point (single link), and relay (multilink networks which can have different transmission subsystems for each link).
- **Phase noise (dBc/Hz):** The amount of single-sided phase noise, contained in a 1-hertz (Hz) bandwidth, produced by a carrier (signal generation) source and referenced in decibels below the full (unsuppressed) carrier output power.
- **Radio regulations:** International agreements which are promulgated through a series of regulatory documents.
- **Signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD):** The ratio, expressed in decibels (dB), of (a) the recovered audio power (original modulating audio signal plus noise plus distortion) from a modulated radio frequency carrier, to (b) any residual audio power (noise plus distortion) remaining after the original modulating audio signal is removed.
- **Third-order intercept point:** The third-order intercept point is a standard measure of how well a receiver performs in the presence of strong nearby signals. The receiver third-order intercept point is an extrapolated convergence (not directly measurable) of a desired output (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 around 20-30 kilohertz (kHz) apart.) Because mixers are nonlinear devices, additional signals are created. Especially troublesome are third-order intermodulation distortion products which can interfere with desired signal reception.

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

- **ABCA:** American, British, Canadian, and Australian (Armies)
- **ACK:** acknowledgment
- **AGC:** automatic gain control
- **AJ:** anti-jamming
- **ALC:** automatic level control
- **ALE:** automatic link establishment
- **AMD:** automatic message display
- **ARQ:** automatic repeat request
- **ASCII:** American Standard Code for Information Interchange

- **Bd:** baud
- **BER:** bit error ratio
- **bps:** bits per second
- **CCIR:** International Radio Consultative Committee
- **chps:** channels per second
- **CRC:** cyclic redundancy check
- **dB:** decibel
- **dBc:** dB referred to the carrier
- **DBM:** data block message
- **DCE:** data circuit-terminating equipment
- **DO:** design objective
- **DODISS:** Department of Defense Index of Specifications and Standards
- **DTE:** data terminal equipment
- **DTM:** data text message
- **FCS:** frame check sequence
- **FDM:** frequency division multiplex
- **FEC:** forward error correction
- **FIPS:** Federal Information Processing Standards
- **FSK:** frequency shift keying
- **HF:** high frequency
- **Hz:** hertz
- **ICW:** interrupted continuous wave
- **IF:** intermediate frequency
- **IMD:** intermodulation distortion
- **ISB:** independent sideband
- **ISDN:** Integrated Services Digital Network
- **ITU:** International Telecommunication Union
- **kHz:** kilohertz
- **LF:** low frequency
- **LQA:** link quality analysis
- **LSB:** (1) lower sideband (radio) (2) least significant bit (data)
- **max:** maximum
- **MF:** medium frequency
- **MHz:** megahertz
- **min:** minimum
- **MP:** multipath
- **ms:** millisecond
- **MSB:** most significant bit
- **NAK:** nonacknowledgment (request for repeat)
- **NATO:** North Atlantic Treaty Organization
- **NBFM:** narrowband frequency modulation
- **NCS:** net control station
- **NTIA:** National Telecommunications and Information Administration
- **PEP:** peak envelope power
- **PRN:** pseudorandom
- **PTT:** push to talk

- **QSTAG:** Quadripartite Standardization Agreement
- **rf:** radio frequency
- **RTTY:** radio teletypewriter
- **s:** second
- **SINAD:** signal-plus-noise-plus-distortion to noise-plus-distortion ratio
- **SNR:** signal-to-noise ratio
- **SOR:** statement of requirements
- **SSB:** single sideband
- **STANAG:** Standardization Agreement (NATO)
- **SWT:** slot wait timer
- **UHF:** ultra high frequency
- **USB:** upper sideband
- **UUF:** user unique functions
- **UUT:** unit under test
- **VFCT:** voice frequency carrier telegraph
- **VSWR:** voltage standing wave ratio
- **WRTT:** wait response plus tune timer

Definitions of timing symbols. The abbreviations and acronyms used for timing symbols are contained in Annex A to Appendix B.

FS-1045A: General Requirements

4 GENERAL REQUIREMENTS. The functional capability described herein includes automatic signaling, selective calling, automatic answering, and radio frequency 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.

4.1 System test performance. Testing stations designed to this standard shall demonstrate an overall system performance equal to or exceeding the following requirement. Linking attempts made with a test setup configured as shown on Figure 1, using an ALE signal created in accordance with this standard, shall produce a probability of linking as shown in Table I.

The receive audio input to the ALE controller shall be used to simulate the three channel conditions. The CCIR good channel shall be characterized as having 0.5 millisecond (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 for the CCIR good and poor channels (see Table I) shall produce no more than a 1.0 decibel (dB) performance degradation.

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.

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 calling scanning protocol described in par. 5.3.4.3. 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. The time from initiation to establishment shall not exceed 14.000 seconds plus simulator delay time. Performance testing shall include the following additional criteria:

a. The protocol used shall be the individual calling scanning protocol with only TO and THIS IS preambles. Specifically, the call shall not exceed 23 T_{rw}, the Response, 3 T_{rw}, and the Acknowledgement, 3 T_{rw}.

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

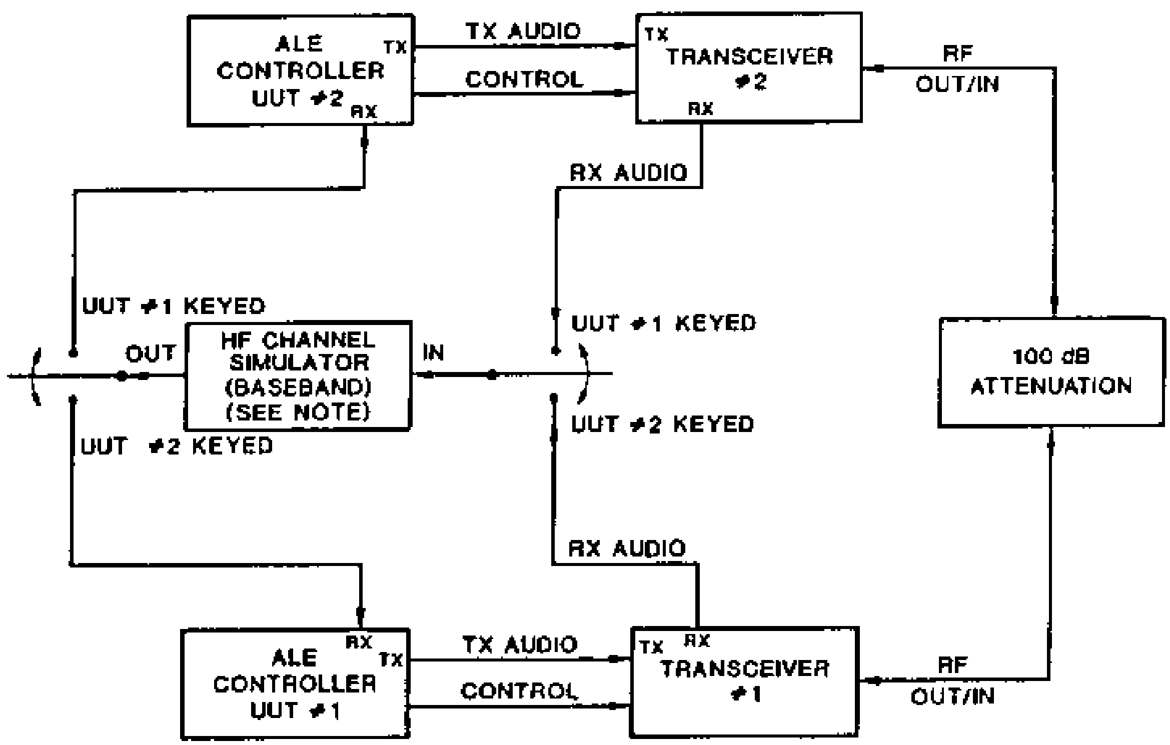
c. Units under test (UUTs) shall be scanning 10 channels at 2 channels per second.

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 start of UUT radio frequency (rf) transmission, not from activation of the ALE protocol) to link establishment, shall not exceed 14.000 seconds, plus simulator delay time.

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

Figure 1. 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.

TABLE I. Probability of linking

	Signal-to-Noise Ratio (dB)		
Probability of Linking (P^{l})	Gaussian Noise Channel	CCIR Good Channel	CCIR Poor Channel

≥ 25%	-2.5	+0.5	+1.0
≥ 50%	-1.5	+2.5	+3.0
≥ 85%	-0.5	+5.5	+6.0
≥ 95%	0.0	+8.5	+11.0

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

- sounding information
- group net association
- modulation type (associated with frequency)
- transmit/receive modes
- filter width (DO)
- automatic gain control (AGC) setting (DO)
- antenna selection (DO)
- input/output information port selection (DO)
- noise blanker setting (DO)
- receive and transmit subaudible tone selection (if narrow band frequency modulation (NBFM)) capable) (DO)
- transmit power level (DO)
- traffic or channel use (voice, data, etc.) (DO)
- security (DO)
- sounding self addresses (DO)

Any channel shall be capable of (1) being recalled manually and also under the direction of an automated controller if associated and (2) being altered after recall without affecting the original stored information settings.

TABLE II. Channel memory example

Channel	Frequency (MHz) TX	Frequency (MHz) RX	Mode TX	Mode RX	T/R	SCAN	SCTY	(3) Next Sound	Sound interval	* ANT	* PWR	* USE	Example comments
C-1	17,777.7	17,777.7	USB	USB	T/R	Y	C	14 min	40 min	1	LO	V	Typical simplex channel, low power, voice, clear
C-2	22,222.2	22,222.2	USB	USB	R	Y	C	--	--	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	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	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	--	--	2	LO	D	Typical simplex, non-scan, data only, secure
:	:	:	:	:	:	:	:	:	:	:	:	:	:
C-100	0.0	5,000.0	--	AM	R	N	C	--	--	1	-	V,D	Receive only, non-scan, clear

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

4.3 Scanning. The radio shall be capable of repeatedly scanning selected channels stored in memory (in the radio or controller) under manual control or under the direction of an automated controller if associated. The scanned channels should be selectable by groups such as 10, and also individually within the groups, to enable flexibility in channel and network scan management. The design shall incorporate selectable scan rates of 2 channels per second (chps) and 5 chps (DO: 2, 5, and 10 chps). Performance shall meet the requirements of par. 4.1. The radio shall stop scanning and wait on the most recent channel during the advent of any of the following selectable events:

- automatic controller input of stop scan (the normal mode of operation)
- manual input of stop scan
- activation of push-to-talk (PTT) line (DO)
- activation of external stop scan line (DO)

4.4 Self-address memory. The radio shall be capable of storing, retrieving, and employing at least 20 different sets of information concerning self-addressing. The self-address information storage shall be nonvolatile. These sets of information include self (its own personal) address(es), valid channels which are associated for use, and net addressing. Net addressing information shall include (for each "net member" self-address, as necessary) the net address and the present slot wait time T_{swt} (in multiples of wait time (T_w)). See Table III. The slot wait time values for each slot number are T_{swt}(SN) (slot number) from the formula in par. 5.3.6.2. Stations called by their net call address shall respond with their associated self (net member) address with the specified delay T_{swt}(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 address) within a group call shall respond in the derived slot, and with that address, as specified in the star group (scanning) calling protocol. If a station is called by one of its net addresses and has no associated net member address, it shall pause and listen to the entire transmission but shall not respond (unless subsequently called separately with an available self or net member address).

4.5 Other address memory. 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 (T_{wr}) if not the default value.

Net information shall include their net and net member associations, their relative slot sequences, and their net wait for reply times (T_{wrn}) for use when calling. See Table IV.

As a DO, any excess capacity which is not programmed with preplanned other address information should be automatically filled with any (transmitted) 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 those stations (if needed) and for activity evaluation.

4.6 Connectivity and LQA memory. 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 nonvolatile. The information in each address/channel "cell" shall include as a minimum, the bilateral (two-way) bit error ratio (BER) values of (1) the signals received at the station and (2) the station'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 shall also include bilateral SINAD and multipath (MP) values 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 2.

TABLE III. Self-address memory example

Index	Self (or net member) address	Net address	T_{swt}(SN)= slot wait time	(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 can be used.

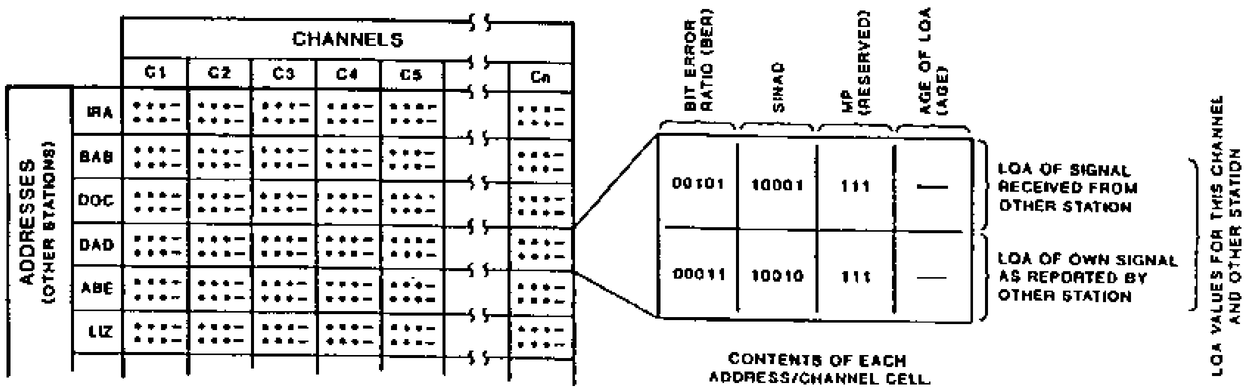
TABLE IV. Other address memory example

Net or other address	Individual or net member address and slots	Valid channels	(Net) wait for reply time (T_w)	Example comments

	slot 1	slot 2	slot 3	slot 4			
IRA	NA	NA	NA	NA	All	T_{wr}	Individual address
BAB	NA	NA	NA	NA	C1-C12	T_{wr}	Same
GUY	BEN*	DOC	DAD	ABE	All	$T_{wrn}(5)$	own net 4 members
GAL	AMY	LIZ	JANE	CLAUDETTE*	C3-C7	$T_{wrn}(5)$	own net 4 members
PEOPLE	JOE*	BILL	SUE	NA	C1-C9	$T_{wrn}(4)$	own net 3 members
PARTY	**	NA	NA	NA	C5-C12	0	one-way broadcast net, no responses
CLUSTER	ALFA	BRAVO	CHARLIE	NA	C2-C10	$T_{wrn}(4)$	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, in the assigned slot; i.e., station is a member of listed net.
3. Excess capacity should (DO) be filled with any other addresses heard.
4. Addresses for example only.
5. **Indicates that the station is a member of the listed net, but does not respond when called.

Figure 2. Connectivity and LQA matrix



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").

5 DETAILED REQUIREMENTS.

5.1 Waveform.

5.1.1 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 and their meanings, the timing and rates, and their accuracy.

5.1.2 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 3 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 the encoded and interleaved data bits constituting a word, as described in pars. 5.2.2 and 5.2.3. The transitions between tones shall be phase continuous and should be at waveform maxima or minima (slope zero).

5.1.3 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 3 shows the frequency and time relationships. The transmitted bit rate shall be 375 bits per second (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 (T_w) shall be 130.66... ms (or 16.33... symbols), and the triple word (basic redundant format) period (3 T_w) shall be 392 ms.

5.1.4 Accuracy. At baseband audio, the generated tones shall be within ±1.0 Hz. At rf, the transmitted tones shall be within a range of 1.0 dB in amplitude. The symbol timing, and therefore the bit and word rates, shall be within 10 parts per million.

5.2 Signal structure.

5.2.1 Introduction. The ALE signal structure is defined in this section, including bit and word format and structure, coding, forward error correction, framing, and synchronization. This section also describes addressing, signal quality analysis, and the functions of the standard word preambles associated with the signal structure.

5.2.2 Word format. The basic ALE word shall consist of 24 bits of information, designated W1 [most significant bit (MSB)] through W24 (LSB). The bits shall be designated as on Fig. 4.

5.2.2.1 Structure. The word shall be divided into four parts; a 3-bit preamble and three 7-bit characters. The MSB for all parts, and the word, is at the left on Fig. 4 and is sent earliest. Before transmission, the word shall be divided into two 12-bit halves for forward error correction (FEC) encoding, as described in par. 5.2.3.

5.2.2.2 Word types. The leading 3 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.

5.2.2.3 Preambles. The word types (and preambles) shall be as shown in Table V and described herein.

5.2.2.3.1 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 (three 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 and 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 par. 5.2.2.3.2.

NOTE: The THRU word is 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.

Figure 3. ALE symbol library

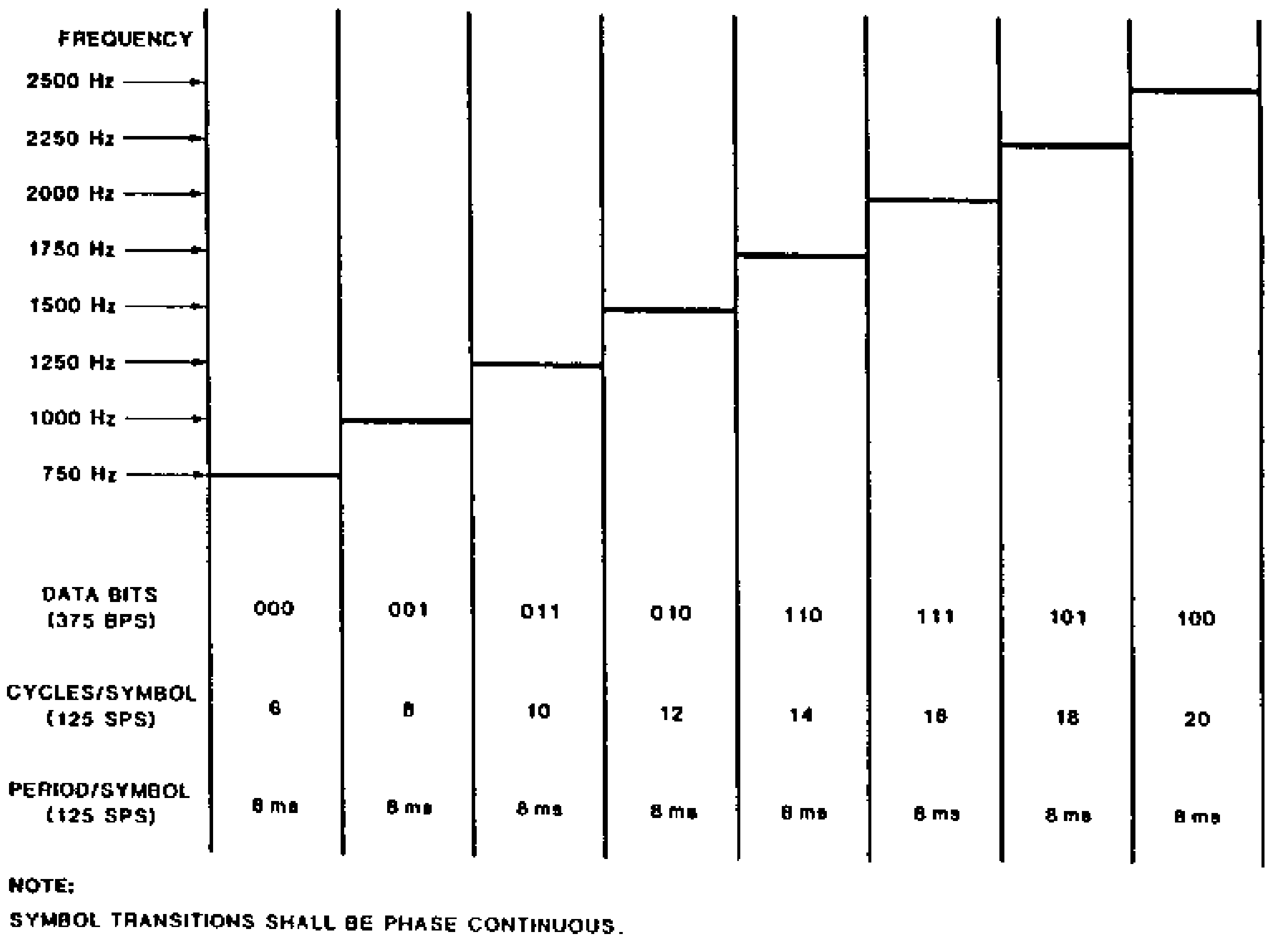
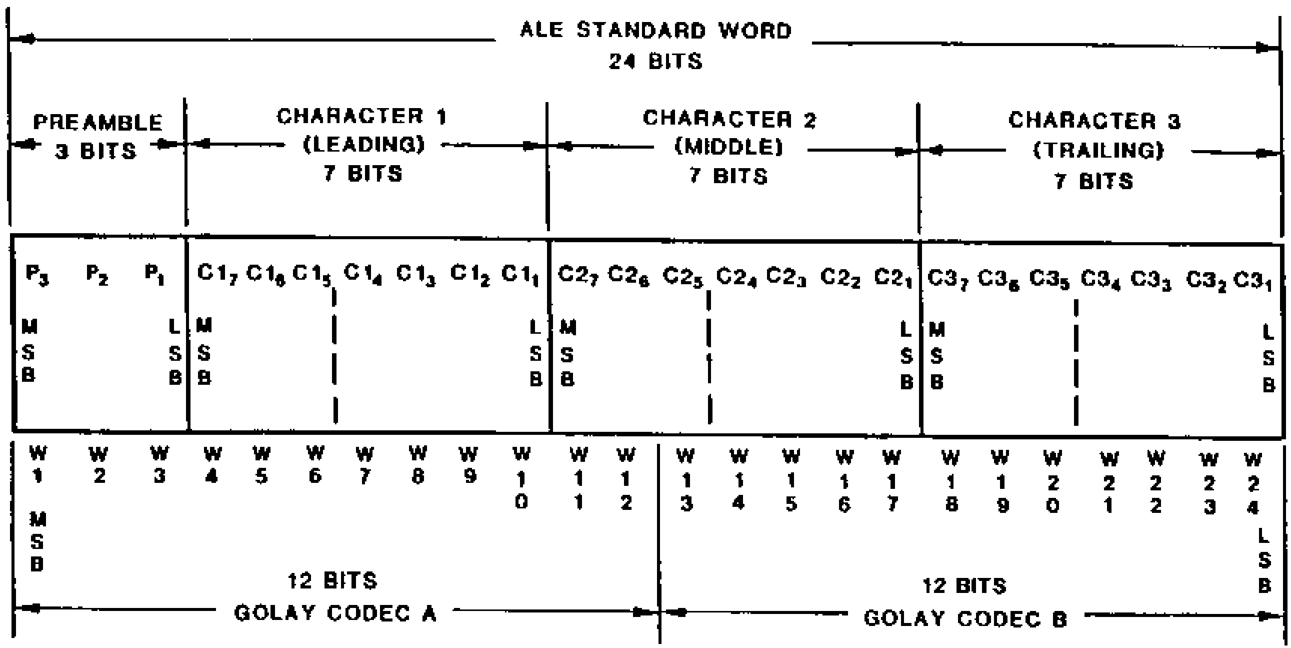


Figure 4. ALE basic word structure



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.

TABLE 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 word or information defined by the previous COMMAND
REPEAT	1	1	1	duplication and information	duplication of the previous preamble, with new data field, or information defined by the previous COMMAND
	P3 MSB W1	P2 W2	P1 LSB W3		

5.2.2.3.2 TO. The TO word (010) is a routing designator which shall indicate the address of the present destination station(s) which is (are) to directly receive the call. It 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 of up to one basic address word (three 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. The sequence shall only be TO, DATA, REPEAT, DATA, and REPEAT, which 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 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.

5.2.2.3.3 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. It 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 sec. 5.4 for orderwire messages and functions.

5.2.2.3.4 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 (par. 5.2.2.3.2). 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" (identification) 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 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 position than immediately before the COMMAND word.

5.2.2.3.5 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 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 acknowledgments 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 word of the calling station's address, which shall be up to one basic address word (three 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.

5.2.2.3.6 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 acknowledgments 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 a THIS WAS, as they are mutually exclusive.

5.2.2.3.7 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 15 characters. When used with COMMAND, its function is predefined by the standard as specified in sec. 5.4.

5.2.2.3.8 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 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 sec. 5.3.6. Also see par. 5.2.2.3.1 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.

5.2.2.3.9 Valid sequences. The eight ALE word types which have been described shall be used to construct calls and messages only as permitted on Fig. 5. The size and duration of ALE calls, and their parts, shall be limited as described in Table VI.

5.2.2.4 Characters.

5.2.2.4.1 General. 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.

5.2.2.4.2 Basic 38-ASCII subset. The basic 38-ASCII subset shall include all capital alphabetics (A-Z), all digits (0-9), plus designated utility and wildcard symbols "@" and "?," as shown on Fig. 6. The basic 38 subset shall be used for all basic addressing functions as described in sec. 5.2.5. 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-ASCII subset in any combination. In addition, the "@" and "?" symbols shall be used for special functions only as described in sec. 5.2.5.4. Digital discrimination of the basic 38-ASCII 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 10 invalid symbols which would be improperly accepted).

5.2.2.4.3 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 Fig. 7. The expanded 64-ASCII subset shall be used for all basic orderwire message functions, as described in sec. 5.4, plus special functions as may be standardized. For orderwire message use, the subset members shall be enclosed within a sequence of DATA (and REPEAT) words, shall be preceded by an associated COMMAND (such as data text message) which designates the usage of the information which follows, and shall also be preceded by a valid and appropriate calling cycle using the basic 38-ASCII subset addressing. Digital discrimination of the expanded 64-ASCII subset may be accomplished by examination of the two MSBs (b_7 and b_6), as all of the members within the "01" and "10" MSBs are acceptable. No parity bits are transmitted, because the integrity of the information is protected by the basic ALE FEC and redundancy, and may be ensured by optional use of the COMMAND CRC (cyclic redundancy check) as described in sec. 5.4.

5.2.2.4.4 Full 128-ASCII set and binary data. The full 128-ASCII set shall include all characters, symbols, and functions available within the ASCII code, and all 7-bit combinations are acceptable. See Fig. 8. For digital data communications of any kind, including ASCII characters and binary bits, the information shall be enclosed within a sequence of DATA (and REPEAT) words, shall be preceded by an associated COMMAND (such as data text message (DTM)) which designates the usage of information which follows, and shall also be preceded by a valid and appropriate calling cycle using the basic 38-ASCII subset addressing. No parity bits are transmitted, as the integrity of the information is protected by the basic ALE FEC and redundancy, and may be ensured by optional use of the COMMAND CRC as described in sec. 5.4.

5.2.3 Coding.

5.2.3.1 Introduction. The effective performance of ALE 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.

Figure 5. Valid word sequences

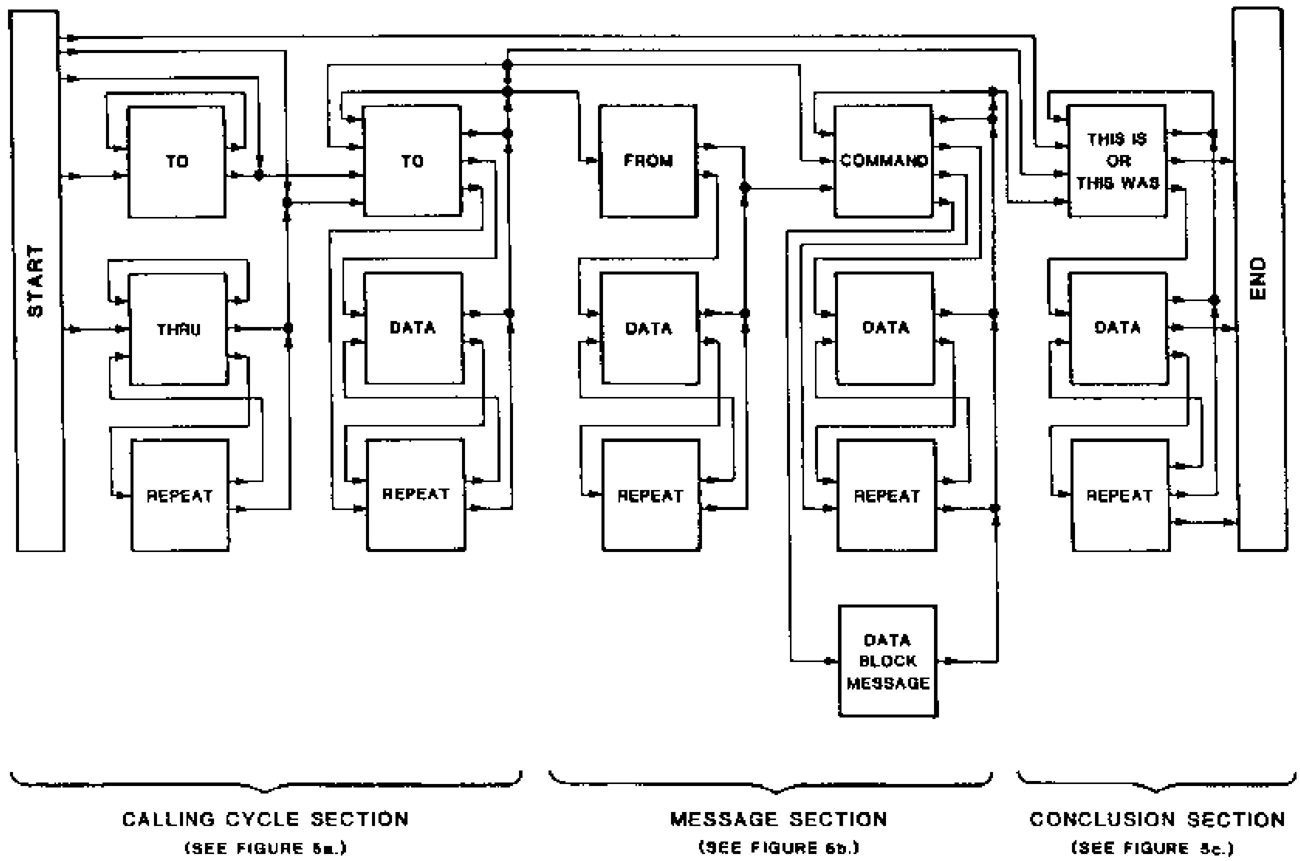


Figure 5a. Valid word sequences (Continued: calling cycle section)

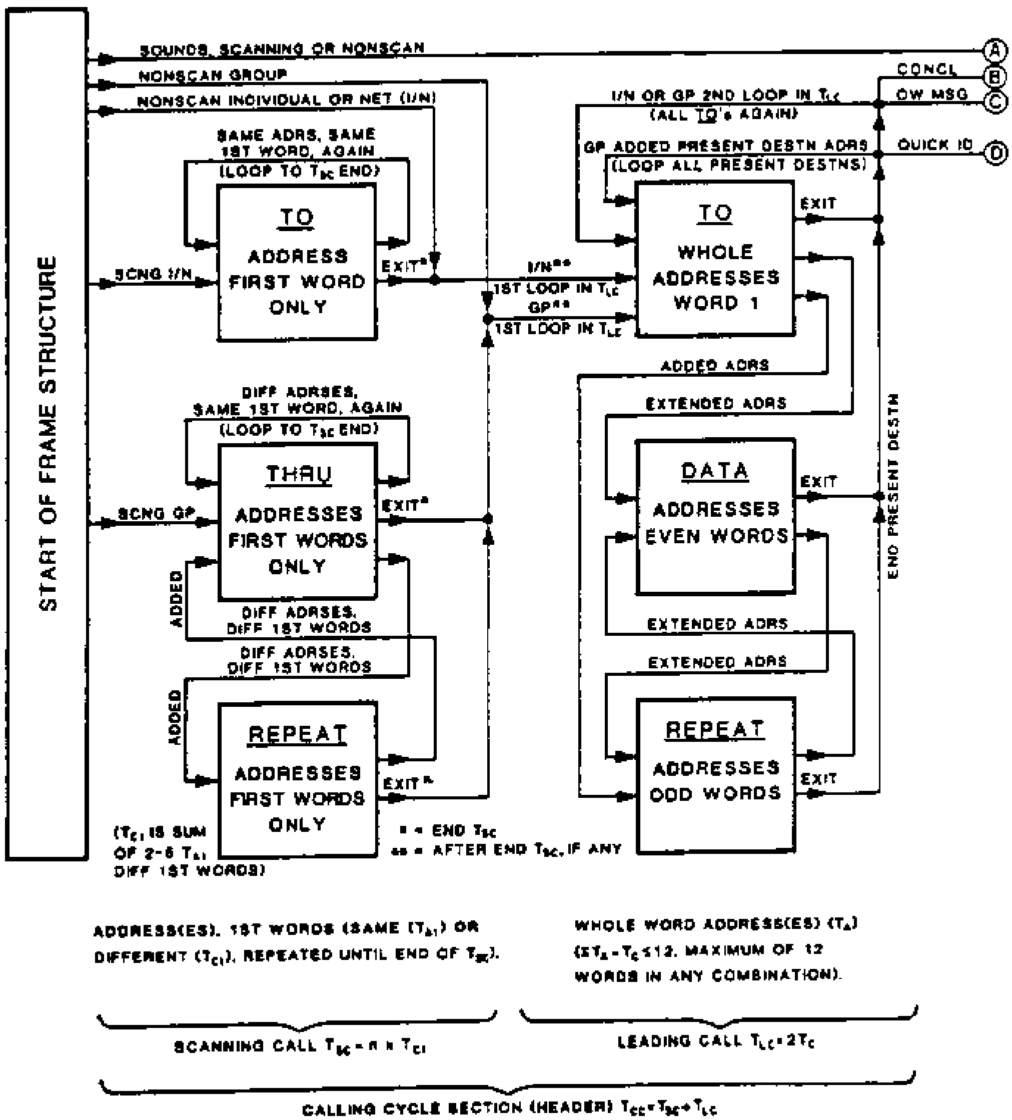


Figure 5b. Valid word sequences (Continued: message section)

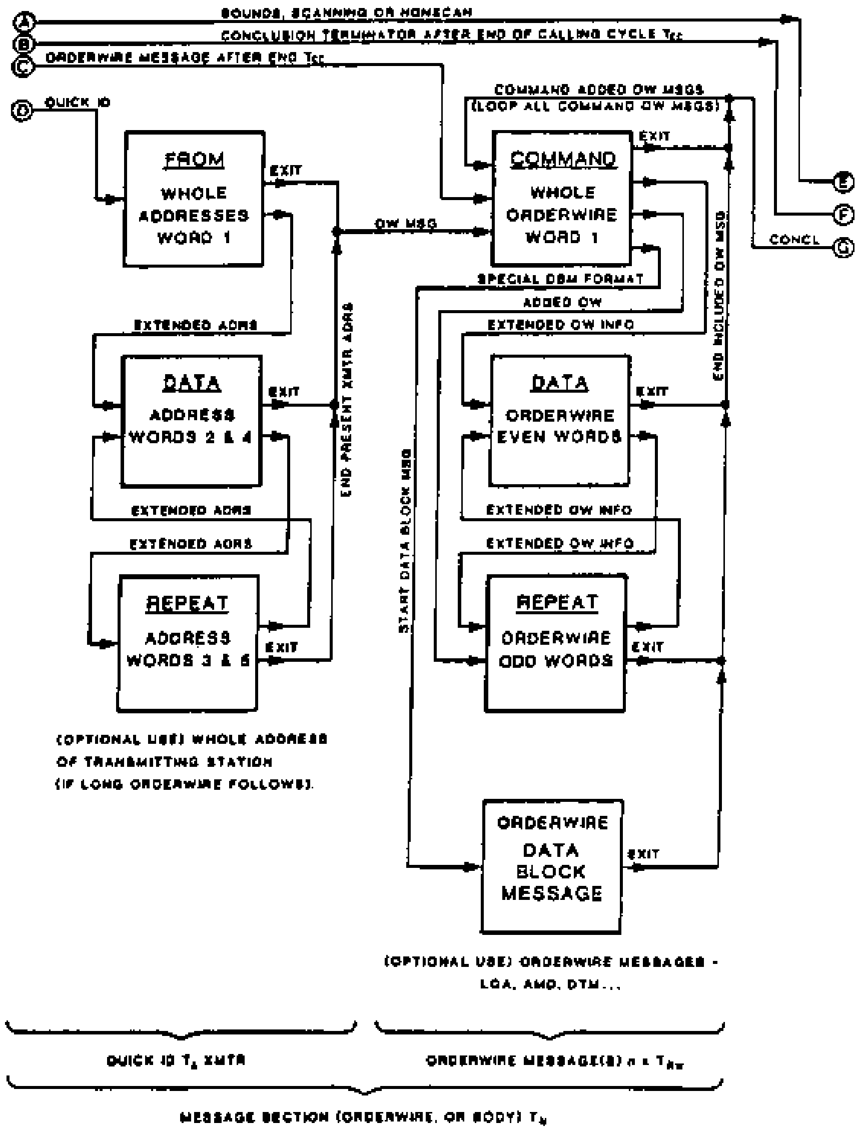


Figure 5c. Valid word sequences (Continued: conclusion section)

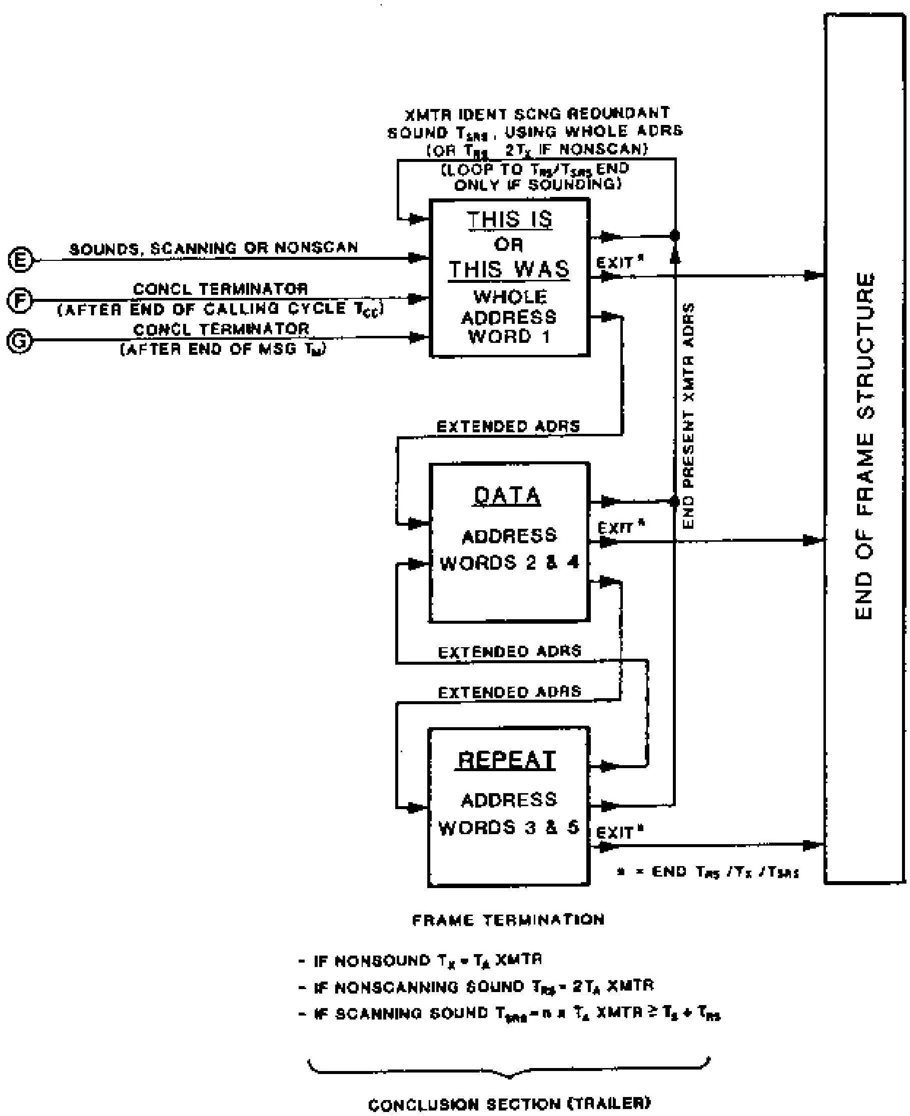


TABLE VI. Limits to size and duration of ALE calls

Calls	Limit
Address size (5 words) (T_a max)	1960 ms
Call time (12 words) (T_c max of the call)	4704 ms
Scan period (T_s max)	50 seconds (s)
Message section basic time (T_m max basic) (unless modified by AMD extension, or by COMMAND (such as	11.76 s

DTM or DBM))	
Message section, time limit of AMD (90 characters) (T_m max AMD)	11.76 s
Message section, time limit of DTM (1053 characters) (T_m max DTM)	2.29 minutes (entire data block)
Message section, time limit of DBM (37377 characters) (T_m max DBM)	23.26 minutes (entire deeply interleaved block)
max - maximum DBM - data block message mode AMD - automatic message display NOTE: 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 extending orderwire protocol, and the message section shall terminate at the end of that orderwire without additional extension. The conclusion shall start at the end of the message section.	

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

Figure 7. Expanded 64-ASCII subset

BITS b4	b3	b2	b1	b7 b6 b5 →	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
				ROW ↓ / COLUMN →	0	1	2	3	4	5	6	7
0	0	0	0	0	NUL	DLE	SP	0	@	P	`	p
0	0	0	1	1	SOH	DC1	!	1	A	Q	a	q
0	0	1	0	2	STX	DC2	"	2	B	R	b	r
0	0	1	1	3	ETX	DC3	#	3	C	S	c	s
0	1	0	0	4	EOT	DC4	$	4	D	T	d	t
0	1	0	1	5	ENQ	NAK	%	5	E	U	e	u
0	1	1	0	6	ACK	SYN	&	6	F	V	f	v
0	1	1	1	7	BEL	ETB	'	7	G	W	g	w
1	0	0	0	8	BS	CAN	(	8	H	X	h	x
1	0	0	1	9	HT	EM	)	9	I	Y	i	y
1	0	1	0	10	LF	SUB	*	:	J	Z	j	z
1	0	1	1	11	VT	ESC	+	;	K	[	k	{
1	1	0	0	12	FF	FS	,	<	L	\	l	|
1	1	0	1	13	CR	GS	-	=	M	]	m	}
1	1	1	0	14	SO	RS	.	>	N	^	n	~
1	1	1	1	15	SI	US	/	?	O	_	o	DEL

Figure 8. Full 128-ASCII set

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

5.2.3.2 Forward error correction (FEC). The Golay (24, 12, 3) forward error correction (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 on Fig. 9. The corresponding parity check matrix H shall contain a transposed matrix P^T and an identity matrix I_{12}, as shown on Fig. 10.

5.2.3.2.1 Encoding. 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 figs. 9, 11, and 12.

5.2.3.2.2 Decoding. Decoding will implement the equation

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

where y = x + e is a received vector which is the modulo-2 sum of a code word x and an error vector e, and where s is a vector of "n - k" bits called the syndrome. See fig. 12B. See Fig. 10 for the value of H. Each correctable/detectable error vector e results in a unique vector s. Because of this, s is computed according to the equation above and is used to index a look-up of the corresponding e, which is then added, modulo-2, to y to give the original code word x. Flags are set according to the number of errors being corrected. The uses of the flags are described in sec. 5.2.4.

If s is not equal to O and e contains more ones than the number of errors being corrected by the decoding mode, a detected error is indicated and the appropriate flag is set.

5.2.3.3 Interleaving and deinterleaving. The basic word bits W1 (MSB) through W24 (LSB), and resultant Golay FEC bits G1 through G24 (with G13 through G24 inverted), shall be interleaved, before transmission, using the pattern shown on Fig. 13. The 48 interleaved bits plus a 49th stuff bit, S49, value = 0 shall constitute a transmitted word, and they shall be transmitted A1, B1, A2, B2... A24, B24, S49 using 16 1/3 symbols (tones) per word (T_w) as described in par. 5.1.3. At the receiver, and after 2-of-3 voting (see par. 5.2.3.4), the first 48 received bits of the majority word (including remaining errors) shall be deinterleaved as on fig. 13, and then Golay FEC decoded, to produce a correct(ed) 24-bit basic word (or an uncorrected error flag). The 49th stuff bit (S49) is ignored.

5.2.3.4 Redundant words. Each of the transmitted 49-bit (or 16 1/3 symbol) (T_w) words shall be sent redundantly (times 3) to reduce the effects of fading, interference, and noise. An individual (or net) routing word (TO...), used for calling a scanning (multichannel) station (or net), shall be sent redundantly as long as required in the scan call T_{sc} to ensure receipt, as described in sec. 5.3.4. However, when the call is a non-net call to multiple scanning stations (a group call, using THRU and REPEAT alternately), the first (and therefore initial) individual routing word (THRU) and all the subsequent individual routing words (REPEAT, THRU, REPEAT, ...) shall be sent three adjacent times (T_{rw}). These triple words for the individual stations shall be rotated in group sequence as described in sec. 5.3.6. See Fig. 14. At bit time intervals (approximately $T_w/49$), the receiver shall examine the present bit and past bit stream and perform a 2-of-3 majority vote, on a bit-by-bit basis, over a span of three words. See tables VII and 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 sec. 5.2.4. An example of ALE encoding and decoding is shown on Fig. 14a.

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 set COMMAND DTM mode (which also accepts random data bits). Larger blocks of information may be Golay FEC coded and deeply interleaved using the COMMAND DBM mode. Longer messages over very poor circuits may be transmitted using the COMMAND ARQ (automatic message repeat) mode. Integrity of the data may be ensured using the COMMAND CRC mode. See section 5.4. 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.

Figure 9. Generator matrix for (24, 12) extended Golay code

$$
G = \begin{array}{c} \quad\quad I_{12} \quad\quad\quad\quad\quad\quad\quad\quad\quad P \\ \left(\begin{array}{cccccccccc}
100 & 000 & 000 & 000 & : & 101 & 011 & 100 & 011 \\
010 & 000 & 000 & 000 & : & 111 & 110 & 010 & 010 \\
001 & 000 & 000 & 000 & : & 110 & 100 & 101 & 011 \\
000 & 100 & 000 & 000 & : & 110 & 001 & 110 & 110 \\
000 & 010 & 000 & 000 & : & 110 & 011 & 011 & 001 \\
000 & 001 & 000 & 000 & : & 011 & 001 & 101 & 101 \\
000 & 000 & 100 & 000 & : & 001 & 100 & 110 & 111 \\
000 & 000 & 010 & 000 & : & 101 & 101 & 111 & 000 \\
000 & 000 & 001 & 000 & : & 010 & 110 & 111 & 100 \\
000 & 000 & 000 & 100 & : & 001 & 011 & 011 & 110 \\
000 & 000 & 000 & 010 & : & 101 & 110 & 001 & 101 \\
000 & 000 & 000 & 001 & : & 010 & 111 & 000 & 111
\end{array} \right) \end{array}
$$

Figure 10. Parity-check matrix for (24, 12) extended Golay code

$$H = \left(\begin{array}{cccc|cccc} \multicolumn{4}{c|}{P^T} & \multicolumn{4}{c}{I_{12}} \\ 111 & 110 & 010 & 010 & 100 & 000 & 000 & 000 \\ 011 & 111 & 001 & 001 & 010 & 000 & 000 & 000 \\ 110 & 001 & 110 & 110 & 001 & 000 & 000 & 000 \\ 011 & 000 & 111 & 011 & 000 & 100 & 000 & 000 \\ 110 & 010 & 001 & 111 & 000 & 010 & 000 & 000 \\ 100 & 111 & 010 & 101 & 000 & 001 & 000 & 000 \\ 101 & 101 & 111 & 000 & 000 & 000 & 100 & 000 \\ 010 & 110 & 111 & 100 & 000 & 000 & 010 & 000 \\ 001 & 011 & 011 & 110 & 000 & 000 & 001 & 000 \\ 000 & 101 & 101 & 111 & 000 & 000 & 000 & 100 \\ 111 & 100 & 100 & 101 & 000 & 000 & 000 & 010 \\ 101 & 011 & 100 & 011 & 000 & 000 & 000 & 001 \end{array} \right)$$

Figure 11. Golay word encoding

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	111

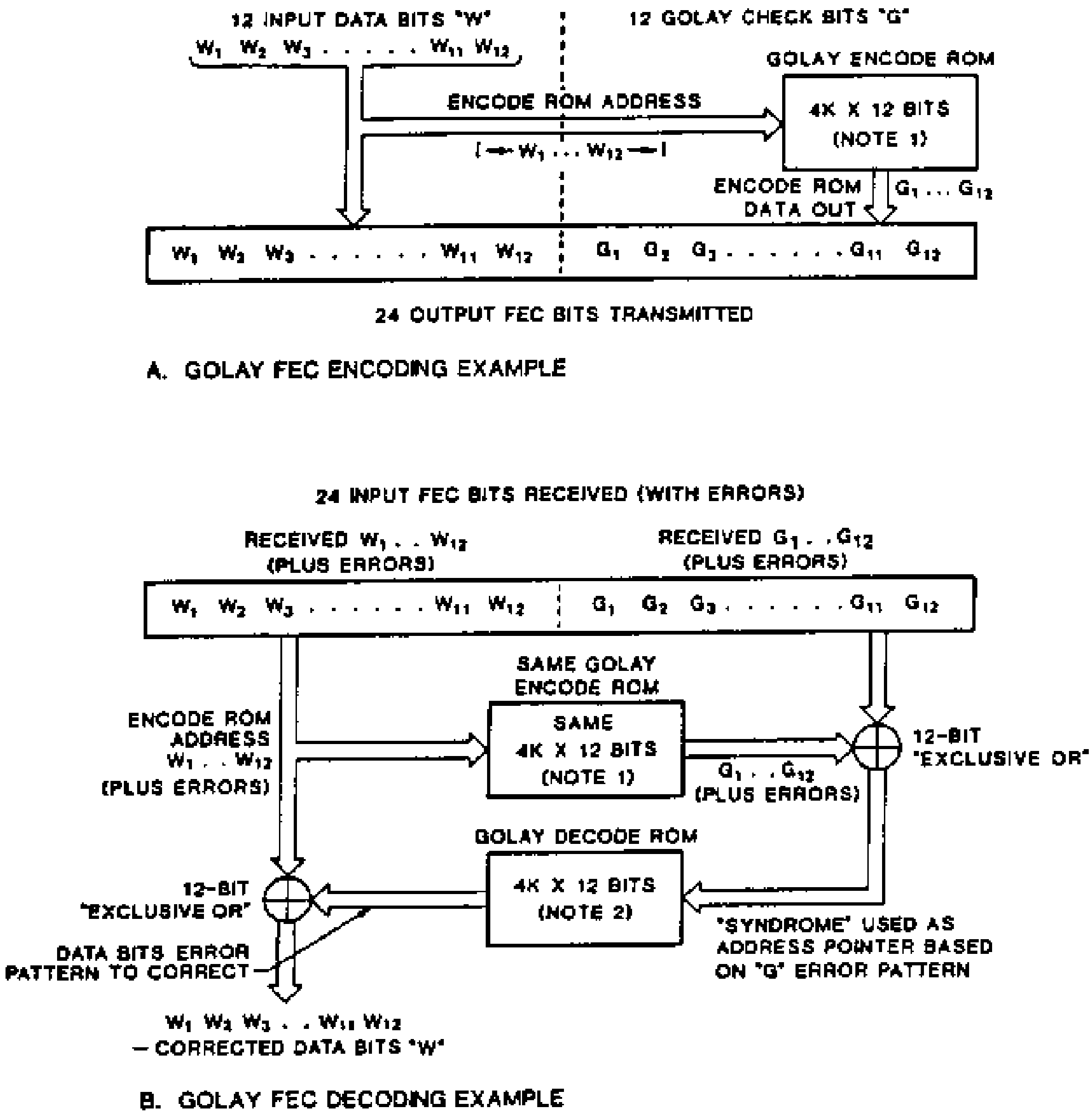
110	100	010	101	010	101	100	110
ENCODED DATA BITS* $W_1 \ldots W_{12}$ (OR $W_{13} \ldots W_{24}$)				GOLAY CHECK BITS $G_1 \ldots G_{12}$ (OR $G_{13} \ldots G_{24}$)			
24 BITS CODE WORD TO SEND							

*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 12. Golay FEC coding examples



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 13. Word bit coding and interleaving

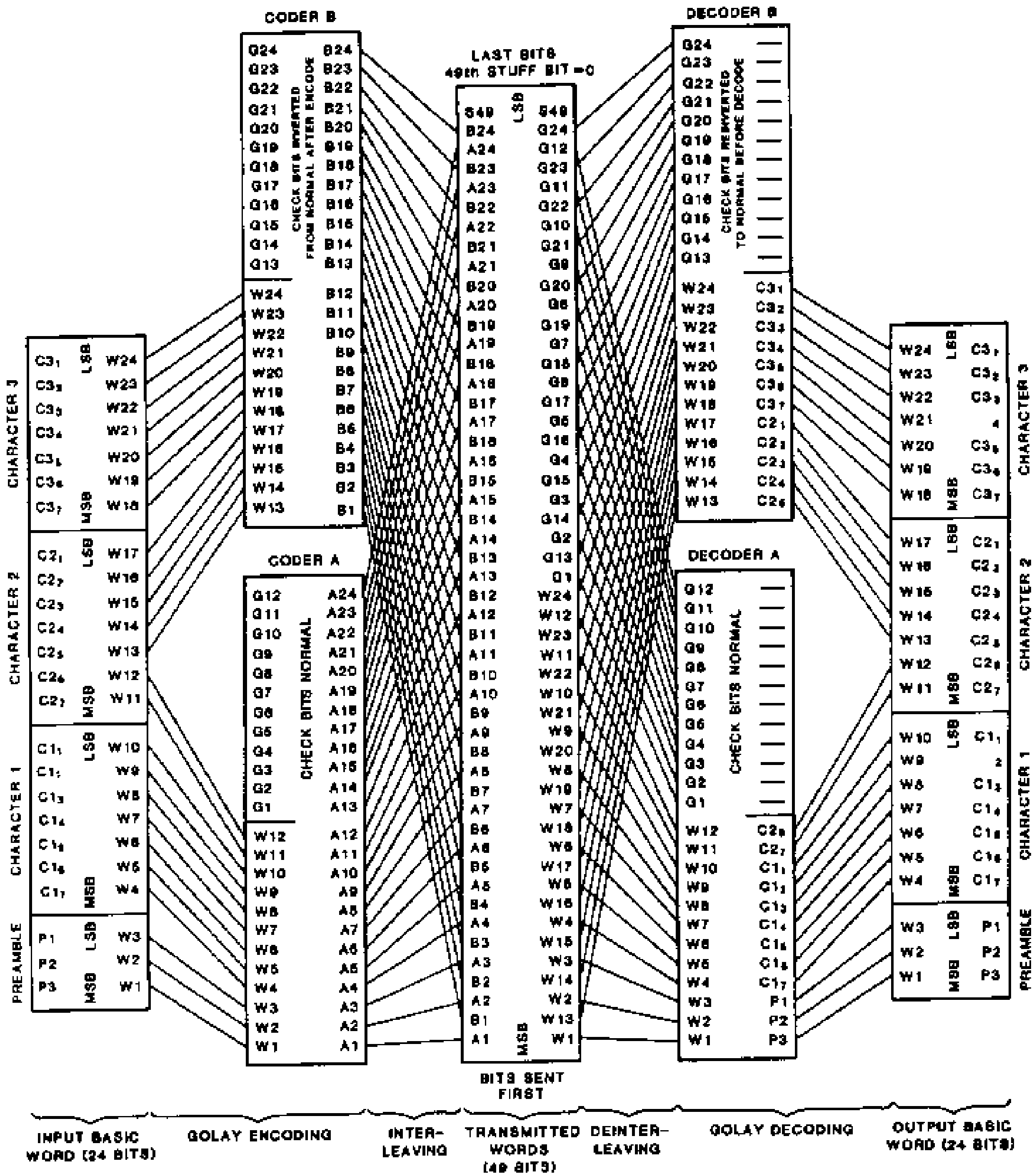


Figure 14. Bit and word decoding

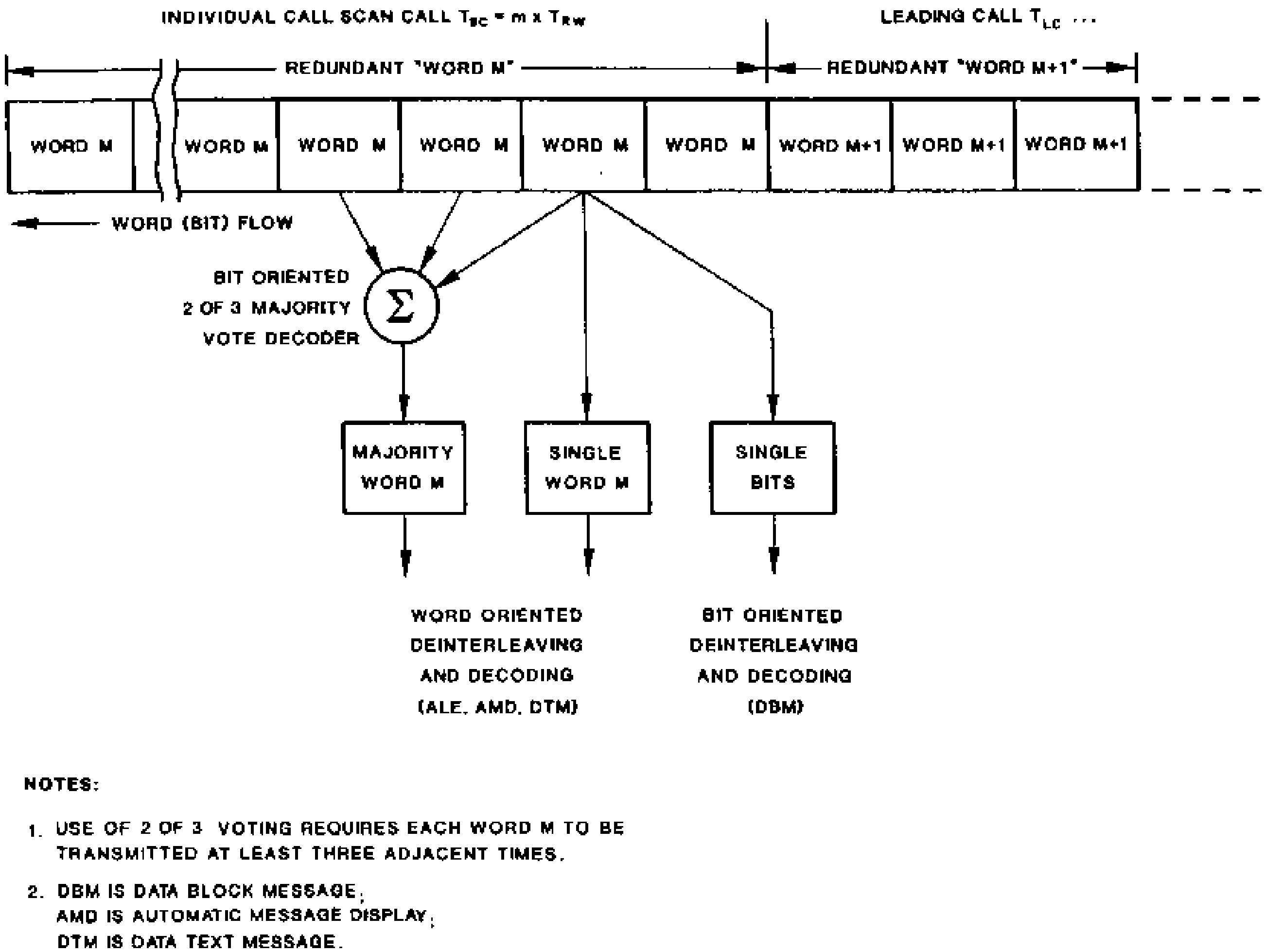


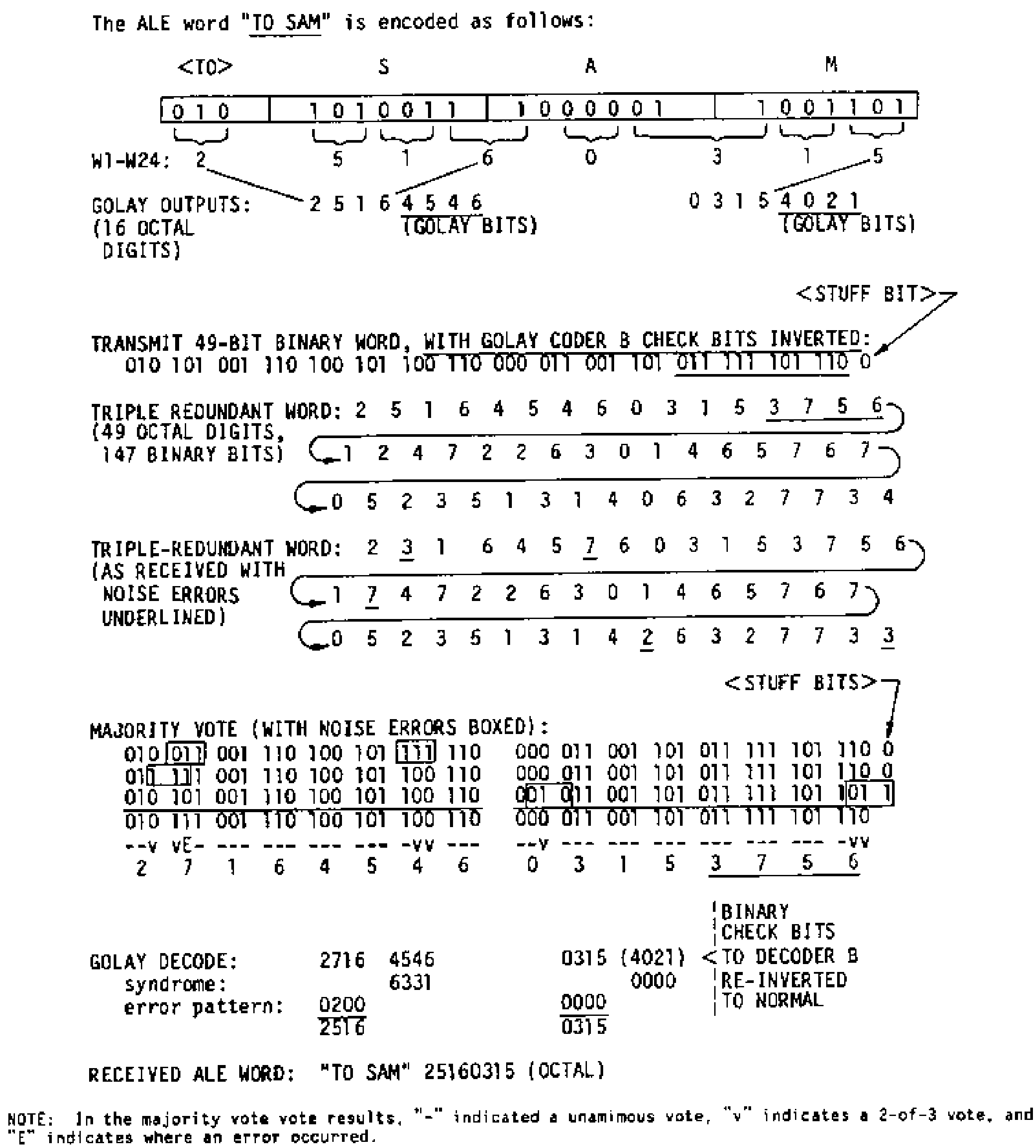
TABLE VII. 2-of-3 majority vote decoding

Received Bit R	Received Time	Eight Possible Bit Combinations
$R_{(n)}$	T	0 0 0 0 1 1 1 1
$R_{(n-49)}$	T-130.66... ms	0 0 1 1 0 0 1 1
$R_{(n-98)}$	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 VIII. Majority word construction

Relative Time	Received Bits R(time) For 2/3 Voting			Majority Words Bit M	Used As Decoder Bits
Stuff bits	R(n)	R(n-49)	R(n-98)	M(n)	S49 ignored
Recent (LSB)	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					

Figure 14a. ALE encoding/decoding example



5.2.4 Word framing and synchronization.

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

5.2.4.2 Framing. All ALE transmissions, commonly referred to herein as "calls," are based on the tones, timing, bit, and word structures described in secs. 5.1 and 5.2.2. All calls shall be composed of a "frame," which shall be constructed of contiguous redundant words, in valid sequence(s) as described on fig. 15, as limited in Table VI, and in formats as described in sec. 5.3. There are three basic frame sections: calling cycle, message, and conclusion. See par. 5.2.4.2.4 for basic frame structure examples.

5.2.4.2.1 Calling cycle. The initial section of all calls (except sounds) is termed a calling cycle (T_{cc}), and it is divided into two parts; a scanning call (T_{sc}), and a leading call (T_{lc}). 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 Fig. 15. The use of REPEAT and DATA is described in sec. 5.2.5. The set of different address first words (T_{c1}) may be repeated as necessary for scanning calling (T_{sc}) to exceed the scan period (T_s). There is no unique "flag word" or "sync word" for frame synchronization as will be described below. Therefore stations may acquire and begin to read an ALE signal at any point after the start. The start of the call shall be initiated after the transmitter power has risen to at least 90 percent of the rated rf output power. 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: The frame start 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 ALE 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 power rises to full power level (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.

5.2.4.2.2 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 a 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 Fig. 16. The use of REPEAT and DATA is described in sec. 5.4. The message section is not repeated within the call (although messages or information itself, within the message section, may be).

5.2.4.2.3 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 Fig. 17. Sounds, an exception, shall start immediately with THIS IS (or THIS WAS) words as described in sec. 5.3.5. REPEAT shall not immediately follow THIS IS or THIS WAS. Both conclusions and sounds contain the whole address of the transmitting station.

5.2.4.2.4 Basic frame structure examples. Contained in Fig. 18 are basic examples (except 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.

5.2.4.3 Synchronization.

5.2.4.3.1 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 pars. 5.1.3 and 5.1.4. After the start of each transmission by a station, the ALE transmit modulator shall maintain a constant phase relationship, within the specified timing accuracy, among all transmitted triple redundant words, at all times, until the final frame in the transmission is terminated.

Specifically, T(later triple redundant word) - T(early triple redundant word) = $n \times T_{rw}$, where T( ) is the event time of a given triple redundant word within any frame, T_{rw} is the period of three words (392 ms) and n is any integer.

Word phase tracking should only be implemented within a transmission and not between transmission. 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 par. 5.1.4.

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

Therefore, all transmissions after the first (in a handshake) shall synchronize by adding a delay T_{rwp} = 0 to 392 ms after the time the controller would normally initiate the next transmission.

Figure 15. Calling cycle sequences

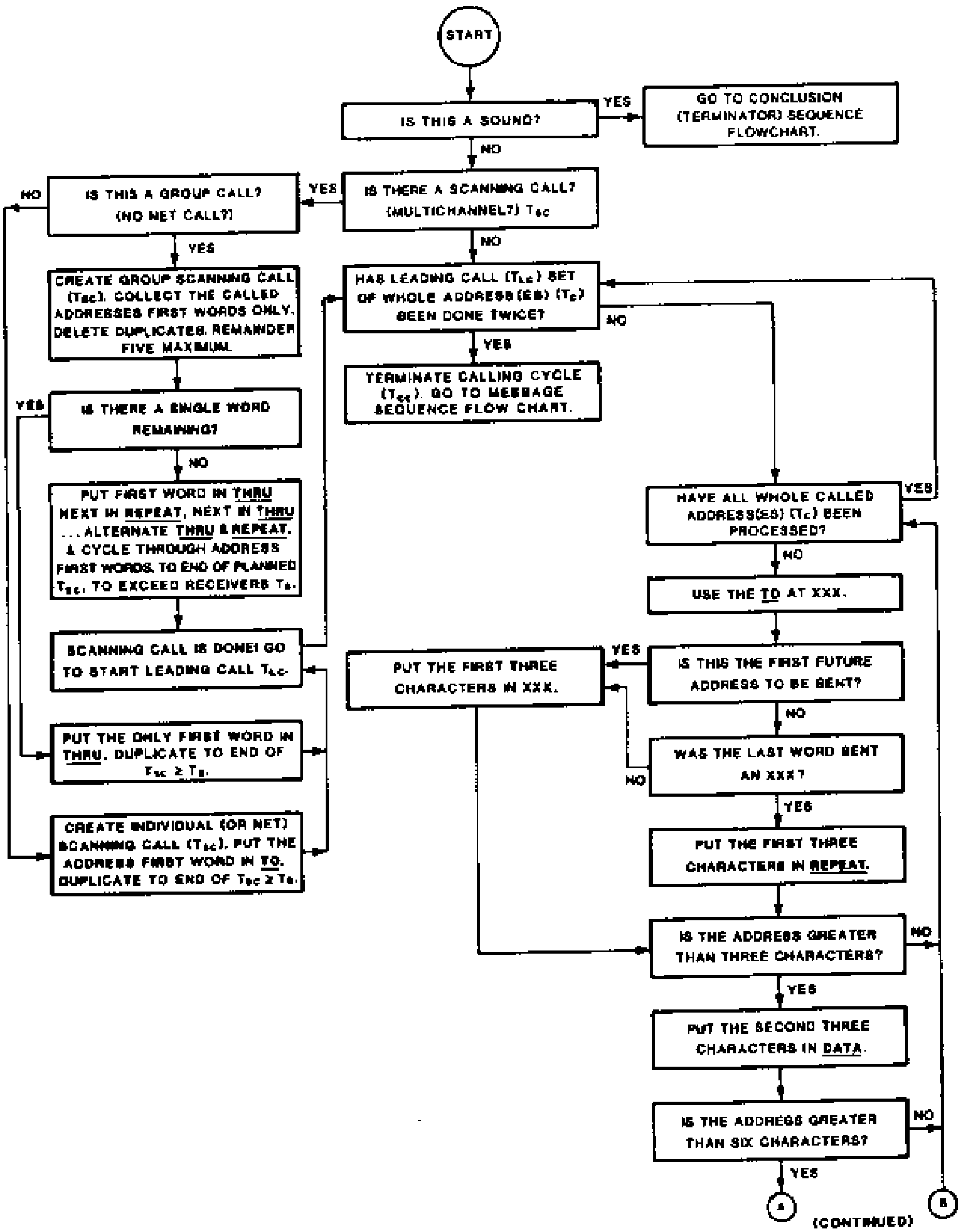


Figure 15a. Calling cycle sequences (Continued)

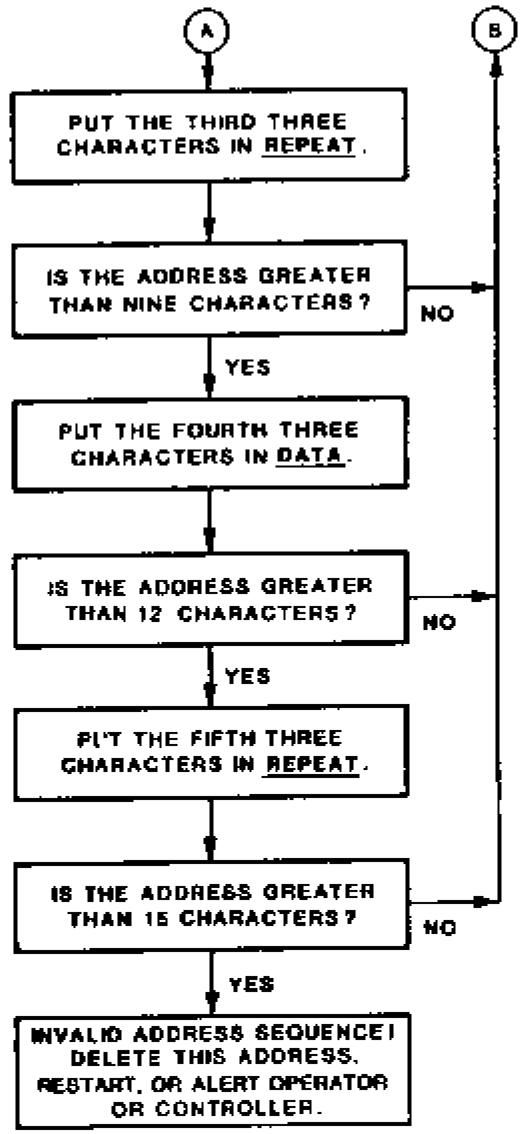


Figure 16. Message sequences

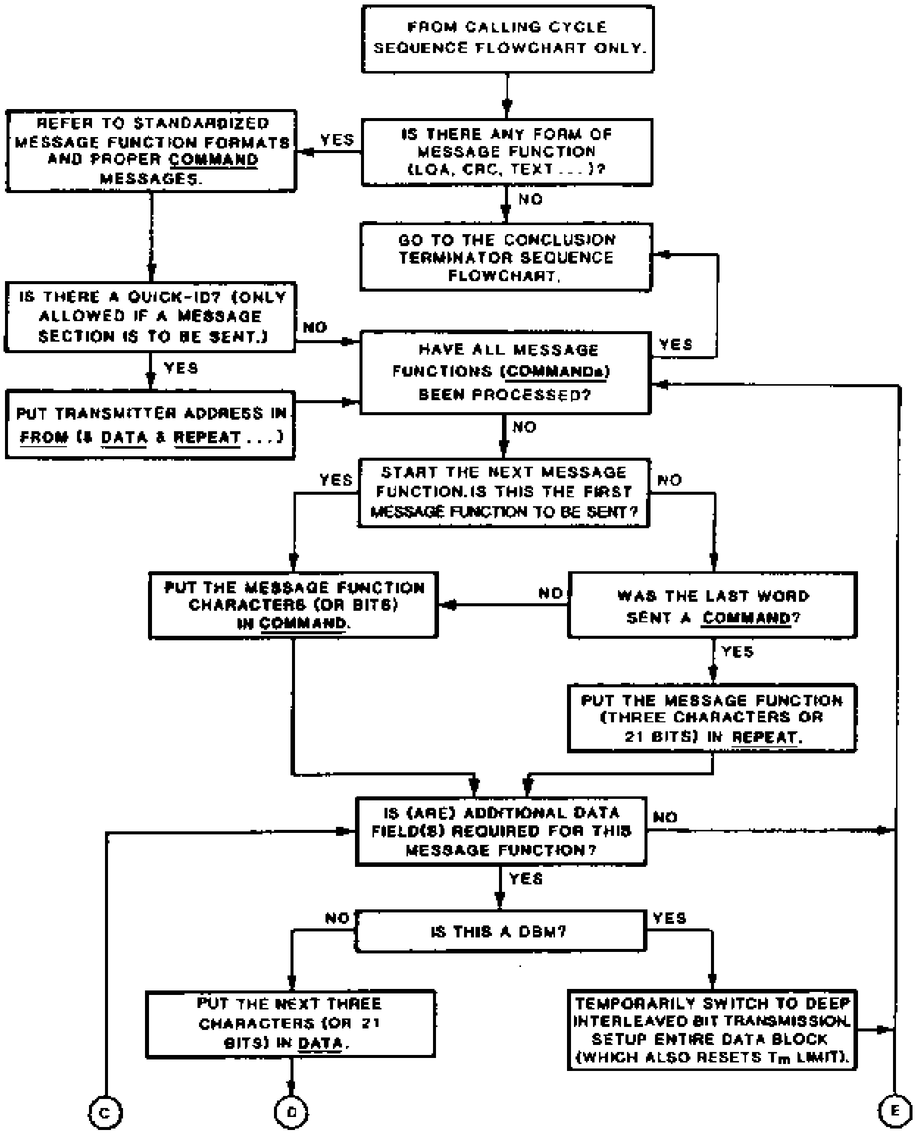


Figure 16a. Message sequences (Continued)

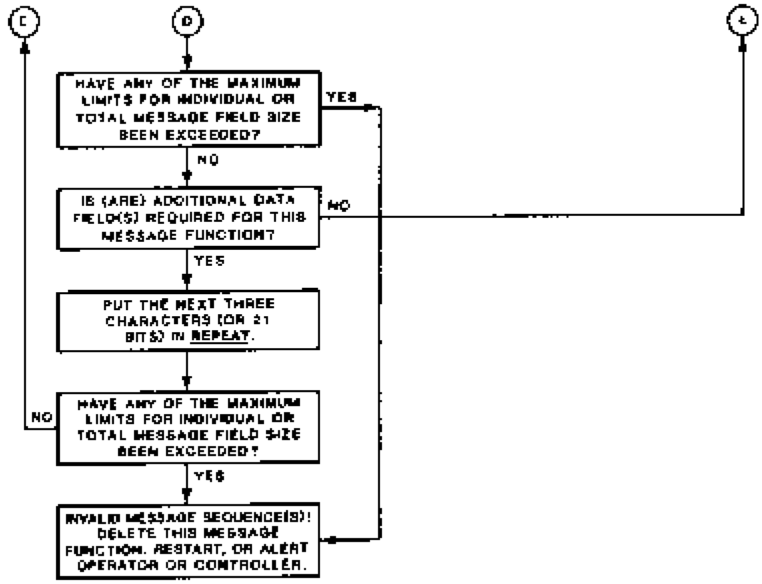


Figure 17. Conclusion (terminator) sequence

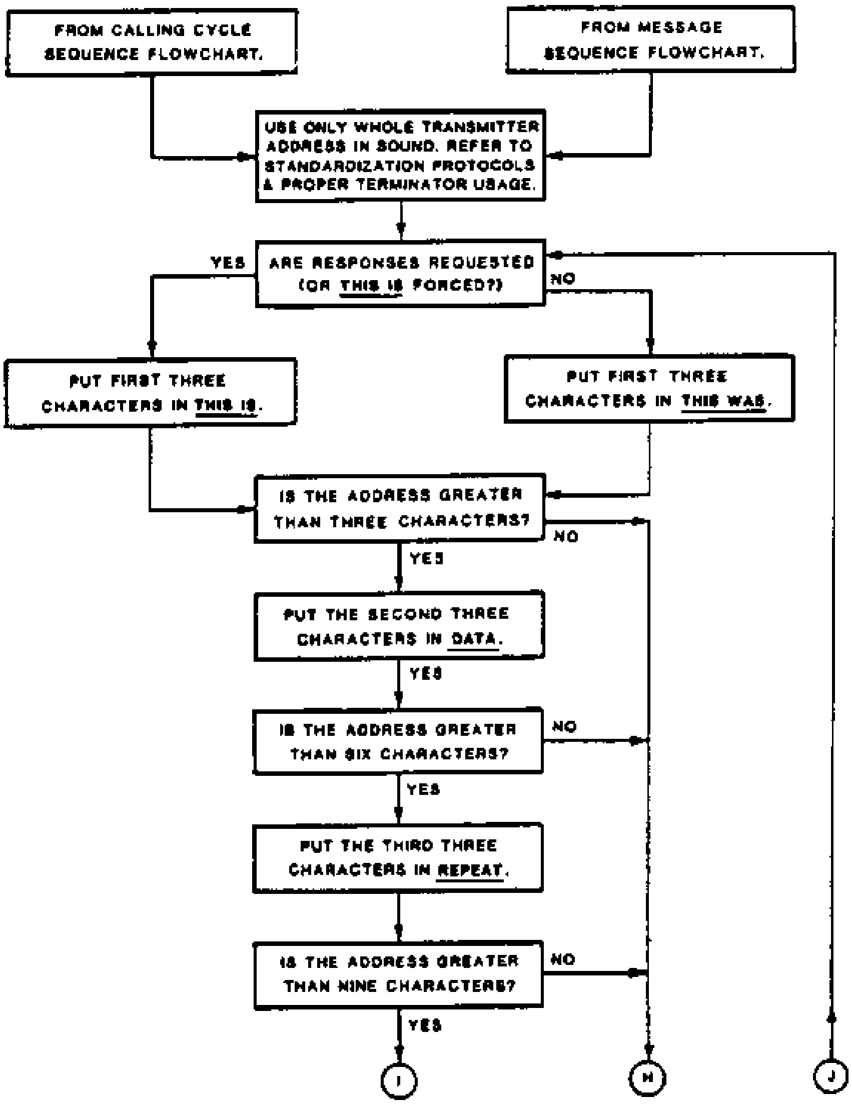


Figure 17a. Conclusion (terminator) sequences (Continued)

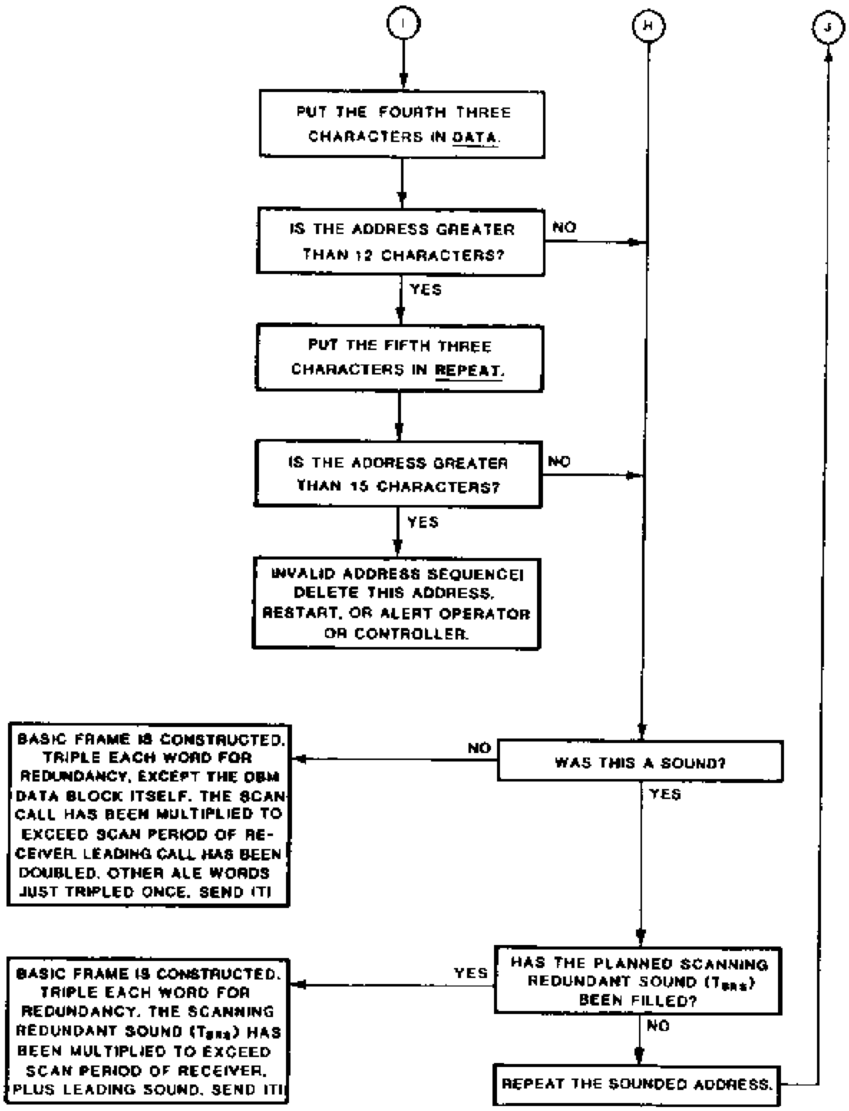
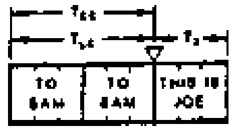
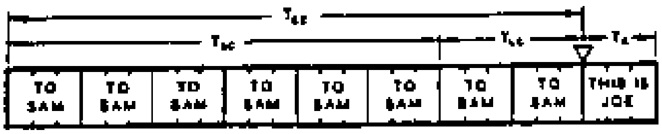


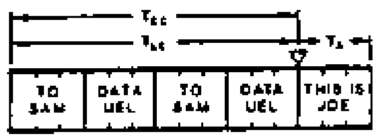
Figure 18. Basic frame structure examples



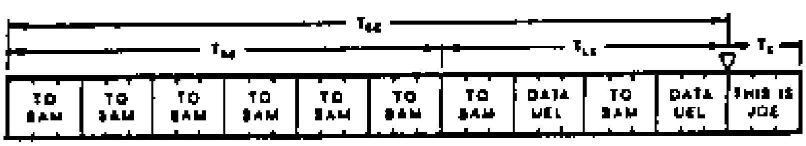
A. 1-CHANNEL NONSCAN, 1-WORD ADDRESSING, DIRECT, INDIVIDUAL (OR NET) CALL.



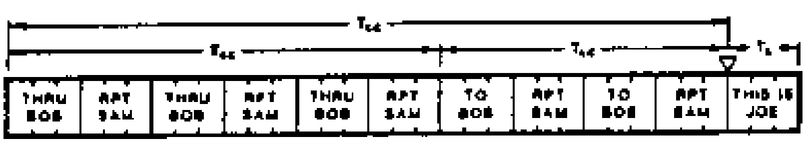
B. N-CHANNEL SCANNING, 1-WORD ADDRESSING, DIRECT, INDIVIDUAL (OR NET) CALL.



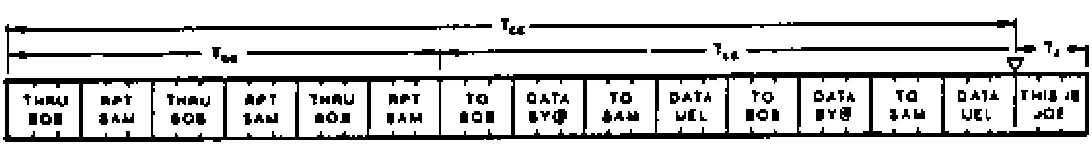
C. 1-CHANNEL NONSCAN, 2-WORD ADDRESSING, DIRECT, INDIVIDUAL (OR NET) CALL.



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.

5.2.4.3.2 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 Fig. 14. In DBM mode, the receive demodulator shall also be capable of reading single data bits for deep deinterleaving and decoding.

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

- must meet or exceed a threshold of unanimous votes in the 2-of-3 majority vote decoder
- successful Golay decode of "A" word bits
- successful Golay decode of "B" word bits
- acceptable preamble according to valid word sequences as shown on Fig. 5
- acceptable first character bits (of basic 38-ASCII subset)
- acceptable second character bits (of basic 38-ASCII subset)
- acceptable third character bits (of basic 38-ASCII subset)
- history, status, expectations, and protocol
- correct triple redundant word phase (within a transmission)

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 sec. 5.2.2.2, 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 T_{cc}). 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 3 characters would have to be within the basic 38-ASCII 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 without the necessary knowledge of the previous word, in most cases it would be considered irrelevant and should be rejected.

5.2.5 Addressing.

5.2.5.1 Introduction. The ALE system deploys a digital addressing structure based upon the standard 24-bit (3 character) word and the basic 38-ASCII subset characters. As is 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 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.

5.2.5.2 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, it is no longer than three characters), it shall be termed a "basic" size and, if it exceeds the one word, it shall be termed an "extended" size.

5.2.5.2.1 Basic. The basic address word shall be composed of a routing preamble (TO, or possibly a REPEAT which follows a TO in T_{lc} of group call, or a THIS IS or THIS WAS) plus three-address characters, all of which shall be the alphanumeric members of the basic 38-ASCII subset. The use of the utility symbols "@" and "?" shall be as described in par. 5.2.5.5. The 3 characters in the basic individual address provide a basic 38-ASCII subset address capacity of 46,656 using only the 36 alphanumerics, and this single word is the minimum structure. Use of only 1 or 2 characters is discouraged because they provide a basic 38-ASCII subset 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. 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. 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 5.3, the basic individual addresses of various stations may be combined to implement flexible linking and networking.

5.2.5.2.2 Extended. Extended addresses provide address fields which are longer than 1 word (3 characters), up to a maximum system limit of 5 words (15 characters). See Table 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 TO or THIS IS, as described above, plus additional words as necessary to contain the additional characters, in the sequence DATA, REPEAT, DATA, REPEAT, for a maximum total of five words. All address characters shall be the alphanumeric members of the basic 38-ASCII subset. The use of the utility symbols "@" and "?" is described in par. 5.2.5.5. All ALE stations shall be assigned at least one (DO: several) two-word address(es) for general use, plus additional address(es) containing the station's assigned call sign(s).

NOTE: 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 "TO EDW," "DATA ARD," and a call to "MISSISSIPPI" would be "TO MIS," "DATA SIS," "REPEAT SIP," "DATA PI@."

5.2.5.3 Multiple stations. It is a critical requirement to simultaneously (or nearly simultaneously) address and interoperate with multiple stations in MF and 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." Protocols for linking and networking with nets and groups are described in sec. 5.3.6. 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.

5.2.5.3.1 Net. 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 sec. 5.3.6, 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. 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.

TABLE IX. Basic (38-ASCII subset) address structures

	Words	Address Characters	Types
Basic	1	1	Stuff-2
	1	2	Stuff-1
	1	3	Basic
	2	4	Basic + Stuff-2
	2	5	Basic + Stuff-1
	2	6	2 Basic
	3	7	2 Basic + Stuff-2
Extended	3	8	2 Basic + Stuff-1
	3	9	3 Basic
	4	10	3 Basic + Stuff-2
	4	11	3 Basic + Stuff-1
	4	12	4 Basic
	5	13	4 Basic + Stuff-2
	5	14	4 Basic + Stuff-1
	5 (limit)	15 (limit)	5 Basic (limit)
NOTES: Basic: ABC Stuff-2: A@@ Stuff-1: AB@			

5.2.5.3.2 Group. (Optional). (Mandatory in FED-STD-1046). 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 common 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 station, in the manner directed by the specific standard protocol. A station's address shall not appear more than once in a group calling sequence, except as specifically permitted in the group calling protocols described in par. 5.3.6.3 and FED-STD-1046.

5.2.5.4 Special modes "@" and "?".

5.2.5.4.1 General. The special modes, which use the utility symbol "@" (1000000) and "?" (0111111), include the following:

- Stuffing
- Allcalls
- Anycalls (See also FED-STD-1046)
- Self address
- Null address
- Wildcards (Reserved for FED-STD-1046)

5.2.5.4.2 Stuffing. 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 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 (T_{1c}) of the calling cycle (T_{cc}).

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

5.2.5.4.3 Allcalls. (Mandatory) An "allcall" is a general broadcast which does not request responses and does not designate any specific address. This essential function is required for emergencies ("HELP!"), sounding-type data exchanges, and propagation and connectivity tracking. See Table 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 T_{sc} and T_{1c} of T_{cc}) in the initial call, shall not be used in any other address field or part of the handshake, and shall use the TO words. The global allcall special address shall be "TO @?@," with standard redundancy. It shall employ only the TO preamble and shall not be followed by REPEAT or DATA. Upon receipt of the allcall, (and unless inhibited or otherwise directed by the operator or controller), all receiving allcalled stations shall temporarily stop their scan (for a preset, limited time T_{cc} max). If the message section or terminator section does not arrive within T_{cc} max, the station shall automatically resume scanning. If a quick-ID (indicated by a FROM after the calling cycle) arrives, the pause for the message section shall be extended for no more than five words (5 T_{rw}), 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 T_m max) to read the message. If the terminator section does not arrive within T_m 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 T_x max) to read the caller's (transmitter's) address. If the end of the signal does not arrive within T_x 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 (T_{wa}), 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 sec. 5.3.5. 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 par. 5.3.5.4. In all handshakes (other than the calling cycle of the initial allcall), the allcall address shall not be used. As an optional 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 T_{sc} and T_{lc} (or possibly "THRU @A@" and "REPEAT @B@" in T_{sc}, and then TO and REPEAT in T_{lc} if more than one subset is also desired), and rotated if necessary. "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 T_{sc} scan call (and finish with TO, REPEAT, TO... in T_{lc}). As in the global allcall, the scanning and optional procedure are the same as for the sounding scanning protocol. The selective allcall is a feature of FED-STD-1046.

TABLE X. Use of "@" utility symbol

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

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 T_{sc} if group call.
5. Reserved for FED-STD-1046.

5.2.5.4.4 Anycalls. (Optional). (Mandatory in FED-STD-1046). An ALE station may call and receive responses from essentially unspecified stations and it thereby can identify new stations and connectivities. An "anycall" is a general broadcast which requests responses without designating any specific address(es). It is required for emergencies, reconstitution of network and systems, and creation of new networks. The anycall, selective-anycall, and double-selective anycall are characterized in Table X. If an ALE station requires an anycall, it shall use the following anycall protocols. The anycall special address structures (a) shall be the exclusive members of the calling cycle in the initial call, (b) shall not be used in any other address field or part of the handshake, and (c) shall use the TO the entire T_{cc}. 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 anycall(ed) stations shall temporarily stop their scan, and examine the call in a manner identical to the procedure used for allcalls (par. 5.2.5.4.3), including the T_{cc} max, T_m max, and T_x max limits. If the anycall is successfully received, the receive station shall automatically perform a slotted response identical to that for a star net (scanning) call protocol (par. 5.3.6.2), but as modified below.

There shall be 17 standardized time slots (slot 0 plus 16) with each one being 20 T_w(2613.33..ms) wide, for a total duration of approximately 44 seconds. As is described in sec. 5.3.6, the primary general variation in slot size is due to the possible addition of LQA information. If the calling station requests LQA in the message, the responses shall expand by 3 T_w to include the LQA, and the slots shall automatically expand by 3 T_w to 23 T_w (3005.33... ms), for a total of approximately 51 seconds. In either anycall case, each responding station shall individually select a slot (of 1 through 16, but not zero unless an emergency), essentially pseudo-randomly (PRN), in which to transmit its response. 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 that consist of TO (with the address of the caller) and THIS

IS (with the address of the responder), with the LQA included if requested. In addition, responses shall not use the anycall special address. The caller shall use a short one-word self-address and shall not use more than three words. The responders shall use a self-address no longer than four words minus the caller address length. (For example, if the caller's address is two words, the responder cannot exceed two words.) Upon receipt of the slotted responses, the calling station shall transmit the acknowledgment (ACK) to any selected combination (individual or group call) of stations which responded and were read. The responders which receive acknowledgments shall alert, unmute their speakers, and shall pause for traffic, (or quit immediately), as indicated by the caller's ACK conclusion THIS IS (or THIS WAS, respectively). The caller shall not use the anycall special address in the ACK. The caller may pause for additional inter-operation and traffic (THIS IS) with the responders, 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 not activity for a preset time (T_{wa}), 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 will be enabled.

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

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

5.2.5.4.5 Wildcards. (Reserved for FED-STD-1046)

5.2.5.4.6 Self-address. 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 "TO ABC," 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. A full-duplex station shall be capable of calling and handshaking with itself.

5.2.5.4.7 Null address. 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 "TO @@@," (or REPEAT @@@), if directly after another TO. The null address shall always use the TO (or REPEAT) and only in the calling cycle (T_{cc}). Null addresses may be mixed with other addresses (group call), in which case they shall appear only in the leading call (T_{1c}), and not in the scanning call (T_{sc}). Nulls shall never be used in the conclusion (terminator) (THIS IS or THIS WAS). 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 tune-ups, or overflow from the previous slot's responder, etc.).

5.2.6 Link quality analysis (LQA).

5.2.6.1 General. LQA concerns the automatic measurement of the quality of the ALE signal on 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 sec. 5.2.7. LQA shall also be used for continual monitoring of the link(s) quality during communications which use ALE signaling. The stored values shall be available to be transmitted upon request or as the network manager shall direct. Unless specifically and otherwise directed by the operator or controller, all ALE stations shall automatically insert the COMMAND LQA word (▼) in the message section of their signals and handshakes, when requested by the handshaking station(s), when prearranged in a network, or when specified by the protocol. See sec. 5.4.2. If an ALE station requires, and is capable of using LQA information (polling capable), it may request the data from another station by setting the control bit KA1 to "1" in the COMMAND LQA word. If an ALE station, which is sending a COMMAND LQA in response to a request, is incapable of using such information itself (not polling capable), it shall set the control bit KA1 to "0." It will be a network management decision to determine if the LQA is to be active or passive. For human factors considerations, LQA scores which may be presented to the operator should have higher (number) scores for better channels.

5.2.6.2 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 votes (out of 48) in the majority vote decoder. The BER values shall be represented internally by a number which shall range from 0(000000) to 48(110000). The BER/LQA measurement is based on each redundant triplet (3 T_w) word which is received and properly decoded as a valid majority word. Therefore, in an ALE transmission, the best BER/LQA value should appear when the majority vote decoder is properly aligned with the incoming signal; that is, all three word inputs are occupied with identical (except for errors) redundant words.

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

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 majority votes for a particular triple redundant word, properly aligned. The value for an entire received signal shall be the linear average of the internal BER/LQA values of the valid received words, shall include a worst case 48(110000) value for rejected words, and shall be for an entire and uninterrupted signal. For transmission in the COMMAND LQA word, the internal average value shall be converted to 5-bit values as shown in Table XI. The 5-bit values, BE5 (MSB) through BE1 (LSB), shall be the binary representation of the average number of counted (or averaged) nonunanimous votes.

5.2.6.3 Signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD). Signal-to-noise and distortion measurements employed within the LQA shall be a SINAD measurement (S+N+D)/(N+D) averaged over the duration of the received ALE signal. The SINAD values shall be measured on all ALE signals and shall be inserted into all LQA words in the same manner as the BER. It shall be communicated in 4-bit values as shown in par. 5.4.2.2.

5.2.6.4 Multipath (MP). (Reserved for FED-STD-1046.)

5.2.7 Channel selection.

5.2.7.1 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 (one- or two-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. The channel(s) with the "best score(s)" shall be tried first (unless otherwise directed by the operator or controller) until all the LQA scored channels are tried. However, if such information is unavailable (or it has been exhausted and other valid channels remain available and untried), the station shall start (or continue) on the highest frequency (untried valid) channel and, if unsuccessful, shall continue with the next highest (untried valid) channel until successful or until all the remaining (untried valid) channels have been tried.

TABLE XI. Basic bit error ratio (BER) values

Average 2-of-3 Votes Counted	LQA transmission bits					Approximate BER
	MSB			LSB		
	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	0	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 votes of 48. 2. The 2-of-3 votes count is the average of 2-of-3 votes of 48 over the words in the reviewed signal.						

5.2.7.2 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. Fig. 19 represents a simple LQA memory example. For each address/channel call, the received LQA (upper section) and reported LQA values (lower section) are stored. Bilateral (handshake) scores in this example are the sum of the two LQA values.

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 on Fig. 19, if a handshake is required with station B, channel C3 would be 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), then C5 with 7, C2-12, 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 were 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.

5.2.7.3 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 BER values in the LQA memory.

NOTE: In the example on Fig. 19, 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 by C6 (36+) and C2 (34+), their 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 ×) (recently failed attempt), and finally C1(two ×).

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

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 ≤ 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 ×). 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.

5.3 Protocols.

5.3.1 Introduction. 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, for both linking and networking.

Figure 19. LQA matrix example

ADDRESSES (OTHER STATIONS)		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

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.

5.3.2 Manual operation. The system is based upon 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.

5.3.2.1 Operator control. 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.

5.3.2.2 Push-to-talk. Push-to-talk (PTT) operation is the most common form of human interaction with MF and 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.

5.3.3 ALE operational rules. The ALE system shall incorporate the basic operational rules listed in Table XII. "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.

5.3.4 Individual calling.

5.3.4.1 Introduction. 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 on Fig. 20, 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 Appendix B, Annex B, and their computation is described in par. 5.3.4.4. 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 "THIS IS A," indicates an individual, over-the-air, 130.66... ms nonredundant word (T_w), of which several duplicates (multiples of 3) are used to communicate them as redundant words (T_{rw}), as shown (usually as boxes with "tic" marks). In this example, the basic required minimum call, which is 3 T_{rw} (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 T_{rw} (392 ms) per original, nonredundant word). The initiation of the outgoing frame shall always be after the transmitter is up to full power (over 90 percent) and shall be word synchronized in accordance with par. 5.2.4.3.1. 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, and the multiple channel description provides an in-depth analysis of the individual protocols.

5.3.4.2 Single channel. The fundamental capability to automatically link on a channel, is provided by the individual calling protocol. This protocol establishes and positively confirms bilateral connectivity between stations on a channel. ALE stations shall employ this protocol for single channel linking, polling, and networking, and for basic automated ALE interoperation on a channel after scanning linking. All ALE stations, when operational and not otherwise committed, shall continually listen for calls; that is, they are "always available." See Fig. 21. The protocol establishes and consists of three parts: an individual call, a response, and an acknowledgment. At the left of Fig. 21, in this single-channel example (1), the caller A should already be properly tuned to the channel (2). The wait buffer (3) provides a listen-before-transmit pause, to avoid "disturbing active channels." It has an optional length (T_{wt}) 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 calling scanning protocol. Normally, both A and B are on channel and available; that is, their speakers are muted; they are "always listening" and they "will respond when called." Starting with the individual call, station A shall call station B by transmitting a calling cycle containing B's address ("TO B"), followed by a conclusion (terminator) containing his own ("THIS IS A") (7). A then shall wait a preset reply time (T_{wr}), a buffer which includes anticipated propagation each way and B's turnaround time) to start to receive B's response (9). Upon receipt of A's call and recognition of both his and A's addresses, B shall tune up (if needed) (2), send the response, and wait his own reply time T_{wr}. Upon receipt of B's response (starting within the reply wait T_{wr}) and recognition of both his and B's addresses, A shall send the acknowledgment, enter the linked state (with B) unmute the speaker, and alert the operator. Upon receipt of the acknowledgment (starting within B's reply time T_{wr}), B shall also enter the linked state (with A), alert his own operator and unmute his speaker. During the linked state (A-B), the operators may then pick up their microphones and exchange conventional PTT voice communication, radio teletypewriter (RTTY), morse code (ICW), or anything else required. If the expected reply from B does not start to arrive within the preset wait for reply time (T_{wr}), the handshake shall be terminated, A does not enter the linked state, and A's operator or controller shall be notified. If the expected acknowledgement from A does not start to arrive within the preset wait for reply time (T_{wr}), the handshake shall be terminated, B does not enter the linked state, and B's operator or controller should be notified. However, it may be reinitiated by the operator or controller at any time. In rare cases when the acknowledgement to B is lost, A will be in the linked state (without B) but shall return to scan or "available" after the wait for activity timer (T_{wa}) expires.

TABLE XII. 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. Minimizes time on channel
11. Minimizes power used (as capable)
NOTE: Listed in order of precedence.

Figure 20. Basic call structure

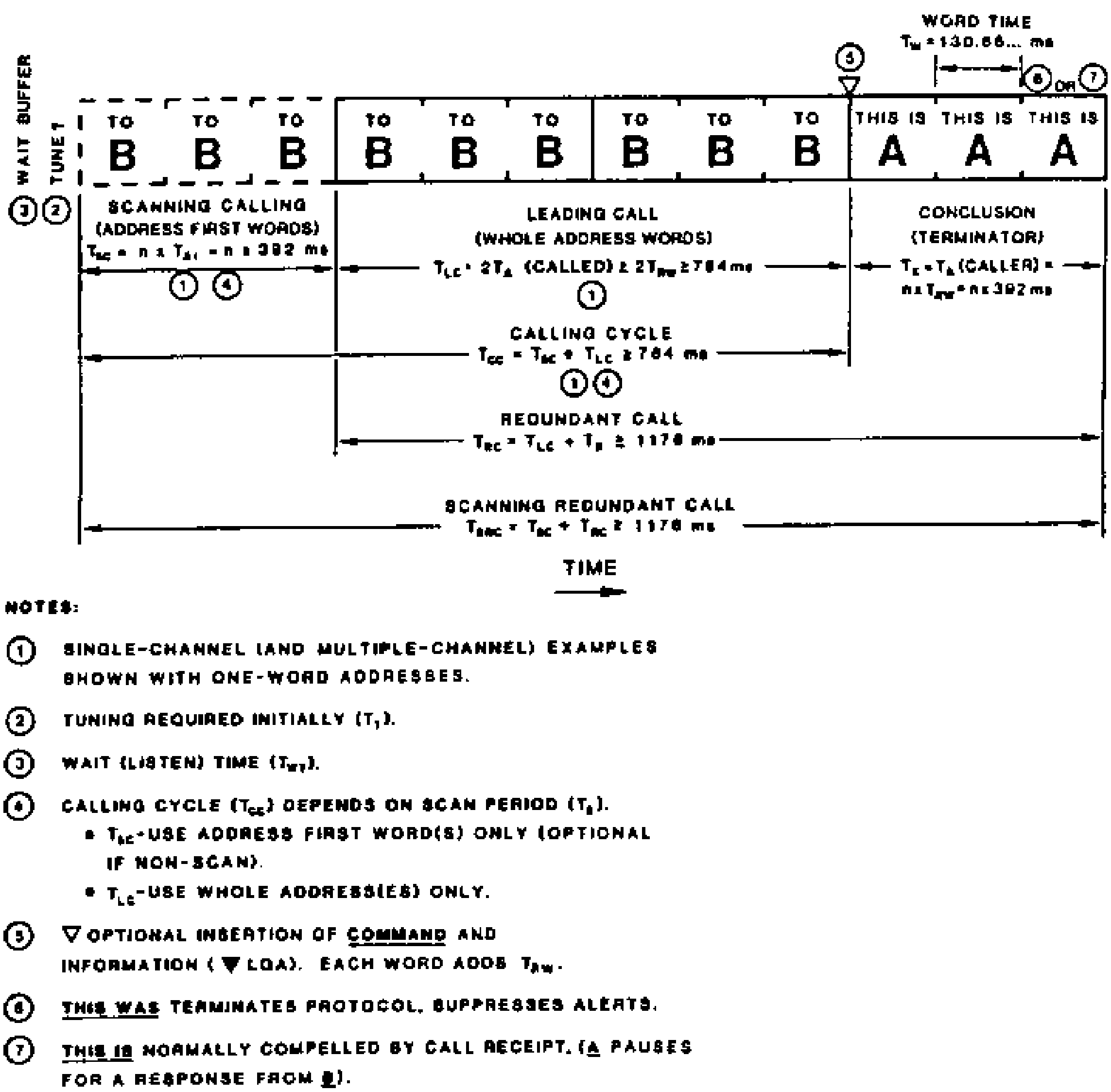
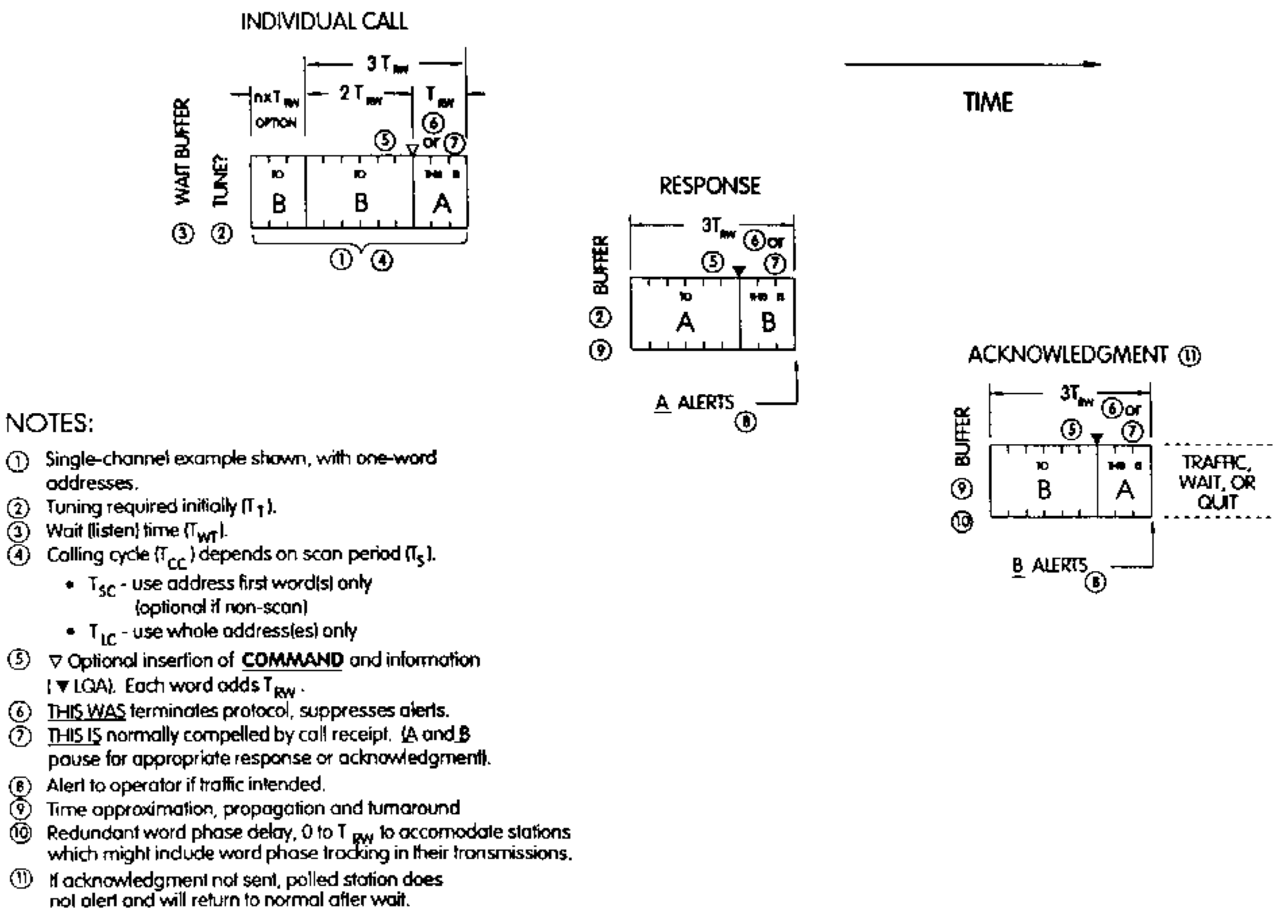


Figure 21. Individual call protocol



If implemented, termination of the linked state (after successful linking handshake(s)) shall be accomplished by the use of a (non-scanning) basic call using THIS WAS, from any station to any other linked station(s) which is (are) 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 pars. 5.3.6.2 or 5.3.6.3.

When the operators or controllers are through communicating, they should reset the stations, terminate their linked states, and mute the speakers, therefore restoring them to ALE "available". As an option, 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 linked channel within a preset wait for activity time limit (T_{wa}), 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 disableable by the operator or net manager. This timed reset is not required to cause a termination (THIS WAS) transmission, as specified above, however, as a recommended (default) operator or net manager selected option, a termination should be sent to reset the other linked station(s) and immediately free them for being "available".

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

There are several specific variations to the protocol. If an automated message (or COMMAND sequence) is to be sent in any of the signals, it shall be inserted at the (∇) delta location (5), and the signal frame will be appropriately lengthened. The message can provide many options, such as the insertion of LQA information at (▼), and it may significantly affect the protocol and timing, as described in sec. 5.4. Normally, A's use of "THIS IS" in the call compels B's response, and the substitution of a "THIS WAS" 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 acknowledgment. However, if B sends a "THIS WAS", A shall not alert or send an acknowledgment, 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 acknowledgment to B appears identical to A's individual call to B, but it does not cause B to provide another response to the acknowledgment (resulting in an endless "ping-pong" handshake) because A's acknowledgment arrives within the narrow time window (T_{wr}) of B's first response, and A is responsible for sending the ACK within this time limit. If A does not receive B's response within this 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 acknowledgment arrives late (after T_{wr}), 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 (T_{rw}) detect good ALE words. If such a dropout occurs during an initial received call and continues for a period in excess of 3 T_{rw} (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 an ALE station receives a complete individual call to it (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, par. 5.3.5.4) to reinitiate the calling station.

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

All ALE 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 (T_d 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 (T_s min) is equal to the product of the number of channels (C) times the minimum dwell time on each channel (T_d min); that is, $T_s \text{ min} = C \times T_d \text{ min}$. However, the receive scan period (T_s) (for calling transmit (T_{sc}) computations) should be based on the probable maximum pause (T_d) to read words on each channel, or $T_{drw} = 784$ ms. Thus $T_s = C \times T_d = C \times 784$ ms. The net manager may adjust the T_d to optimize system performance.

All ALE 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 (T_{cc}) is composed of a scan call (T_{sc}) plus a leading call (T_{lc}). The scan calling time (T_{sc}), in order to capture the scanning receiver, must equal or exceed the total scan period (T_s) of the called station and shall also be composed of multiple address first words ($\sum T_{a1} = T_{c1}$), which are a multiple of the redundant word time, T_{rw}; that is,

$$T_{sc} = n \times \sum T_{a1} = n \times T_{c1} \geq T_s.$$

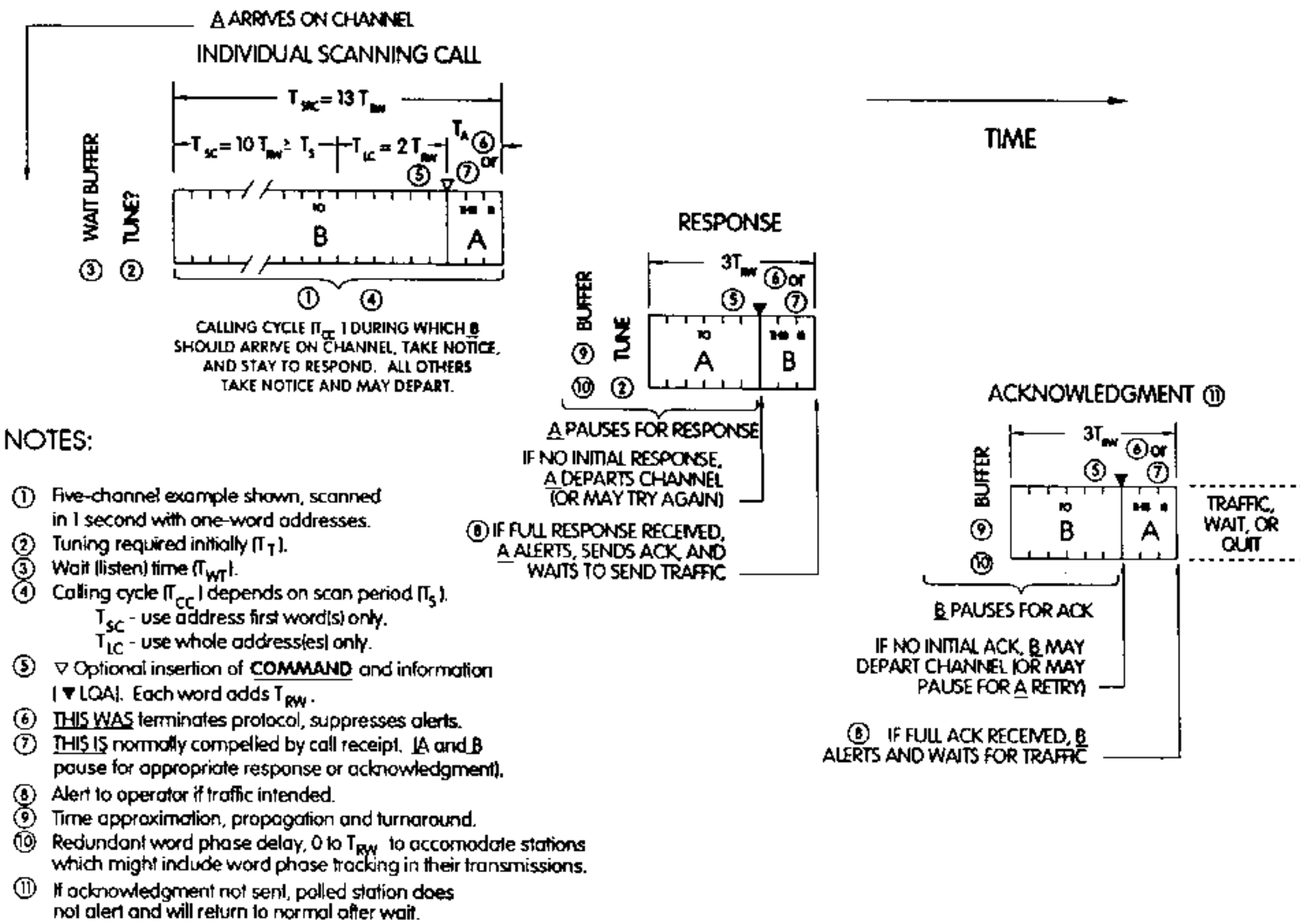
The scanning call contains only the called address(es) different first words ($\sum T_{a1}$) in rotation. The leading call contains only the whole called station address(es), repeated twice ($2T_c = 2 \sum T_a$). Therefore, the calling cycle should be:

$$T_{cc} = T_{sc} + T_{1c} = (n \times \sum T_{a1}) + 2\,T_c \geq T_s + 2\,(\sum T_a).$$

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 ALE scanning calling station shall stop and link on the first channel which supports the handshake with the called station(s). After scanstop, 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 calling 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 scanning capability, it shall rerank the channels (downgrading the rejected and the previously failed channels) and restart the calling on the newly expected best channel. If the station has a fixed calling channel sequence, it shall restart the scan calling on the next channel which would have been tried 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). During the calling scanning cycle, the caller often encounters 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 ALE 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 par. 5.3.4.4 for the specific details of ALE timing.

Figure 22. Individual scanning calling protocol



When an appropriately addressed ALE call ("TO B") is detected by, and addressed to, scanning ALE 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 22 illustrates the individual calling scanning protocol handshake for ALE stations in a typical five channel network and employing a standard scan rate of 5 chps. The protocol starts with A's arrival on channel, shown at the left. Upon arrival, A shall pause for a preset buffer time (T_{wt}) 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 transmission chain (2) as rapidly as possible (T_t) and initiate the transmission. The scanning call (T_{sc}) of the calling cycle (T_{cc}) is deliberately longer than B's scan period (T_s) 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 (T_s) and therefore during A's additional and longer scan calling time (T_{sc}), B shall attempt to detect ALE signaling (within dwell time T_d min) and then shall decide to wait a preset time (T_{drw}) to read possible ALE words if ALE signaling was detected. If no signaling is detected within T_d 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 T_{drw}, 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 (T_{wce}) 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 quick-ID or a message (COMMAND sequence) starts within T_{wce}, B shall wait and attempt to read the message within a new preset, limited time (T_m max). If no quick-ID or message starts within T_{wce}, or no terminator starts within T_m max (or T_{wce} 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 (T_x 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 acknowledgment) within B's reply window, T_{wr}, 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 T_x 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 (T_{rw}) 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, T_{lww}, or T_{rw}) 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 ALE 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 (T_{wrt}), as B must be provided with an additional period (T_t) to tune (2) for an initial reply. However, called station B shall use the shorter single channel wait time (T_{wr}) when waiting for A's reply (acknowledgment) 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 T_{wrt}. If A successfully reads an appropriate response ("TO A") starting within T_{wrt}, it shall plan to reply (acknowledge) and shall wait a preset, limited time (T_{drrw}) to read the next rotating redundant word, which in the protocol shown is the "THIS IS B" terminator. If A does not receive this appropriate response calling cycle ("TO A") starting within T_{wrt}, or if A does not later receive the appropriate terminator ("THIS IS B") starting after T_{lc} (plus T_m 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 T_{lc} (plus T_m max, if message included), A shall wait to reply (acknowledge) and shall expect the handshake to be successfully completed within the time window T_{wr}. Meanwhile, A shall continue to read the incoming ALE signal and shall search for a new preset, limited "last word wait" time ($T_{lww} = T_{rw}$) for additional words (if any) and the end of the terminator signal (absence of detected word), which will trigger A's acknowledgment. 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 T_{lww}, (plus the additional multiples of T_{rw} 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 T_{lww}, 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 acknowledgment (using "THIS IS A"), and shall unmute A's speaker. Both A and B shall continue to use the same methodology, criteria, and timing described above for the successful transfer of the acknowledgment, in which case station B shall alert his operator that the correct acknowledgment has been received and shall unmute B's speaker. The bilateral ALE 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 acknowledgment. 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 (T_{hs}) in the example given on Fig. 22 is about 9 seconds on the channel.

5.3.4.4 Timing. The ALE system depends upon a selection of timing functions for optimizing the efficiency and effectiveness of automatic link establishment. The primary timing functions and values are listed in Table XIII. Appendix B, Annex A defines the timing symbols, and Annex B explains the timing analysis and computation.

5.3.5 Sounding.

5.3.5.1 Introduction. 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. Implementation is simple. A timer is added to the ALE controller to periodically initiate sounding signals (if the channel(s) is (are) 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 1 or 2 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 ALE 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, it may not be necessary to sound 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 and also should reset the sounding interval timer to a fresh start, while compactly concentrating the sounding equivalents in a small amount of channel time. Specifically, in the single-channel case, any identifiable transmission (THIS IS, THIS WAS) shall reset the sounding timer. In the multichannel case, the longer scanning sounds shall reset the sounding timer, as well as a net (or group) protocol which contains all desired receiving stations.

All ALE 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. The address information shall be derived from sounding or the conclusion section of other ALE transmissions. The display shall have the capability to show and temporarily retain the address of the last station heard and, if the operator or controller initiates the call function, an ALE call to that address shall automatically be sent on that channel. 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 Fig. 23.

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 length (T_{rs}) is equal to the standard one-word address leading call; that is, $T_{rs} = T_{lc}$ min = 2 T_a min = 2 T_{rw} = 784 ms. Described below are both single channel and multiple channel protocols, plus detailed timing and control information, for designing ALE stations.

TABLE XIII. Timing

Basic System Timing • Tone rate = 125 symbols per second (sps) • Tone period = T_{tone} = 8 ms • On-air rate = 375 bps • On-air word: T_w = 130.66... ms • On-air redundant word: $T_{rw} = 3\ T_w$ = 392 ms • On-air leading redundant word: $T_{lrw} = 2\ T_{rw}$ = 784 ms • On-air individual (net) address time: $T_a = mxT_{rw}$ for m = 1 to 5 max words. T_a = 392 ms to 1960 ms • Propagation: T_p = 0 to 70 ms
System Timing Limits • Address size limit 5 word: T_a max = 1960 ms • Address first word limit: T_{a1} = 392 ms • Call time limit 12 words of the call: T_c max = 4704 ms • Maximum scan period: T_s max = 50s • Group addresses first word limit: T_{c1} = 1960 ms • Message section basic time (unless modified by AMD extension, or by COMMAND (such as DTM or DBM(): T_m basic = 11.76 s • Message section time limit of AMD (90 characters): T_m max AMD = 11.76 s • Message section time limit of DTM (1053 characters): T_m max DTM = 2.29 min (entire data block) • Message section time limit of DBM (37377 characters): T_m max DBM = 23.26 min (entire deeply interleaved block with COMMAND) • Termination time limit: T_x max = 1960 ms NOTE: Refer to Appendix B, Annex A and Annex B for details.
Individual Calling • Minimum dwell time: $T_d(5)$ min = 200 ms, basic receive scanning (5 channels per second) • Minimum dwell time: $T_d(2)$ min = 500 ms, minimum receive scanning, 2 characters per second (chps) • Probable maximum dwell time per channel, for T_s computations, let $T_d = T_{drw}$ = 784 ms • Number of channels: C • Scan period: $T_s = C \times T_d$ • Call time: $T_c = T_a$ (or more whole addresses as required $\sum T_a$) in T_{lc} • Call time: $T_{c1} = T_{a1}$ (or more different first words $\sum T_{a1}$) in T_{sc}

- Leading call time: $T_{lc} = 2\ T_c$
- Redundant call time: $T_{rc} = T_{lc} + T_x$
- Scanning call time: $T_{sc} = n \times T_{c1} \geq T_s$
- Calling cycle time: $T_{cc} = T_{sc} + T_{lc} \geq T_s + T_{lc}$
- Scanning redundant call time: $T_{src} = T_{sc} + T_{rc}$
- Last word wait delay: $T_{lww} = T_{rw}$ = 392 ms
- Wait for response time delay: $T_{wr} = T_{td} + T_p + T_{lww} + T_{ta} + T_{rwp}$ (if not first transmission)+ $T_{ld} + T_p + T_{rd}$
- Late detect delay: $T_{ld} = T_w$ = 130.66... ms
- Redundant word phase delay: T_{rwp} = 0 to T_{rw} (0 to 392 ms)
- Turnaround time: $T_{ta} = T_{rd} + T_{dek} + T_{enk} + T_{tc} + T_{tk} + T_{td}$ (See Appendix B for definition of terms)
- Wait for calling cycle end time: $T_{wce} = 2 \times$ own T_s (default)
- Tune time: T_t (as required by slowest tuner)
- Wait for reply and tune time: $T_{wrt} = T_{wr} + T_t$
- Detect signaling period: $T_{ds} \leq (T_d(5) = 200$ ms)
- Detect redundant word period: $T_{drw} = T_{rw}$ + spare T_{rw} = 784...ms
- Detect rotating redundant word period: $T_{drrw} = 2\ T_{rw}$ + spare T_{rw} = 1176 ms

<u>Sounding</u>

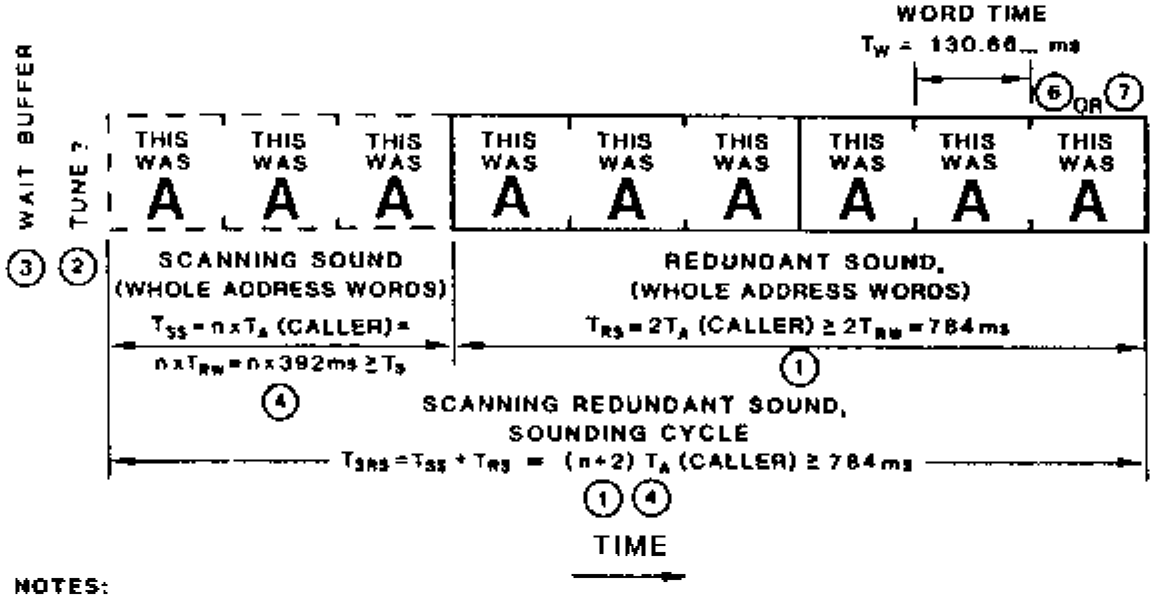
- Redundant sound time (similar to T_{lc}): $T_{rs} = 2\ T_a$ (caller)
- Scanning sound time (similar to T_{sc}): $T_{ss} = n \times T_a$ (caller) $\geq T_s$
- Scanning redundant sound time (similar to T_{cc}): $T_{srs} = T_{ss} + T_{rs} \geq T_s + T_{rs}$

<u>Star Calling</u>

- Minimum standard slot widths: T_{sw} min = 14,17 T_w for 1st handshake slots, or 17,20 for subsequent handshake slots, or other T_w as set by COMMAND.
- Slot widths: T_{sw} = 14, 17, 9, or other T_w
- Slot number: SN
- Slot wait time: $T_{swt} = T_{sw} \times$ SN (uniform case)
- Slot wait time (delay to start reply): T_{swt} for each slot is the sum of all the previous slot times and so must be different for each slot and is cumulative. $T_{swt}(SN) = T_{sw} \times SN$ for uniform slots or generally: $T_{swt}(SN) = SN \times [5\ T_w + 2T_a$(caller) + (optional LQA)T_{rw} + (optional message)T_m] + T_a(caller) + [(sum of all previous called addresses) m = SN - 1 $\sum T_a(m)$ (called)] m = 1
- Number of slots: NS
- Wait for net reply (at calling station): $T_{wrn} = (T_{sw} \times NS)$ for uniform slots, or generally $T_{wrn} = T_{swt}(NS)$
- Wait for net acknowledgment (at called stations): $T_{wan} = T_{wrn} + T_{drw}$
- Turnaround and tune limits: T + T $\leq$ 360, 2100, or 1500 ms, depending on

whether slot 0, 1, or others • Maximum star group wait for acknowledgement: T_{wan} max = 107 T_w + 27 T_a(caller) + 13 T_{rw} (optional LQA) + 13 T_m (optional message) • For late arrival stations if caller uses one word addresses and no message calling: T_{wan} max = 188 T_w, or 227 T_w if LQA
Programmable Timing Parameters Typical Values • Wait (listen first): T_{wt} = 2 seconds, general uses; = 784 ms, ALE/data only channels • Tune time: T_t = 8 T_w = 1045.33 ms (default), "blind" first call; = 20 seconds, next try • Automatic sounding: T_{ps} = 30 minutes • Wait for activity: T_{wa} = 30 seconds

Figure 23. 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).

5.3.5.2 Single channel. The fundamental capability to automatically sound on a channel is provided by the sounding protocol as shown on Fig. 23. ALE stations shall employ this protocol for single channel sounding, connectivity tracking, and the broadcast of their availability for calls and traffic. 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 par. 5.3.4.3. If sounding is directed to multichannel stations, A should use the totally compatible sounding scanning protocol, presented in par. 5.3.5.3. Normally both A and all other ALE 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 par. 5.3.5.4. 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 call 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.

5.3.5.3 Multiple channels. Sounding must be compatible with the scanning timing. All ALE stations shall be capable of performing the scanning sounding protocols described herein, even if on a fixed frequency. See figs. 23, 24, and 25. 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. ALE stations shall employ these protocols for multichannel sounding, connectivity tracking, and the broadcast of their availability for calls and traffic.

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

NOTE: The scanning sound is identical to the single channel sound except for the extension of the redundant sound (T_{rs}) by the scanning sound (T_{ss}) additional words to form a scanning redundant sound (T_{srs}); that is, $T_{srs} = T_{ss} + T_{rs}$. The scanning sound period (T_{ss}) is identical in purpose to the scanning call period (T_{sc}) 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 Fig. 24. In this illustration, station A is sounding and station B is scanning normally. If a station (A) plans to ignore calls (from B) which may follow his 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 (T_{wt}) to see if the channel is clear (3), tunes (T_t) his transmitter chain, comes to full power, and initiates the frame of his scanning sound (T_{srs}). This scanning sound is computed to exceed B's (and any others) scan period (T_s) by at least a leading redundant sound (T_{rs}), which will ensure an available detection period exceeding T_{drw} = 784 ms. In this five-channel example, with B scanning at 5 chps, A sounds for at least 12 T_{rw} (4704 ms). A also uses "THIS WAS A," redundantly, to indicate that calls are not invited. Upon completion of the scanning sounding frame transmission, A immediately leaves the channel and goes to the next channel in the sound set. This procedure repeats until all channels have been sounded or skipped if occupied. When the calling ALE station has exhausted all the prearranged sound set channels, it shall automatically return to the normal "available" receive scan mode. As shown in the illustration, the timing of both A and B have been prearranged to ensure that B has at least one opportunity, on each channel, to arrive and "capture" A's sound.

Specifically, B arrives, detects ALE sounds, waits for good words, reads at least three (redundant) "THIS WAS A" (in 3 to 4 T_w), 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 Fig. 25. In this illustration, A is sounding and B is scanning normally. If a station (A) plans to welcome calls (from B) which may follow his sound, the following call acceptance scanning sounding protocol shall be used. In this protocol, A sounds for the same time period as before. However, since A is receptive to calls, he shall use his normal scanning dwell time (T_d) or his preset wait before transmit time (T_{wt}), 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 (T_{wrt}) identically to the wait for response to calls (T_{wrt}) in the individual scanning calling protocol, in this case shown to be 6 T_w (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 (like responses) are received, A shall leave the channel.

Figure 24. Call rejection scanning sounding protocol

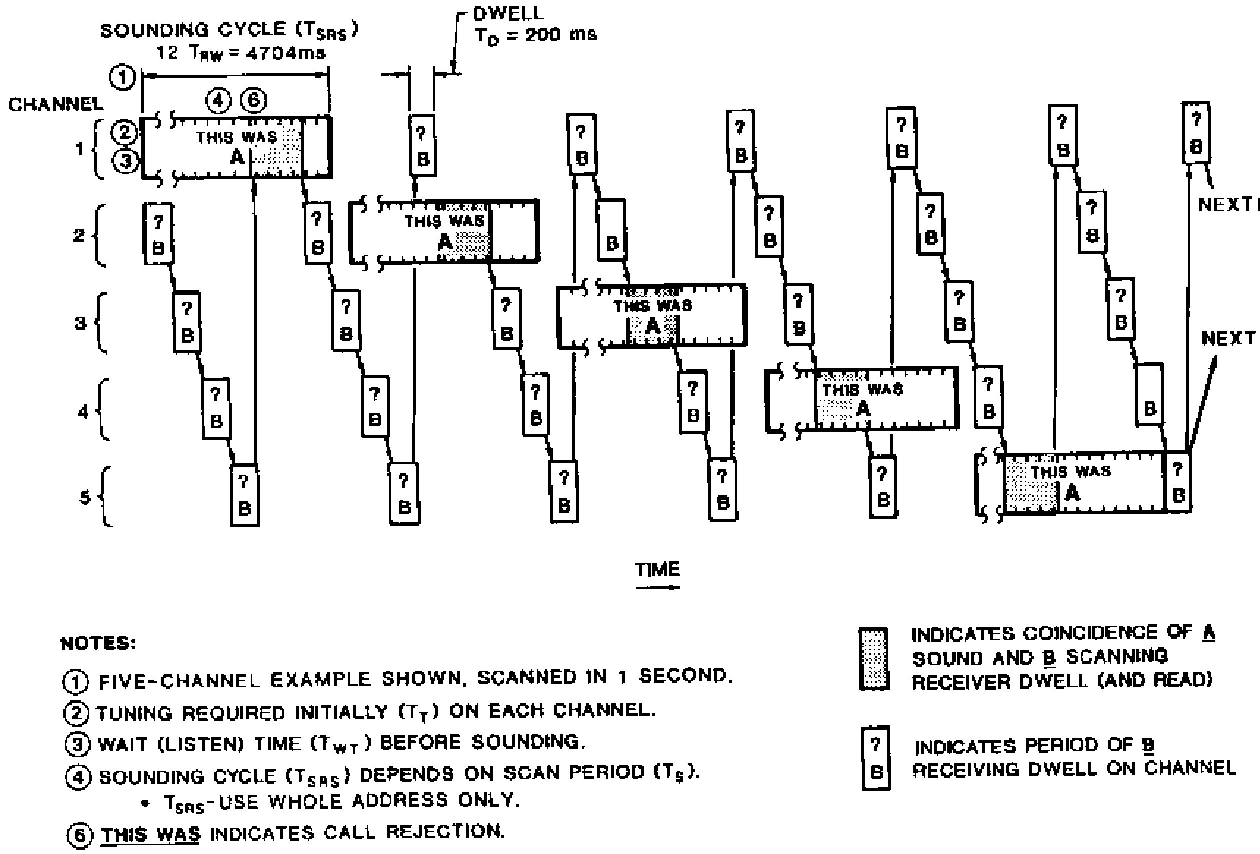
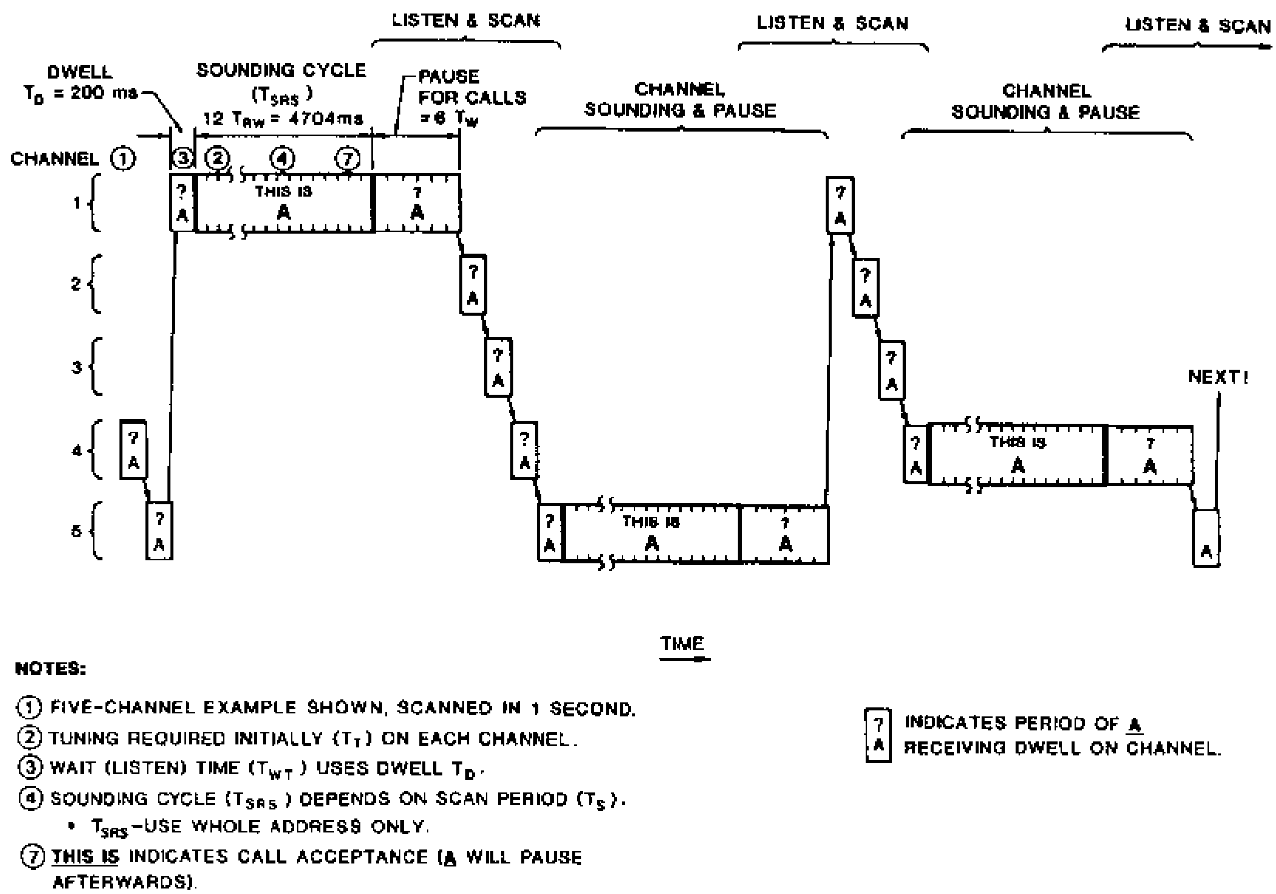


Figure 25. Call acceptance scanning sounding protocol



5.3.5.4 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 Fig. 26. In this illustration, A is scanning sounding and is receptive to calls, and B is receive scanning (or waiting in ambush on a channel) and requires contact with A if heard. A uses the standard call acceptance scanning sound, including the "THIS IS A" and the pause for calls. In this case, B calls A. When ALE stations are scanning sounding and receptive to calls, or require contact with such a station, the optional handshake protocol should be used. The calling station should immediately initiate the call upon the determination that the station to be called has terminated its transmission. A wait time before transmit time is not required. Therefore, if B hears A's sound and is seeking A, B calls immediately using the simple single channel call. Also, if B's operator or controller identifies A's address, it can attempt the optional handshake.

5.3.6 Multiple stations operations.

5.3.6.1 General. A critical requirement for MF and 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 and 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 stations 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:

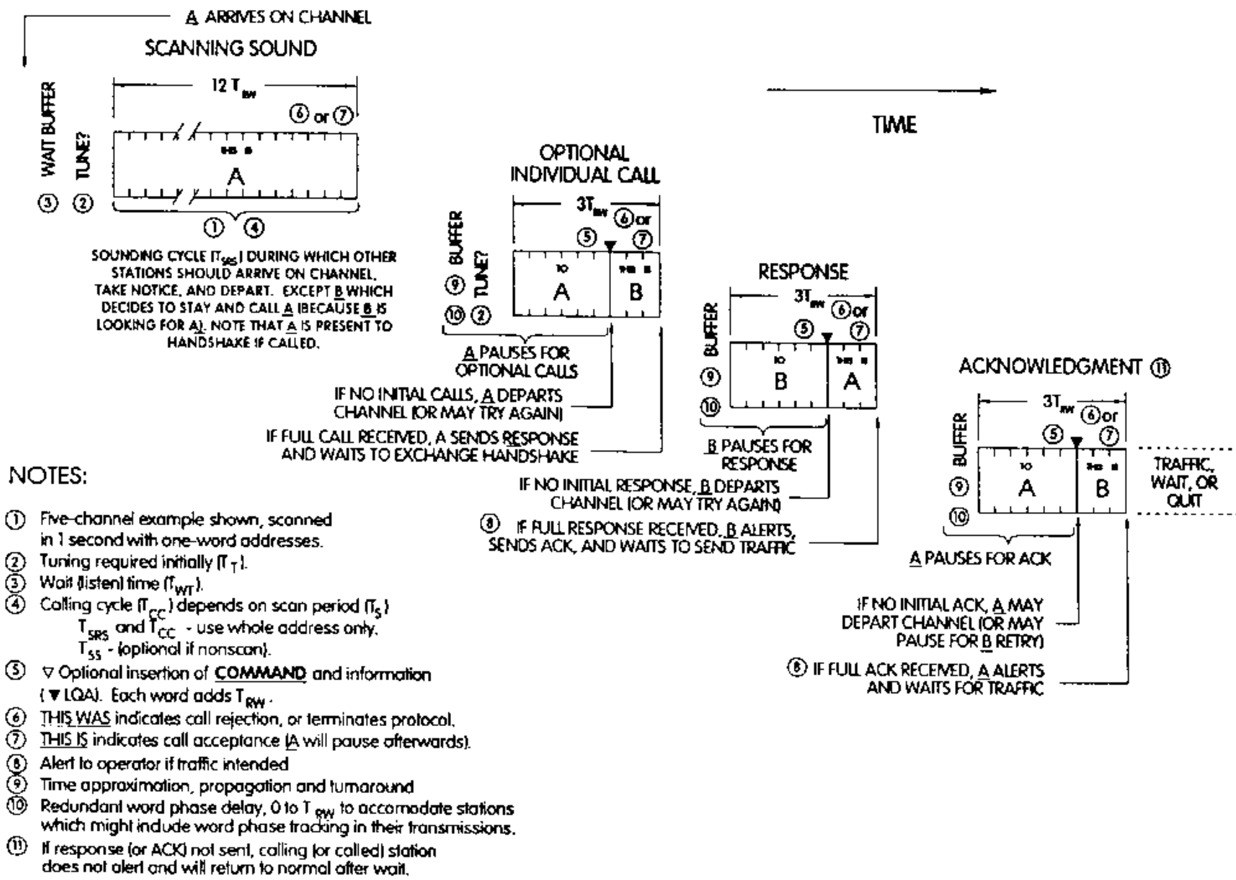
- link L = 1
- star L = (N-1)
- multipoint L = $(N^2-N)/2$

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, the fundamental types of multiple station operations are described:

- star net
- star group (optional)

5.3.6.2 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 sec. 5.2.5. In association with the net address, each station must also store information regarding its proper response(s) and timing(s), as will be described below and as described in secs. 4.4 and 4.5. A net manager may select minimum, uniform, or variable slot widths as required and as described herein.

Figure 26. Scanning sounding with optional handshake protocol



When a star net calling type function is required, ALE stations shall use the star net (scanning) calling protocols described herein for all single-channel (and multichannel) calling, polling, and interoperations. See Fig. 27. As shown, station A is calling the net address (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 T_w (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 (T_{swt}), 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 time out ($T_{swt} = 0$). Each station's SWT is set to a time value (T_{swt}) which in this uniform, minimum case, equals the product of his assigned slot number (SN) times the standard (or prearranged) slot width (T_{sw}). That is, $T_{swt} = T_{sw} \times SN$. However, as a system standard default, T_{sw} is usually the minimum 14 T_w = 1829.33... ms, but in any case shall always be an integral multiple of the word time (T_w); that is, $T_{sw} = n \times T_w$, therefore $T_{swt} = n \times T_w \times SN$. For a net call, each net station's T_{swt} 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.

Meanwhile, A has automatically set its "wait for response and tune timer" (WRTT) to a preset "wait reply net" call value (T_{wrn}) equal to the product of the total number of slots (NS) and the slot width (T_{sw}); that is, in this uniform case, $T_{wrn} = (NS \times T_{sw})$. 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 T_{wrn}), 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 acknowledgment to the net (unless inhibited).

As each net member's SWT triggers its slotted response, it shall immediately key its (already tuned) transmitter, wait until up to at least 90 percent of full power, release its response frame, and return to receiving on the channel. The responses shall be identical to those in the individual call but in the slots. If capable, the station continues to acquire and store connectivity information. Each net member station shall have its own "wait for response and tune timer" (WRTT) for use in determining the calling station's (A) expected acknowledgment. Upon receipt of the net call, the called net member station's WRTT timers are automatically preset to the value (T_{wan}) equal (in this uniform case) to the product of the total number of slots (NS) and the slot width (T_{sw}) plus a minimum leading call (T_{1c} min = 2 T_{rw}). That is, $T_{wan} = (NS \times T_{sw}) + T_{1c}$ min = $T_{wrn} + 2\ T_{rw}$. 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 acknowledgment from A before their WRTT times out. Note that the value for their WRTT (T_{wan}) is the same as that for the caller's (A's) WRTT, except that it shall add a margin (T_{1c} min) to detect the acknowledgment (TO NET).

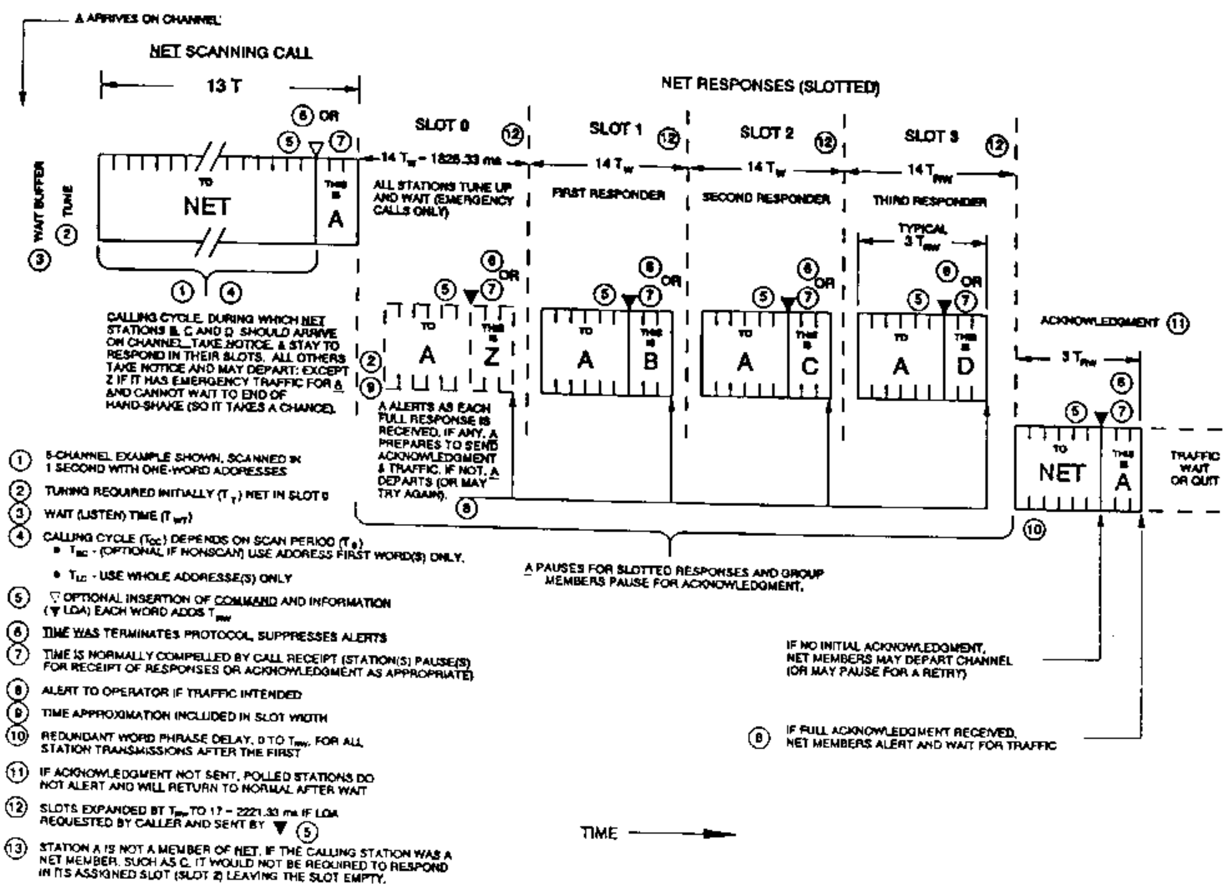
At the end of the slot times, net calling station A should have acquired all successful responses from the net stations B, C, and D, its WRTT (starting at T_{wrn}) should time out to O, and A shall automatically send its acknowledgment, unless no responses have arrived or A is otherwise directed by the operator, controller, or protocol. A's acknowledgment shall be identical to the individual call acknowledgment, 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 acknowledgment, A may select one or any combination of responding stations (including any station responding in emergency slot 0) and substitute an individual (or group) call acknowledgment to any selected station(s) to retain them. If the calling station sends an acknowledgment

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 acknowledgment. The caller should follow the acknowledgment with a standard link termination call (THIS WAS) addressed to the specific rejected stations.

Figure 27. Star net scanning calling protocol



NOTE: In the five-channel net call example shown on Fig. 27, the total elapsed handshake time (T_{hs}) 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 (T_{ws}) is affected by many factors including maximum propagation times each way, signal detection delays, station turnaround, and tuning times. The 14-T_w 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 $T_{rw} = 3\ T_w$ for the data. The standard slot shall be $T_{sw} = 14\ T_w$ (1829.33... ms), shall contain a standard basic response word of 9 T_w (1176 ms), and shall employ single word (no more than 3 characters) addressing. If the net calling station requests LQA, all slots and responses shall automatically expand by T_{rw} (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 T_{rw} (392 ms) per additional word required. All following slots shall be shifted over (delayed) by T_{rw} per word also.

The slotted general formula for determining the correct timing for tailored net responses in non-minimum or nonuniform cases shall be as follows. The slot wait timer time (T_{swt}) for a selected SN is

T_{swt}(SN) = SN × [5 T_w + 2 T_a(caller) + (optional LQA)T_{rw} + (optional message)T_m] + T_a(caller) + [(sum of all previous called addresses)

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

T_a(caller) is the address length (in T_{rw}) of the calling station; T_a(m) (called) is the address length of a preceding called station (in slot m). (Optional LQA)T_{rw} is an optional LQA if requested by COMMAND LQA, and (optional message)T_m 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 T_{wrn} (calling) = T_{swt} (NS) where T_{swt} (NS) is T_{swt} (SN) computed for maximum NS used. The slotted general formula for the called station acknowledgment timer shall be T_{wan} (called) = T_{wrn} (calling) + 2 T_{rw}.

Slot 0 shall normally be used at the net tuneup period. This enables commonly available MF and 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 T_{lww}) in no more than 1500 ms (T_{ta} + T_t) 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. T_{ta}, the turnaround time, shall include decoding, encoding, transmit and receive switching, control handshaking, propagation within the transmitter and receiver, and all other delays internal to the station. T_t is the tune time. The sole exception is a station assigned to slot 1, which must turnaround and tune in not more than 2100 ms ($T_{ta} + T_t$).

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 Fig. 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 T_c (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 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 ($T_{ta} + T_t$), 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 tuneup in slot 0 (and more time if necessary) and standby for a preset, limited time. This limited time is typically implemented through the standard WRTT being preset to a selected "net wait response time" (T_{wrn}) which allows the necessary actions to occur and which provides a default (timeout) termination limit. The suppression of slotted responses is accomplished by setting the SWT timer value T_{swt} to a maximum (default) value, or at least to exceed T_{wrn}, 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 tuneup 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 sec. 5.4, which also presents several other relevant commands, such as halt and wait, which would be especially useful for a one-way broadcast where no responses are required.

5.3.6.3 Star group. (Optional). (See FED-STD-1046). A star group is a non-prearranged 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 an NCS. In many cases, little or nothing is known about the stations except their individual addresses and scanned channels (frequencies).

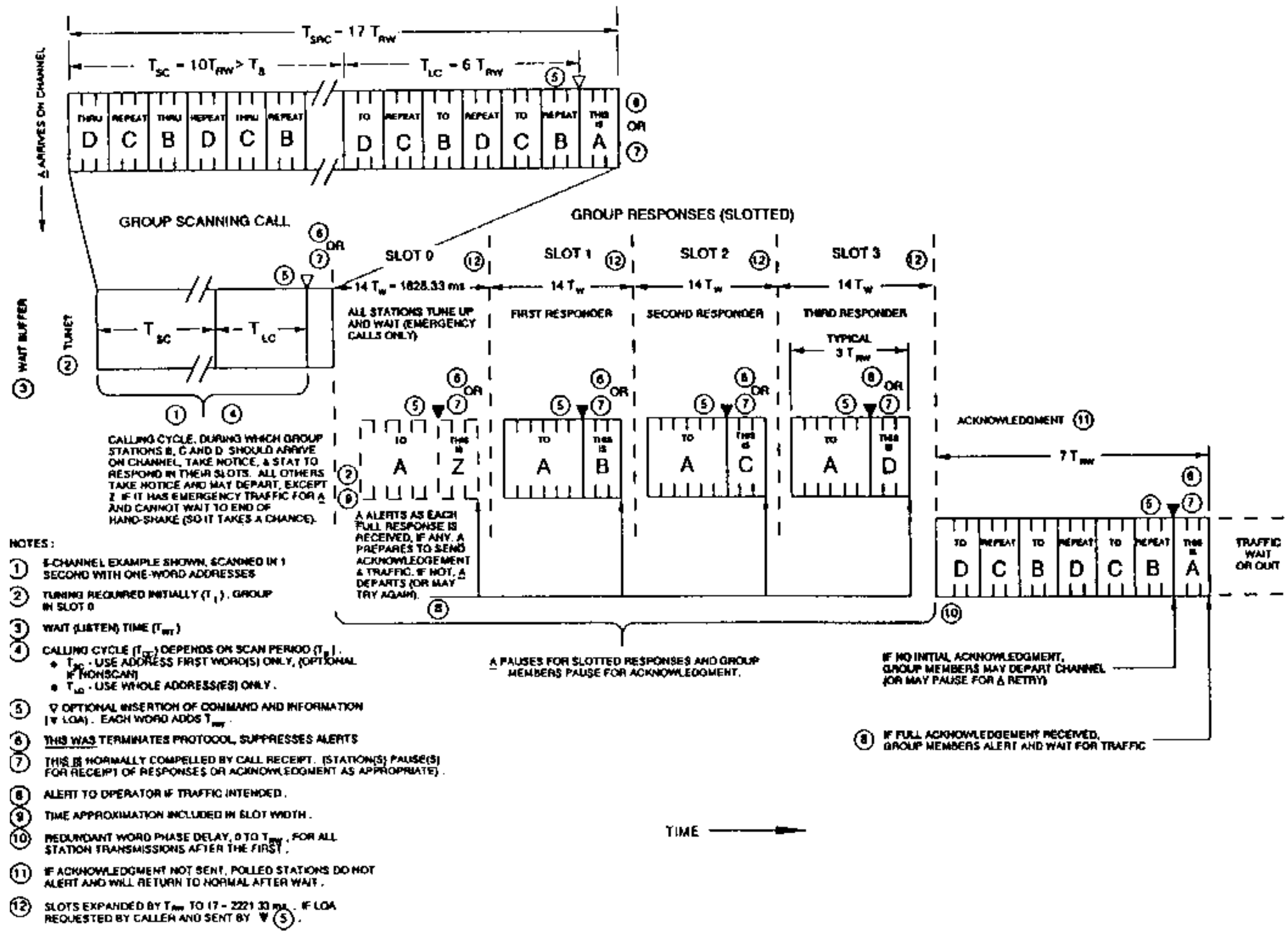
5.3.6.3.1 Star group call. The purpose of a star group call, like any group call, is to rapidly and efficiently establish contact with multiple non-prearranged (group) stations, by the use of a compact combination of their own addresses, which are assigned individually. (See sec. 5.2.4 for details on addressing). 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 time slots, because the stations' own individual addresses are used and nothing is prearranged. As will be shown, the group call members derive and construct their own response action, based on the actual received call structure. Basically, the group call protocol is identical in all regards to the net call protocol, except as specified herein.

When a star group calling-type function is required, stations shall use the star group (scanning) calling protocols described herein for all single-channel and multichannel calling, polling, and interoperations. The star group scanning calling protocol enables rapid and flexible linking with multiple stations without using a common address. As shown on Fig. 27a, station A is calling a group of three non-prearranged stations; B, C, and D. All essential parts of the star group (scanning) protocol are virtually identical to those of the star net (scanning) protocol described in par. 5.3.6.2, and all timing and functional considerations shall apply identically, except as noted herein.

Considering first the simpler, single-channel case with minimum uniform time 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 (T_{lc}) twice in rotation; that is, D, C, and B, then D, C, and B again. If a single-channel call is to be made, the first word of the standard leading call (T_{lc}) would be "TO D", as usual for the individual calling protocol. However, the next address would follow immediately with the standard redundant words (T_{rw}) as "REPEAT C" and then the next "TO B" and similarly until all group whole addresses have been included twice in rotation. The single channel calling cycle, therefore, consists of all of the redundant whole addresses, rotated through twice. The leading call time, T_{lc}, is twice the sum of the lengths ($\sum T_a$) for all the individual whole address words (T_a), (at $n \times T_{rw}$ each). That is, single-channel protocol $T_{lc} = 2 \times$ (sum of all called whole address words) $\sum T_a(m) = 2 \times (NAW \times T_{rw})$, where NAW is the number of original individual address words. Obviously, if it was an individual call, NAW = 1, therefore $T_{lc} = 2\ T_{rw}$, as expected.

In this example of a single-channel group call, stations D, C, and B would each hear a call addressed to them and plan to respond. However, they would notice that other station addresses also appear in the calling cycle; therefore, it must be a group call. Specifically, as shown on fig. 27A, a station such as station D would hear its address ("TO D") being called. It would plan to respond immediately to whichever station is calling (A), because it appears to be (and at this point is) identical to an individual call. However, upon reading another called address ("REPEAT C"), station D realizes that it is actually a group call and slotted time responses are required, therefore station D starts to count addresses (starting with his own) until the calling cycle ends. When the "TO B" arrives, station D identifies another group-called address and counts to three. If the call repeats, as shown for scanning cases at the left on Fig. 27a, when "REPEAT D" arrives, station D has counted to three. Station D immediately knows that there are only three stations involved in the group call (D, C, and B). Station D now must find its time slot, so it resets its counter to one (itself). Station D continues to read the following rotated addresses (C and B again) and continues to count until the calling cycle ends. Meanwhile, C and B are doing the same thing, and they also determine that three stations (D, C, and B) are involved. However, when counting up to the end of the calling cycle, "THIS IS A" in this case, D reaches three, C reaches two, and B reaches one. They have automatically identified the response time slots: D in time slot 3, C in time slot 2, and B in time slot 1. The remainder of the protocol is identical to the star net protocol. Note that if one of the stations, such as C, was to miss the earlier parts of the calling cycle but receive its last "TO C", it would still respond properly in time slot 2 because it would read the "REPEAT B" which follows, realize that the call 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 it, it would mistake it for an individual call and respond immediately (essentially in time slot 0) instead of time slot 1. Therefore, in a group call, the called stations automatically sort themselves into their proper response time slots.

Figure 27a. Star group scanning calling



In a multichannel (multifrequency) scanning group call protocol, the leading call, T_{lc}, must be lengthened, as in the individual scanning call protocol. In that case, T_{cc} is increased beyond the basic T_{lc} by the scan call time T_{sc}, which is larger than the scan time T_s of the called station; that is , $T_{cc} = T_{sc} + T_{lc} = n \times T_d + T_{lc} \geq T_s + T_{lc}$. Similarly, the T_{cc} for the scanning group call must increase by a group scan call time $T_{sc} \geq T_s$. In the group call,as noted above, the basic leading call, $T_{lc} = 2T_c = 2 \times$ (sum of all called whole addresses) $\sum T_a(m)$. The group scan call time, T_{sc}, shall be composed of a rotated combination (T_{cl}) of only the different first words (T_{al}) of the called group addresses, such that the sum ($n \times T_{cl}$) exceeds T_s and is a multiple of T_{rw}. To indicate that this is a group call, the address first word(s), in T_{sc}, shall be within THRU (and alternating with REPEAT), and in T_{lc}, shall be in TO (and REPEAT). The addresses first words (T_{cl}) rotated in T_{sc} are not required to be an integral multiple of the addresses in T_c, as some first words may be duplicated and shall be deleted (to produce a minimum set T_{cl}). The addresses in both T_{sc} (T_{cl}) and T_{lc} (T_c) shall be rotated in the same basic sequence.

Therefore,the scan call time $T_{sc} = n \times T_{cl} = n \times \sum T_{al} \geq T_s = C \times T_d$, where C is the number of channels scanned and T_d is the potential dwell time on each channel.

Therefore, the total calling cycle time $T_{cc} = T_{sc} + T_{lc} = 2 \times (NAW \times T_{rw}) + T_{sc} = (n + 2 NAW) \times T_{rw}$, provided $n \geq T_s/T_{rw}$.

Note that n is any integer sufficient to make the last equation true, and the total number of times that the called address first words (T_{al}) are included in the entire scanning call (T_{sc}) for the scanning case is n. Also, when T_{sc} (and T_s) is less than T_{cl}, it is possible for some addresses to appear only once in the final T_{cl} period before the end of T_{sc}. In the example on Fig. 27a, T_s = 3920 ms, $n \geq T_s/T_{rw}$ = 3920/392, and therefore n = 10, at least. Since NAW = 3, the calling cycle $T_{cc} = (n + 2\ NAW) \times T_{rw} = (10 + 6) \times T_{rw} = 16\ T_{rw}$, as shown. The "THIS IS A" terminator of T_{rw} increases the entire group scanning call to 17 T_{rw}. As can be seen on Fig. 27a, 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 limit of the system, the maximum group size in a single call has been set at five different address first words (T_{cl} max = 5 T_{rw} = 1960 ms),or 12 whole address words in T_c, which allows up to 5 one-word, 5 two-word, 4 three-word, 3 four-word, or 2 five-word addresses, or any other combination which does not exceed a rotating address cycle period (T_c) (each address once) of 12 T_{rw}.

Unlike the net calls, the time slot sizes in group calls are not pre-tailored for the specific network situation, although as a system minimum uniform standard they shall be 14 T_w wide (17 T_w with LQA), as described above. These 14 T_w response slots require the basic, single-word, intranet addressing for both calling and called stations, resulting in a 9 T_w wide response, plus adequate HF signal propagation and turnaround margins. If the calling station uses a two or more word address for itself, each time slot shall be expanded by T_{rw}, for each address word in excess of one, in addition to optional T_{rw} 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 time slot shall also be expanded by T_{rw} per address word in excess of one, (in addition to the caller address and any LQA and message expansions). Therefore, all time slots 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 (T_{sw}, T_{swt}, T_{wrn}, T_{wan}) 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 T_{wan}, it shall use a default value for T_{wan} which is equal to the longest permissible group call of 12 one-word addresses. Based on the slotted general formula, $T_{wan} = 107\ T_w + 27\ T_a$ (called) + 13 T_{rw} (optional LQA) +13 T_m (optional message). In the case of no message field and a one-word address caller, T_{wrn} max = 188 T_w (25 seconds), or 277 T_w (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 its response than he can fit in his assigned time 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" time slot for "overflow", immediately following that responder's slot. This overflow slot, typically the minimum width (because "NULL" is a one-word address), provides an almost five additional data-word (T_{rw}) capacity. Optionally, as another special, but not excluded case, a station may be called multiple times in a group call, even by different addresses, and it shall properly respond in the derived time slots as though it were multiple, separate stations.

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

In the leading call (T_{lc}), (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 (T_{sc}), 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 T_{sc}.

5.4 Orderwire messages.

5.4.1 Introduction. In addition to automatically establishing links, stations shall have the capability to transfer information within the orderwire, or message, section of the frame. This section describes these messages, including data, control, error checking, networking, and special purpose functions. Table XIV provides a summary of the COMMAND 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 set COMMAND DTM mode (which also accepts random data bits). Larger blocks of information may be Golay FEC coded and deeply interleaved using the COMMAND DBM mode. Both modes have an ARQ error-control capability. Integrity of data may be ensured using the COMMAND CRC mode. See par. 5.4.6. 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.

5.4.2 Link quality analysis (LQA). This mandatory function is designed to support the exchange of LQA information among ALE stations. The COMMAND LQA word shall be constructed as shown in Table XV. The preamble shall be COMMAND (110) in bits P3 through P1 (W1 through W3). The first character shall be "a" (1100001) in bits C1-7 through C1-1 (W4 through W10), which shall identify the LQA function "analysis." It carries three types of analysis information (BER, SINAD, and MP) which are separately generated by the ALE analysis capability. Note that when the control bit KA1 (W11) is set to "1," the receiving station shall respond with 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.

5.4.2.1 Bit error ratio (BER). The mandatory BER shall be empirically derived by all ALE stations from the basic digital signaling, and shall be communicated as follows. The transmitted BER is represented as 5 bits of information, BE5 through BE1 (W20 through W24). Refer to Table XI for the assigned values.

5.4.2.2 Signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD). If the mandatory SINAD is analytically derived by suitably equipped stations from the ALE analog signaling, it shall be communicated as follows. The SINAD is represented as 5 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.

5.4.2.3 Multipath. MP3 through MP1, 3 bits (W12 through W14) are reserved for multipath information exchange. Until standardized, these bits shall be set to 111 (meaning no measurement available).

5.4.3 Automatic message display (AMD) mode. The mandatory automatic message display (AMD) function 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 subset shall be available for this purpose.

TABLE XIV. Summary of COMMAND functions

COMMAND	ABC	(EXT. 64)	Automatic Message Display (AMD) (mandatory). Contains text 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 compressed 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 . .	(1111000)	Cyclic Redundancy Check (CRC) (optional). Mandatory with DTM and DBM.
	y	(1111001)	Contains error detection information for preceding

	z . . { . .	(1111010) (1111011)	words.
COMMAND	| . .	(11111100)	User unique functions (UUFs) (optional). Contains unique information for a specific user system (special registration).
NOTE: All others are reserved until standardized.			

TABLE XV. Link quality analysis (LQA) structure

	LQA BITS		WORD BITS	
Command preamble	MSB LSB	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	LSB	W20 W21 W22 W23 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".				

The station shall have the capability to both send and receive AMD messages from and to both the operator and the controller. The station shall also have the capability to display any received AMD messages directly to the operator and controller upon arrival, and to alert them. The operator and controller shall have the capability to disable the display and the alarm when their functions would be operationally inappropriate.

When an ASCII short orderwire AMD type function is required, the following COMMAND AMD protocol shall be used, unless another protocol in this standard is substituted. An AMD message shall be constructed in the standard word format, as described herein, and the AMD message shall be inserted in the message section of the frame. As an option, the operator and controller shall be capable of placing an AMD message in any message section of the ALE protocol (see Fig. 22). The receiving station shall be capable of receiving an AMD message which is contained in any ALE frame, including calls, responses, acknowledgements, and all others.

Within the AMD structure, the first word shall be a COMMAND AMD word, which shall contain the first three characters of the message. It shall be followed by a sequence of alternating DATA and REPEAT words, which shall contain the remainder of the message. The COMMAND, DATA, and REPEAT words shall all contain only characters from the expanded 64-ASCII subset, which shall identify them as an AMD transmission. Each separate AMD message shall be kept intact and shall only be sent in a single frame, and in the exact sequence of the message itself. If one or two additional characters are required to fill the triplet in the last word sent, the position(s) shall be "stuffed" with the "space" character (0100000) automatically by the controller, without operator action.

The end of the AMD message shall be indicated by the start of the frame conclusion, or by the receipt of another COMMAND. Multiple AMD messages may be sent within frame, but they each shall start with their own COMMAND AMD with the first three characters.

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

The AMD word format shall consist of a COMMAND (110) in bits P3 through P1 (W1 through W3), followed by the three standard character fields C1, C2, and C3. In each character field, each character shall have its most significant bits (MSBs) b_7 and b_6 (C1-7 and C1-6, C2-7 and C2-6, and C3-7 and C3-6) set to the values of "01" or "10" (that is, all 3 characters are members of the expanded 64-ASCII 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 T_m max limitation of 30 words (90 characters). T_m max shall be extended 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"). Therefore, none of the expanded 64-ASCII subset characters shall be used for this error indication function. The display shall have a capacity of at least 20 characters (DO: at least 40). The AMD message storage capacity, for recall of the most recently received message(s), shall be at least 90 characters plus sending station address (DO: at least 400). By operator or controller direction, the display shall be capable of reviewing all messages in the AMD memory and shall also be capable of identifying the originating station's address. If words are received which have the proper AMD format, but are within a portion of the message section under the control of another message protocol (such as DTM), the other protocol shall take precedence and the words shall be ignored by the station's AMD function.

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

5.4.4 Data text message (DTM) mode. (Optional). (See FED-STD-1046). The data text message (DTM) orderwire message function enables stations to communicate (either 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 data terminal equipment (DTE) devices through their standard data circuit-terminating equipment (DCE) ports. The DTM mode is a standard speed mode (like AMD) with improved robustness, especially against weak signals and short noise bursts. When used over MF and 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 par. 5.4.3.

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 in Table XVI and are summarized below:

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, bit	1 - 651	21 - 7371, by 21	0
ALE word redundancy	3 fixed	3 fixed	0
Data transmission	392 ms-12.152 sec	392 ms-2.29 min	0

When an ASCII, or binary bit digital data message function is required, the following COMMAND DTM orderwire structures and protocols shall be used as specified herein, unless another standardized protocol is substituted. The DTM structure shall be inserted within the message section of the standard ALE frame. A COMMAND DTM word shall be constructed in the standard 24-bit format, using the COMMAND preamble (See Table XVII). 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 (T_m max), the DTM protocol shall take precedence and shall extend the T_m 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 T_{rw}, as the basic ALE word structure is used. The transmission time of the DTM data block (DTM words × 392 ms), does not include the T_{rw} for the preceding COMMAND DTM word, or another for the following COMMAND CRC. Fig. 28 shows an example of DTM message structure.

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

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 on the DATA and REPEAT words, and the following COMMAND CRC, plus the expected frame continuation, which shall contain a conclusion (possibly preceded by additional functions in the message section, as indicated by additional COMMAND words).

TABLE XVI. Data text message characteristics

	WORD BITS W15---W19 DTM CODE BITS DC10--DC6	WORD BITS W20---W24 DTM CODE BITS 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 0 ↓ ↓ ↓ ↓ ↓ 0 1 0 1 0 0 1 0 1 0	0 0 0 0 1 0 0 0 1 0 ↓ ↓ ↓ ↓ ↓ 1 1 1 1 0 1 1 1 1 1	1 2 ↓ 350 351	1 2 n 350 351	21 42 21n 7350 7371	3 6 3n 1050 1053	392 ms 784 ms nx392 ms 2.28 min 2.29 min	3 4 n+2 352 353
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 0 1 1 0 0 ↓ ↓ ↓ ↓ ↓ 1 1 1 1 0 1 1 1 1 1 (11 ≤ m ≤ 31) ↓ (11 ≤ m ≤ 31)	(01 ≤ p ≤ 31) ↓ (01 ≤ p ≤ 31) 0 0 0 0 1 0 0 0 1 0 ↓ ↓ ↓ ↓ ↓ 1 1 1 1 0 1 1 1 1 1	352+p 384+p 32m+p 960+p 992+p 32m+1 32m+2 32m+p 32m+30 32m+31	p ↓ p 1 2 p 30 31	(21p+m-31) ↓ (21p+m-31) 1-21 22-42 (21p+m-31) 610-630 631-651	3(p-1 to p) ↓ 3(p-1 to p) 0-3 3-6 3(p-1 to p) 87-90 90-93	px392 ms ↓ px392 ms 392 ms 784 ms px392 ms 11.760 s 12.152 s	p+2 ↓ p+2 w+2 ↓ w+2

NOTES:

1. * - NO COMMAND CRC USED
2. m - BINARY BITS IN LAST WORD + 10
3. p - DTM DATA WORDS

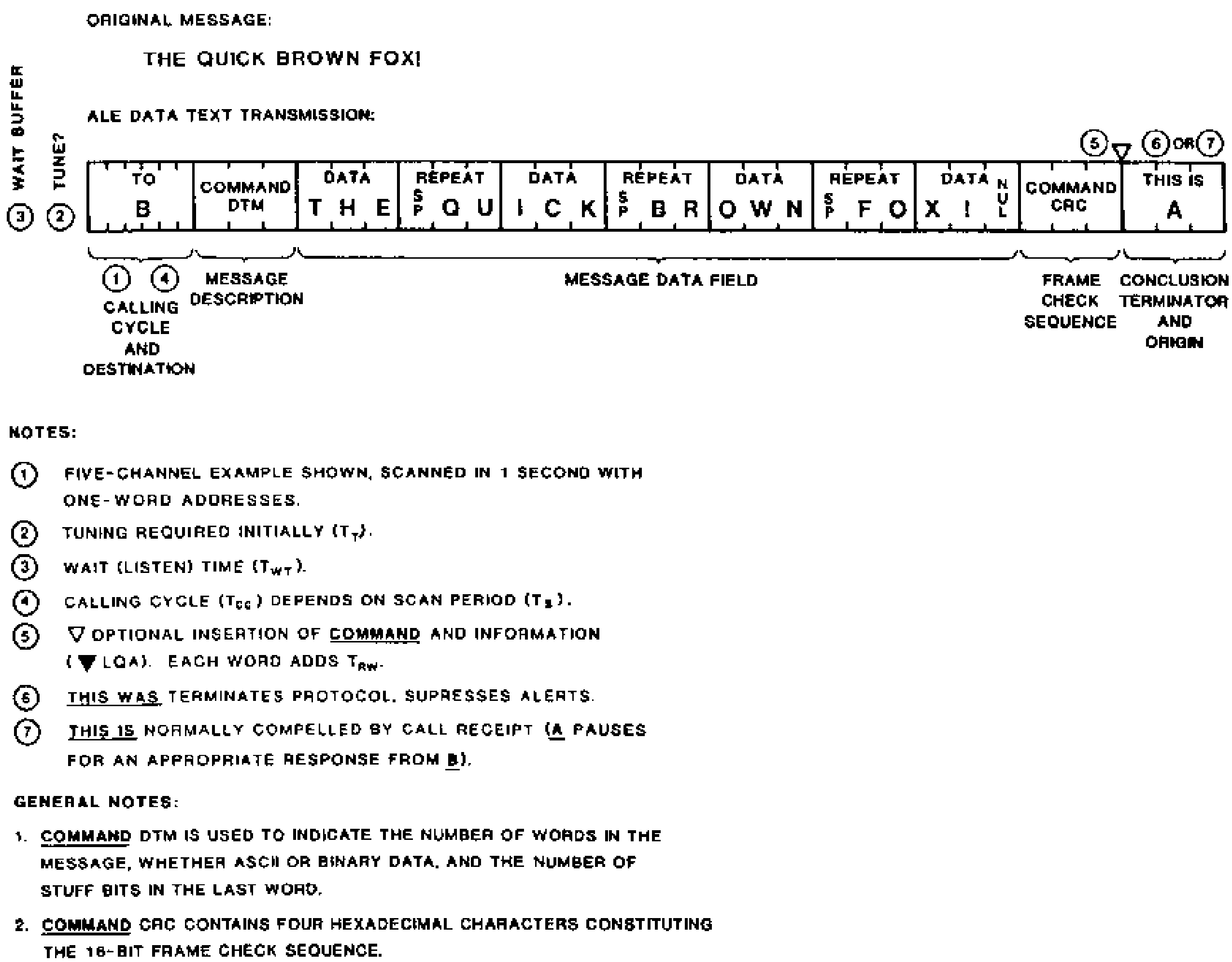
TABLE XVII. Data text message structure

	DTM 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) =1 C1 (bit-2) =0 C1 (bit-1) =0		W4 W5 W6 W7 W8 W9 W10
Control bits	MSB LSB	KD4 KD3 KD2 KD1		W11 W12 W13 W14
DTM data code bits	MSB LSB	DC10 DC9 DC8 DC7 DC6 DC5 DC4 DC3 DC2 DC1	 LSB	W15 W16 W17 W18 W19 W20 W21 W22 W23 W24

NOTES:
1. COMMAND DTM and DTM ARQ first character is "d" for "data."
2. With DTM tranmssions, 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 ACK, and "1" for NAK.
4. With DTM transmissions, 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 fields(s).
7. If a DTM ARQ transmission, control bit KD2 (W13) is set the same as the referenced

DTM transmission.
8. With DTM transmissions, 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 XVI.

Figure 28. Data text message structure example



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 in Table XVI) 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 described below, or if no ACK or DTM ARQ is detected in the returned frame, or if no ALE frame is detected at all, the sending station shall resend an 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 can not 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; (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 that 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 (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 but 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 earlier; 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 errors, as possible, and to create an "improved" data block. See Fig. 29 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 also 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.

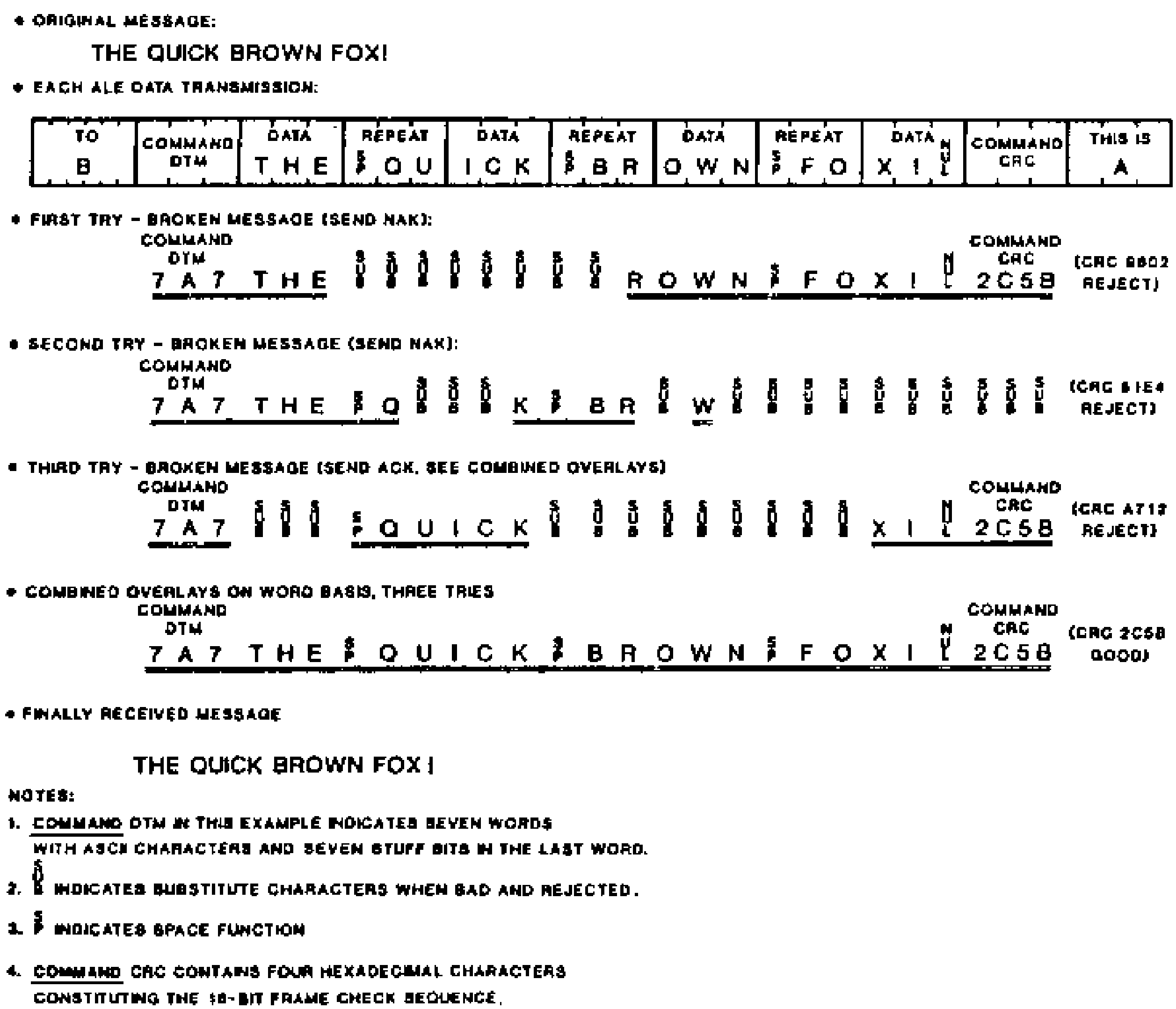
During reception of ALE frames and DTM data blocks, it is expected that fades, interferences, and collisions will occur. The receiving station shall have the capability to maintain synchronization with the frame and the DTM data block transmission, once initiated. It shall also have the capability to 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 that 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 which DTM words which have been damaged and "tag" them for error correction or repeats.

The DTM constructions shall be as described herein. Within the DTM data block structure, a 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, ASCII or binary bits. The ASCII characters (typically used for text) shall be the standard length of 7 bits long; 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 size of the DTM BASIC or EXTENDED data block shall be the smallest multiple of DATA and REPEAT words that will accommodate the quantity of ASCII or binary bits message data to be transferred in that DTM data block. If the message data to be transferred does not exactly fit the uncoded 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 that immediately follows the DTM data block words themselves. All the bits in the data field shall then be inserted into standard DATA and REPEAT words, on a 21-bit or 3-character basis, and then 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 that 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 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 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.

Figure 29. Data text message reconstruction (overlay)



If stations are exchanging DTM data blocks and DTM ARQs, 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 one DTM ARQ shall be allowed in 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 their KD1 sequence control bits alternating with the preceding and following DTM data blocks (except duplicates for ARQ, which shall be exactly the same as their 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, both their KD1 and KD2 sequence and message control bits shall alternate with those in their adjacent DTM data blocks.

The COMMAND DTM words shall be constructed as shown in Table XVII. 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 acknowledgment is required, but when set to "1," it is required. For DTM ARQ, "ARQ" control bit KD4 is set to "0" to indicate acknowledgment or correct data block receipt (ACK). 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 are 7-bit ASCII characters. For DTM ARQ, "flow" control bit KD3 is set to "0" to indicate that the DTM transfer flow should continue, or resume. 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 reconstitute segment by segment the original whole message. 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.

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 NULL's to be sent (the KD1 values therefore alternate, regardless of their message dependencies). When KD1 is set to the same KD1 value in 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 10 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 shall 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 from "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 × 100000) shall be reserved until standardized. See Table XVI for DC values and DTM block sizes and other characteristics.

5.4.5 Data block message (DBM) mode. (Optional). (See FED-STD-1046). 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 terminals 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 par. 5.4.3.

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

The characteristics of the COMMAND DBM orderwire message functions are listed in Table XVIII, and they are summarized below:

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

When an ASCII, or binary bit, digital data message function is required, the following COMMAND DBM orderwire structures and protocols shall be used as specified herein, unless another standardized protocol is substituted. The DBM structure shall be inserted within the message section of the standard frame. A COMMAND DBM word shall be constructed in the standard format. The data to be transferred shall be Golay FEC encoded, then 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 (T_m max), the DBM protocol shall take precedence and shall extend the T_m 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 T_{rw}, as the interleaver depth (ILD) is always a multiple of 49.

The transmission time of the DBM data block (Tdbm) itself is equal to (ILD × 64 ms), not including the T_{rw} for the preceding COMMAND DBM word. Fig. 30 shows an example of an exchange using the DBM orderwire to transfer and acknowledge messages. Fig. 31 shows an example of a DBM data interleaver, and Fig. 32 shows the transmitted DBM bit stream sequence.

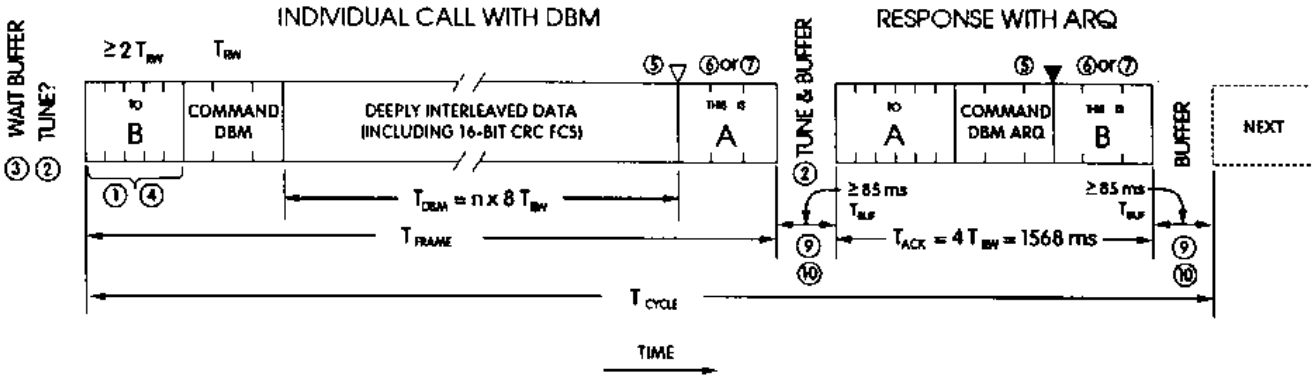
The DBM protocol shall be as described herein. The COMMAND DBM BASIC and EXTENDED formats (herein referred to as DBM data blocks) shall be used to transfer messages and information among ALE stations. The COMMAND DBM ARQ format shall be used to acknowledge other COMMAND DBM formats and for error and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

TABLE XVIII. Data block message characteristics

	WORD BITS W 15 ——— W 24 DBM CODE BITS BC 10 ——— BC 1	DBM CODE (DC) DECIMAL (n)	INTER-LEAVE DEPTH (ID)	BINARY BITS DATA	ASCII CHAR DATA	BLOCK TIME	TOTAL DBM (T_{RW})
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 0 0 0 0 0 0 0 0 1 0 ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ 0 1 1 0 1 1 1 1 1 0 0 1 1 0 1 1 1 1 1 1	1 2 n 446 447	49 98 49 n 21854 21903	572 1160 12 ID−16 262232 262820	81 165 BITS ÷ 7 37461 37545	3.136 s 6.272 s ID x 64 ms 23.31 min 23.36 min	9 17 8 n + 1 3569 3577
DBM BASIC (EXACT)	0 1 1 1 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 1 0 1 1 1 0 0 0 0 1 1 ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ 1 1 1 1 1 1 1 0 1 1 1 1 1 1 1 1 1 1 0 0	448 449 450 ↓ 1019 1020	49 ↓ 49	0 1 2 n−448 571 572	0 0 0 BITS ÷ 7 81 81	3.136 s ↓ 3.136 s	9 ↓ 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

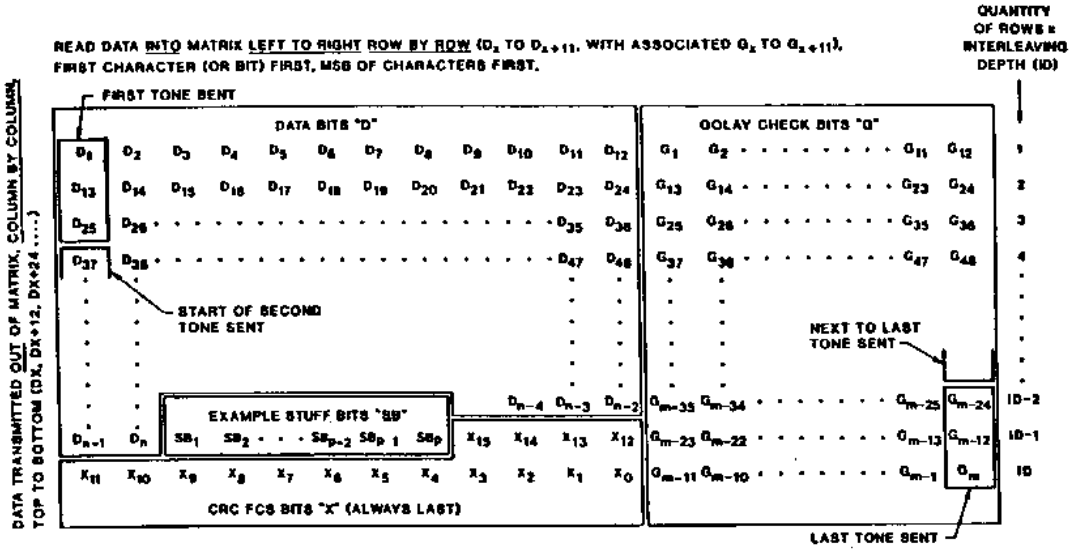
Figure 30. Data block message structure and ARQ example



NOTES:

① One-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} to accomodate stations which might include word phase tracking in their transmissions.

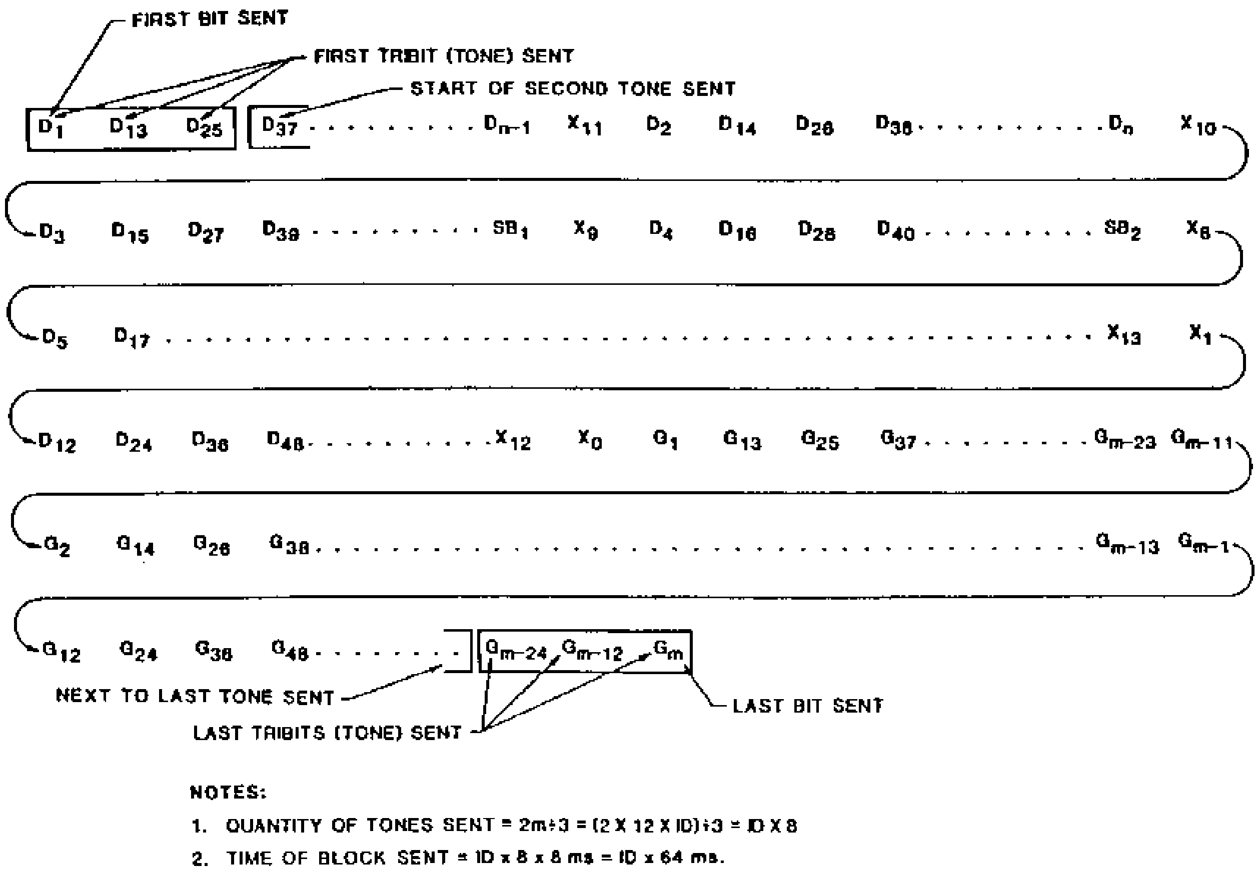
Figure 31. Data block message interleaver and deinterleaver



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: $n = ID \times 12$ FOR BINARY; $n = (ID \times 12) - P$ 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 32. Data block message example



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 conclusion (possibly 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 XIX) 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 sequential order 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 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 stations need to control the flow of the DBM data blocks, they shall use the DBM ARQ to request a pause in, and resumption of, the data flow.

When data transfer ARQ error and flow control is required, the DBM data blocks shall be sent individually 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 send and 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 another, better channel (under operator or controller direction).

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 control bits shall be 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; KB4 set to ACK if the station is ready to accept DBM data transmissions with the specified traffic type, and NAK if it can not or will not participate, or it failed to read the DBM NULL.

The sending (interrogating) station shall handle any and all stations which return a NAK, or do not return a DBM 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; (b) direct them 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 for 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.

TABLE XIX. Data block message structure

	DBM BITS		WORD BITS	
Command preamble	MSB LSB	P3=1 P2=1 P1=0	MSB	W1 W2 W3
First character "b"	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	KD4 KD3 KD2 KD1		W11 W12 W13 W14
DBM data code bits	MSB LSB	DC10 DC9 DC8 DC7 DC6 DC5 DC4 DC3 DC2 DC1	 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 transmissions, 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 fields(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 Data code (BC) bits are from Table XVIII.

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 earlier, the previously unacceptable data block may 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 errors as possible and to create an "improved" data block. See Fig. 29 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 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 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, indicate its length, the type of traffic it contains, its ID, its message and block sequence, 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; 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 ILD shall be the smallest (multiple of 49) which will accommodate the quantity of ASCII or binary bits message data to be transferred in that DBM data block. If the message data to be transferred do 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 resultant 16-bit CRC word shall always occupy the last 16 bit positions 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 on Fig. 31. 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 block bits shall follow in bit format, 3 bits per symbol (tone).

The DBM BASIC data block has a fixed size (ILD 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 are "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 ILD. They should be used as a single, large DBM to maximize the advantages of DBM deep interleaving and FEC techniques, and higher speed (than DTM or AMD) transfer of data. The ILD 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 ILD sizes, should be selected if they optimize DBM data transfer throughput and reliability. However, these multiple data blocks 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 ARQ's, 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 ARQ's may be included in the return direction.

As always throughout the DBM protocol, any sequence of DBM data blocks to be transferred shall have KB1 sequence control bits of each block 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 larger data message shall have all 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, both their KB1 and KB2 sequence and message control bits shall alternate with those in their adjacent DBM data blocks.

The COMMAND DBM words shall be constructed as shown in Table XIX. 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 acknowledgment is required; when set to "1" it is required. For DBM ARQ, "ARQ" control bit KB4 is set to "0" to indicate acknowledgment 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 non-participation 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; when KB3 is set to "1" the message data are 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. 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. When KB2 is set opposite to any sequentially adjacent DBM data blocks, those data blocks contain separate message data and shall not be combined. For DBM ARQ, "message" control bit KB2 shall be set to match the referenced DBM data block KB2 value to provide message confirmation.

For DBM BASIC, EXTENDED, and NULL, the sequence control bit KB1 (W14) shall be set opposite to the KB1 value in the sequentially adjacent DBM BASIC, EXTENDED, or NULLs to be sent (the KB1 values therefore alternate, regardless of their message dependencies). When KB1 is set the same as any sequentially adjacent DBM sent, it indicates that it is 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 10 DBM block code (BC) bits BC10 through BC1 (W15 through W24) shall indicate the DBM mode (BASIC, EXTENDED, ARQ, or NULL). They shall also indicate the size of the message data and the length of the data block. The DBM NULL BC value shall be "0" (0000000000), and it shall designate the single COMMAND DBM NULL word. The DBM EXTENDED BC values shall range from "1" (0000000001) to "445" (0110111101), and they shall designate the COMMAND DBM EXTENDED word and the data block multiple (of 49 ILD) which defines the variable data block sizes, in increments of 588 binary bits or 84 ASCII characters. 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 COMMAND DBM BASIC word and the exact size of the message data in a fixed size (ILD = 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 XVIII.

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

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

The 16-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 16 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, as described in pars. 5.4.4 and 5.4.5, respectively. The first, and the standard usages are described in this section.

The COMMAND CRC word shall be constructed as shown in Table XX. The preamble shall be COMMAND (110) in bits P3 through P1 (W1 through W3). The first character shall be "x" (1111000), "y" (1111001), "z" (1111010), or "{" (1111011) in bits C1-7 through C1-1 (W4 through W10). Note that four identifying characters result from FCS bits x^{15} and x^{14} which occupy C1-2 and C1-1 (W9 and W10) in the first character field respectively. The conversion of FCS bits to and from ALE CRC format bits shall be as described in Table XX 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 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 words shall be analyzed in their nonredundant and uncoded (or FEC decoded) basic ALE word (24 bit) form in the bit sequence (MSB) W1, W2, W3, W4...W24 (LSB), followed by the uncoded 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 message COMMAND CRC inserted and sent in the message section ensures the data integrity of all of the bits of all of the previous checked words, including their preambles. If it is necessary to check the 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 (T_c), 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 CRC COMMAND (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 values with any received CRC words. If a CRC comparison fails, an automatic retransmission request (ARQ) or other appropriate procedure may be used to correct the message as may be defined in this standard.

5.4.7 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 tune-up, and wait on channel for further instructions during the specified time limit. The time limit timer is essentially the WRTT "wait response + tune timer," as used in net slotted responses where its value T_{wrn} 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 tune-up 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 in Table XXI. 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 time bits TB7 through TB1 (W18 through W24) shall be values selected from table XXII and limited as shown in Table XXIII. 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.

TABLE XX. Cyclic redundancy check (CRC) structure

	CRC Bits			Word Bits	
Command preamble		MSB	P3 = 1	MSB	W1
			P2 = 1		W2
		LSB	P1 = 0		W3
First character(s) "x,y,z,{"	(c)	MSB	C1-7 = 1		W4
			C1-6 = 1		W5
			C1-5 = 1		W6
			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^{6}		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.

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.

TABLE XXI. 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	C1 (bit-7) =1		W4

	     LSB	C1 (bit-6) =1 C1 (bit-5) =1 C1 (bit-4) =0 C1 (bit-3) =1 C1 (bit-2) =0 C1 (bit-1) =0		W5 W6 W7 W8 W9 W10
Second character "t"	MSB LSB	C2 (bit-7) =1 C2 (bit-6) =1 C2 (bit-5) =1 C2 (bit-4) =0 C2 (bit-3) =1 C2 (bit-2) =0 C2 (bit-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 tune-up." 2. Time bits TB7 through TB1 are from Table XXII.				

TABLE XXII. Time values

MULTIPLIER: Most Significant Bits (MSBs)				
MSB TB7 (W18)	TB6 (W19)	Exact increment	Approximate increment	Approximate range of "T" values
0	0	T_w 130.66... ms	1/8 second	0 - 4 seconds
0	1	3 T_{rw} 1176 ms	1 second	0 - 36 seconds
1	0	153 T_{rw} 59.976 sec	1 minute	0 - 31 minutes
1	1	9184 T_{rw} 60.002 min	1 hour	0 - 29 hours

INDEX: Least Significant Bits (LSBs)									
TB5	TB4	TB3	TB2	LSB	Index	"T"value	"T"value	"T"value	"T"value

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

5.4.8 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 time values, presented in Table XXI, which have the following ranges based on exact multiples of T_w (130.66... ms) or T_{rw} (392 ms).

- 0 to 4 seconds in 1/8-second (T_w) increments
- 0 to 36 seconds in 1-second (3 T_{rw}) increments
- 0 to 31 minutes in 1-minute (153 T_{rw}) increments
- 0 to 29 hours in 1-hour (9184 T_{rw}) increments

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

5.4.9 User unique functions (UUF). The user unique functions (UUF) are for special uses, as coordinated with specific users or manufacturers, which use the ALE system in conjunction with unique, non-standard 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 who requires the capability to link using ALE, then transmit an HF channel characterization (non-ALE) waveform during the frame or handshake, and then conclude the underlying protocol.

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

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 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 doing 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 signalling, may conflict with functions such as the wait-for-activity timer (T_{wa}), which, in turn, may interfere with the protocols or maintenance of the link. In any case, the users of the UUF shall be responsible for noninterference with other stations and users, and also for controlling their own stations and link management functions to avoid these conflicts.

The user unique function (UUF) shall be constructed as follows and as shown in Table XXIV. 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.

5.5 Linking protection. (Reserved for FED-STD-1049).

TABLE XXIII. 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 tune-up 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 tune-up (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, tune up 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"	(see note 5) (≤ 0011111)	Wait on channel for time T and stay linked; don't transmit unless commanded, and ignore all signals during T if not understood; expect ALE frame reacquisition by T (must be in correct redundant word phase). T in multiples of T_{rw}, as indicated by binary value of last 14 bits (≤0011111 1111111 = 4095s), range of 0 to 26.754 minutes.
Tune and wait	"t"	"t" (1110100)	Stop scan, tune up, do not respond, wait T for instructions, quit and resume scan if nothing. TB = 0, quit after tune-up. TB7 = 0 as 36-second limit.
Width of slots	"t"	"w" (1110111)	Set all slots to T wide for this response. TB = 0, no responses. TB7 = 0 as 36-second limit.
NOTES: 1. Preamble is COMMAND (110). 2. First character is "t" (1110100) for all. 3. Third character field is binary bits TB7 through TB1 (W18 through W24) designating a time interval "T," as a standardized value in Table XXII. 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.			

TABLE XXIV. User unique functions structure

	User unique function bits		word bits	
Command preamble	MSB LSB	P3=1 P2=1 P1=0	MSB	W1 W2 W3
First character "|"	MSB LSB	C1 (bit-7) =1 C1 (bit-6) =1 C1 (bit-5) =1 C1 (bit-4) =1 C1 (bit-3) =1 C1 (bit-2) =0 C1 (bit-1) =0		W4 W5 W6 W7 W8 W9 W10
First UI character	MSB	UI1-7 UI1-6 UI1-5		W18 W19 W20

	LSB	UI1-4 UI1-3 UI1-2 UI1-1		W21 W22 W23 W24
Second UI character	MSB LSB	UI2-7 UI2-6 UI2-5 UI2-4 UI2-3 UI2-2 UI2-1	LSB	W18 W19 W20 W21 W22 W23 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.				

FS-1045A: Appendix A

APPENDIX A
BASELINE RADIO

10 GENERAL REQUIREMENTS.

10.1 General. By convention, frequency band allocation for the MF band is from 0.3 megahertz (MHz) to 3 MHz, and the HF band is from 3 MHz to 30 MHz. However, equipment designed for HF band use has historically been designed with frequency coverage extending down 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.

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 man-pack versions. Although these distinctions still exist in principle, the previously rather sharp demarcation lines have become somewhat blurred. The mobility of HF radio users dictates that a significant amount of long-haul requirements will be met with transportable systems; in some cases, such systems are implemented with design components shared with man-pack radios. When such "tactical" equipment is used to meet a long-haul requirement, the equipment shall meet long-haul minimum performance standards. Accordingly, within this standard, tactical use groups can contain dual value parameters. One parameter reflects usage wherein the frequency determining elements are temperature controlled. The other usage category is deployment related, wherein the frequency determining elements are not temperature controlled (the usual condition for man-pack equipment in tactical operations).

10.2 Equipment operation modes.

10.2.1 Baseline mode. Frequency control of all new HF equipment shall be capable of being stabilized by an external standard. Should multiple frequency (channel) storage be incorporated, it shall be of the programmable memory type and be capable of storing/initializing the operational mode associated with each particular channel. See par. 4.2 and pars. 10.2.1.1 and 10.2.1.2 below.

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

- one nominal 3-kHz channel upper sideband (USB) or lower sideband (LSB) (selectable)
- one (rate dependent bandwidth) interrupted continuous wave (ICW) channel
- a narrowband frequency modulation (NBFM) channel capability should be included as a design objective (DO).

10.2.1.2 Multichannel. All new multichannel HF equipment shall provide, as a minimum, the capability for single-channel operation as set forth in par. 10.2.1.1 above, and the following one-at-a-time selectable operational modes:

- two nominal 3-kHz channels in the USB or LSB (two independent channels in the same sideband, sideband selectable)
- one nominal 6-kHz channel in the USB or LSB (selectable)
- two nominal 3-kHz channels in the USB and two in the LSB (four independent 3-kHz channels, two in each sideband)
- one nominal 6-kHz channel in the USB and one in the LSB (two independent 6-kHz channels, one in each sideband)
- one nominal 3-kHz channel in the USB and one in the LSB (two independent 3-kHz channels, one in each sideband).

10.2.2 Automatic Link Establishment (ALE) Mode. Should an ALE capability be included, it shall be of the channel-scanning type and shall provide for contact initiation by either or both manual and automated control. See par. 10.5 for the list of features required to support this operational mode.

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

10.3 Interface parameters.

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

10.3.2 Electrical characteristics of analog interfaces. See secs. 20.3.6 and 20.4.5.

10.3.3 Modulation and data signaling rates. The modulation rate [expressed in baud (Bd)] or the data signaling rate [expressed in bits per second (bps)] at interface points A and A' on Fig. 33 shall include those contained in the HF modem portion of MIL-STD-188-110.

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

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

10.4.2 Maritime air communications systems. For interoperation with NATO member nations, HF maritime air communications systems shall comply with the applicable requirements of the current edition of STANAG 5035.

10.4.3 High performance HF data modems. For interoperation with NATO member nations, land, air, and maritime, single-channel HF radio equipment shall comply with the applicable requirements of the current edition of STANAG 4285.

10.4.4 Quadripartite Standardization Agreements (QSTAGs). For interoperation among American, British, Canadian, and Australian (ABCA) Armies, HF combat net radio equipment shall comply with the applicable requirements of the current edition of QSTAG 733.

10.5 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

- channel (frequency) scanning capability
- ALE, using an embedded selective calling capability (A disabling capability and an option to inhibit responses shall be included.)
- automatic sounding (station identifiable transmissions) (A capability to disable sounding and an option to inhibit responses shall be included.)
- limited link quality analysis (LQA) for assisting the ALE function - relative SINAD (optional) - relative data error assessment - multipath/distortion assessment (DO).

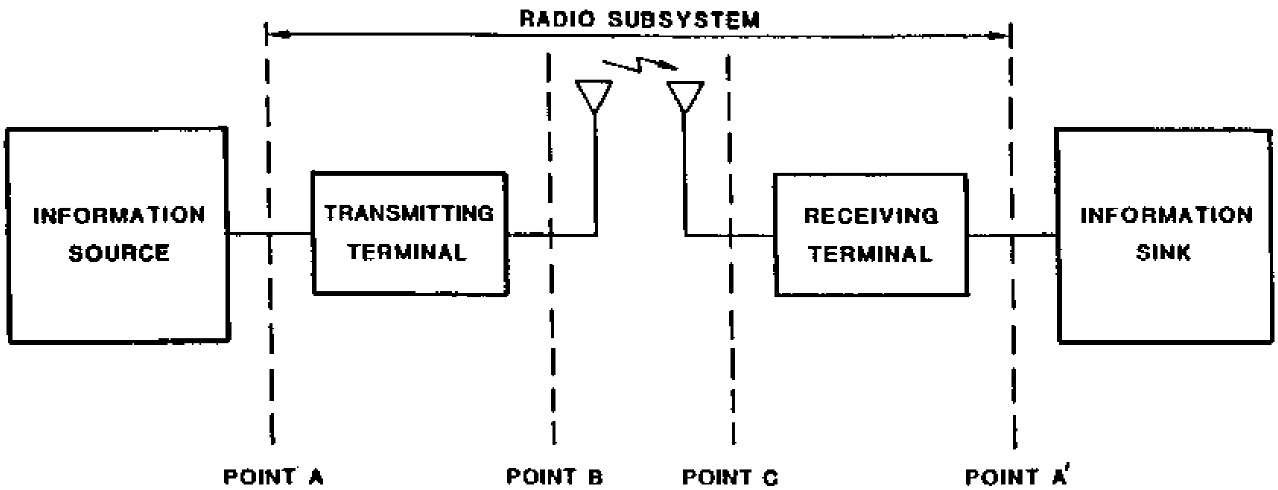
20 DETAILED REQUIREMENTS.

20.1 General.

20.1.1 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 30.0 MHz).

20.1.2 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.

Figure 33. Radio subsystem interface points



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

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

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

20.2.3 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 man-pack equipment and within ± 10 Hz for all others, measured during a period of not less than 30 days.

20.2.4 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 1 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.

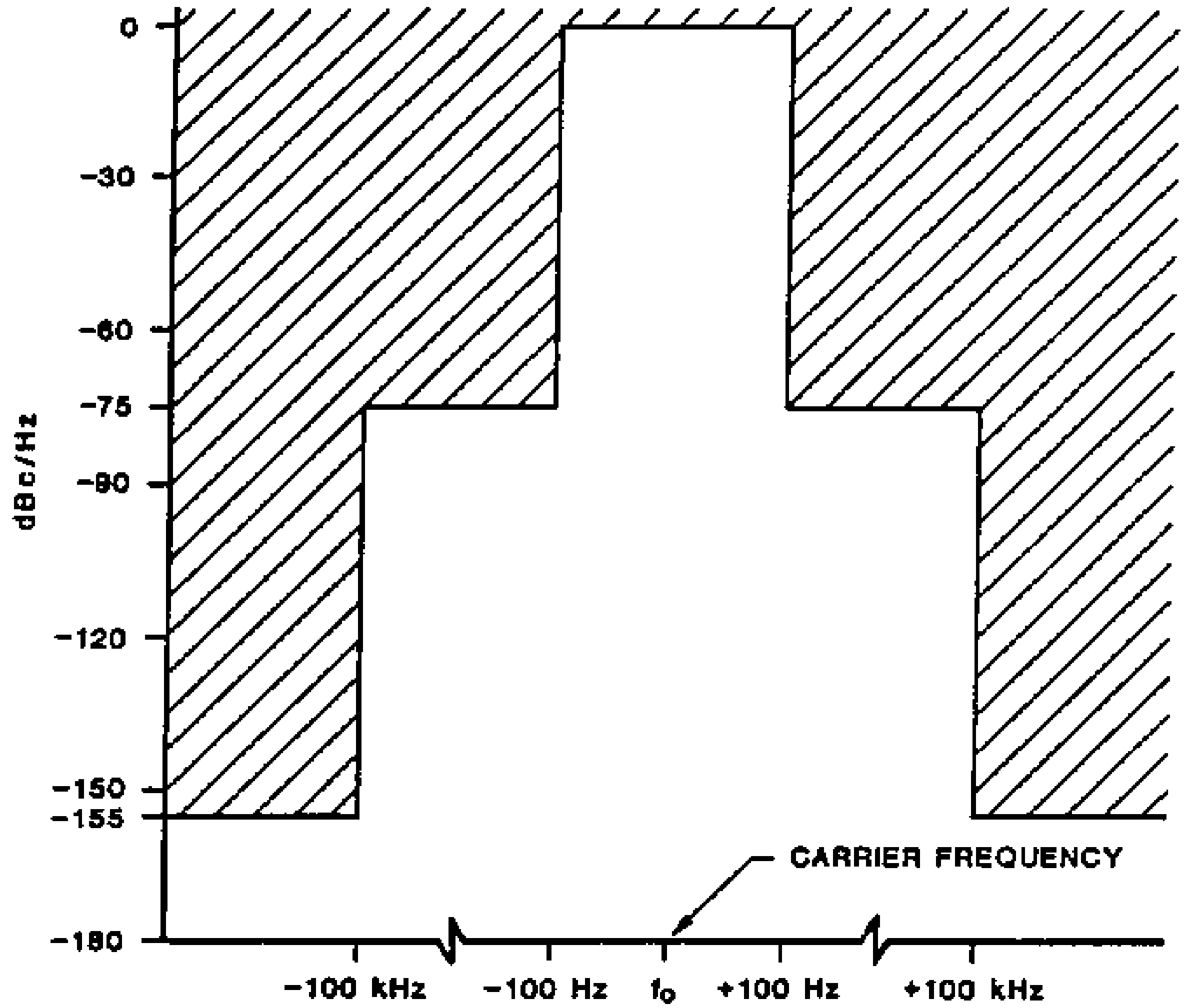
20.2.5 Phase noise. The synthesizer and mixer phase noise spectrum at the transmitter output shall not exceed those limits as depicted on figs. 34 and 35 under continuous carrier single-tone output conditions. Fig. 34 depicts the limits of phase noise for transportable long-haul radio transmitters and Fig. 35 depicts the limits for tactical radio transmitters. See par. 10.1 for applicable statements on dual parameters.

20.2.6 Bandwidths. The bandwidths for high frequency band emissions shall be as shown in Table XXV and figs. 36 and 37. 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 XXV. Bandwidths

Emissions Type	Maximum Allowable Bandwidth (kHz)
Interrupted continuous wave (ICW)	0.5
Frequency shift keying (FSK) (85-Hz shift)	0.3
Frequency shift keying (FSK) (850-Hz shift)	1.1
Single sideband modulation (SSB) single-channel	2.8
Independent sideband modulation (ISB)	
Two channels	6.1
Four channels	12.4

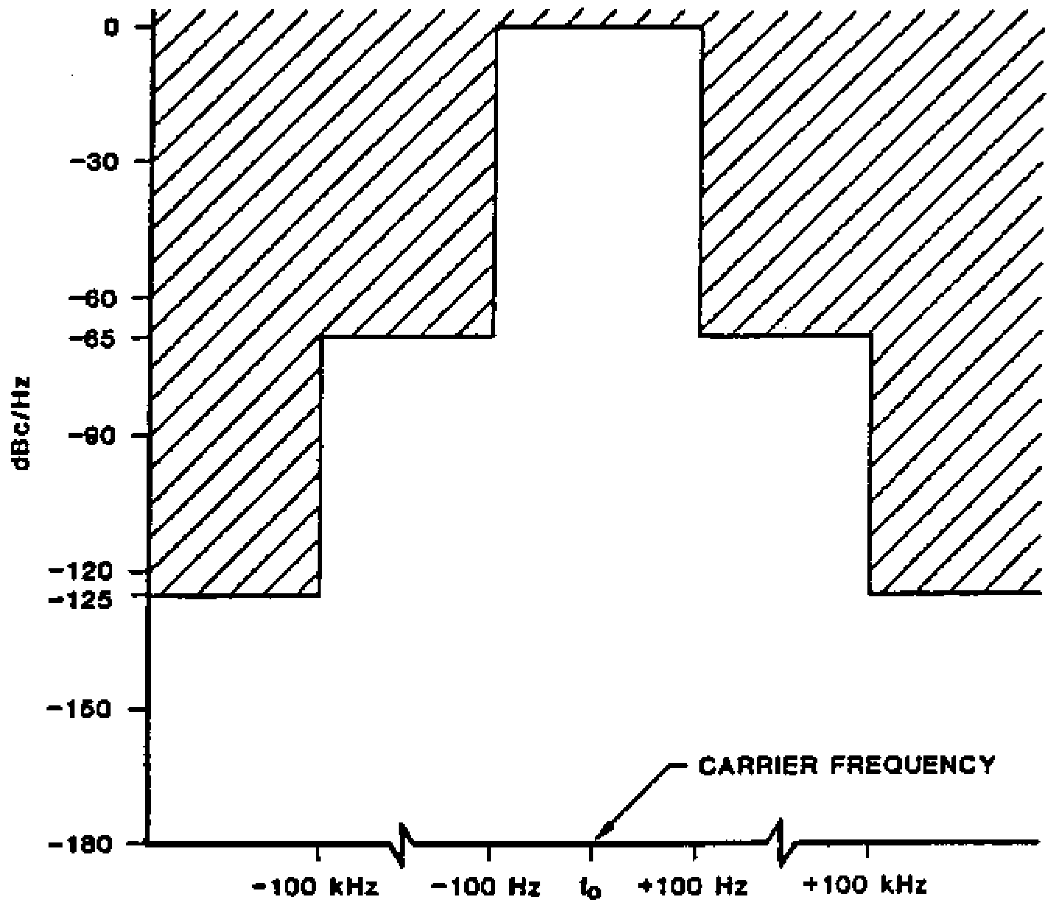
Figure 34. Phase noise limit mask for fixed site and environmentally controlled transportable long-haul radio transmitters



NOTE:

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

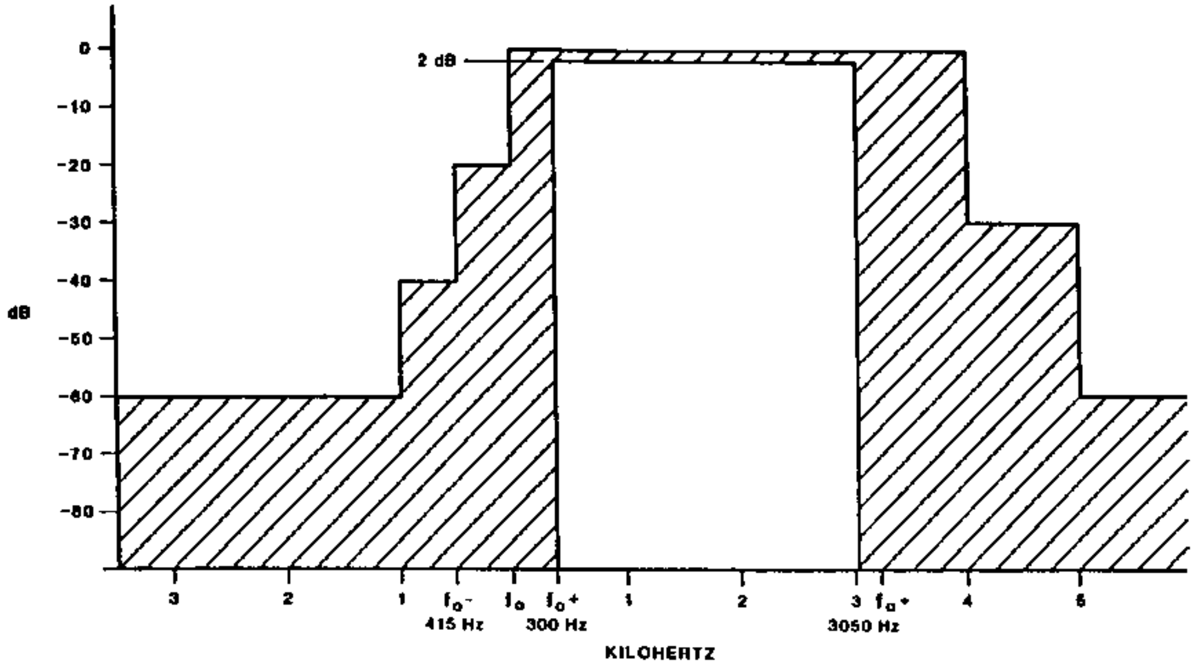
Figure 35. Phase noise limit mask for non-environmentally controlled tactical radio transmitters



NOTE:

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

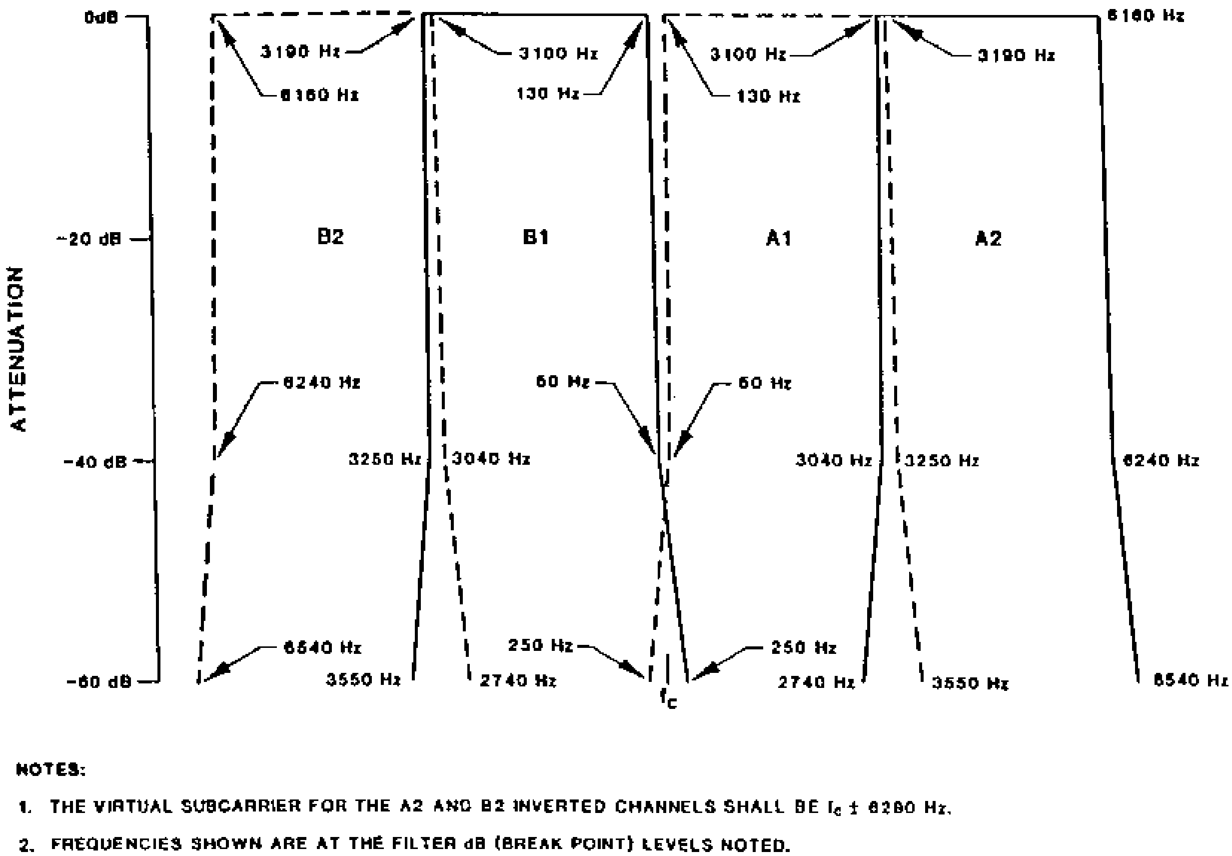
Figure 36. Overall channel response for single-channel or dual-channel equipment



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 37. Overall channel characteristics (four-channel equipment)



20.2.7 Overall channel responses.

20.2.7.1 Single-channel or dual-channel operation. The amplitude vs. frequency response between (f_o + 300 Hz) and (f_o + 3050 Hz) shall be within 2 dB (total) where f_o is the carrier frequency. The attenuation shall be at least 20 dB from f_o to (f_o - 415 Hz), at least 40 dB from (f_o - 415 Hz) to (f_o - 1000 Hz), and at least 60 dB below (f_o - 1000 Hz). Attenuation shall be at least 30 dB from (f_o + 4000 Hz) to (f_o + 5000 Hz) and at least 60 dB above (f_o + 5000 Hz). See Fig. 36. Group delay time shall not vary by more than 0.5 ms over the passband of 300 Hz to 3050 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.

20.2.7.2 Four-channel operation. When four-channel independent sideband operation is employed, the four individual 3-kHz channels shall be configured as shown on Fig. 37, which also shows amplitude response for these four channels. Channels A2 and B2 shall be inverted and displaced with respect to channels A1 and B1 as shown in 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). Refer to Fig. 37. The radio frequency (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 channel'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 500 microseconds over the range 750 Hz to 3000 Hz. Group delay distortion shall not exceed 150 microseconds for any 100-Hz frequency increment between 750 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:

1. For voice operations each independent sideband channel audio input requires a low-pass filter with at least 40-dB attenuation at 2740 Hz.

2. When using multichannel voice frequency carrier telegraph (VFCT) modulation, as specified in 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).

20.2.8 Absolute delay. The absolute delay shall not exceed 10 ms (DO: 5 ms) over the frequency range of 300 Hz to 3050 Hz. The delay shall not vary by more ± 0.5 ms from the measured initial value. Measurements shall be performed end-to-end and back-to-back as in par. 20.2.7.1.

20.2.9 Lincompex. 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 error for the receiver expander function with the start of reception of each Lincompex transmission. The calibration sequence is shown on Fig. 38.

20.3 Transmitter characteristics.

20.3.1 Noise and distortion.

20.3.1.1 In-band noise. Broadband noise in a 1-Hz band within the selected sideband shall be at least 85 dBc below the level of the HF transmitter's rated PEP.

20.3.1.2 Intermodulation distortion (IMD). The IMD products of HF transmitters produced by any two equal-level single-frequency audio test signals between 300 Hz and

3050 Hz, shall be at least 30 dB below each reference tone 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.

20.3.2 Spectral purity.

20.3.2.1 Broadband emissions. When the transmitter is driven with a single tone to rated PEP, the power spectral density of the transmitter broadband emission shall not exceed the level established in Table XXVI and as shown on fig. 39. Discrete spurs shall be excluded from the measurement, and the measurement bandwidth shall be 1 Hz.

Figure 38. Digital Lincompex calibration sequence

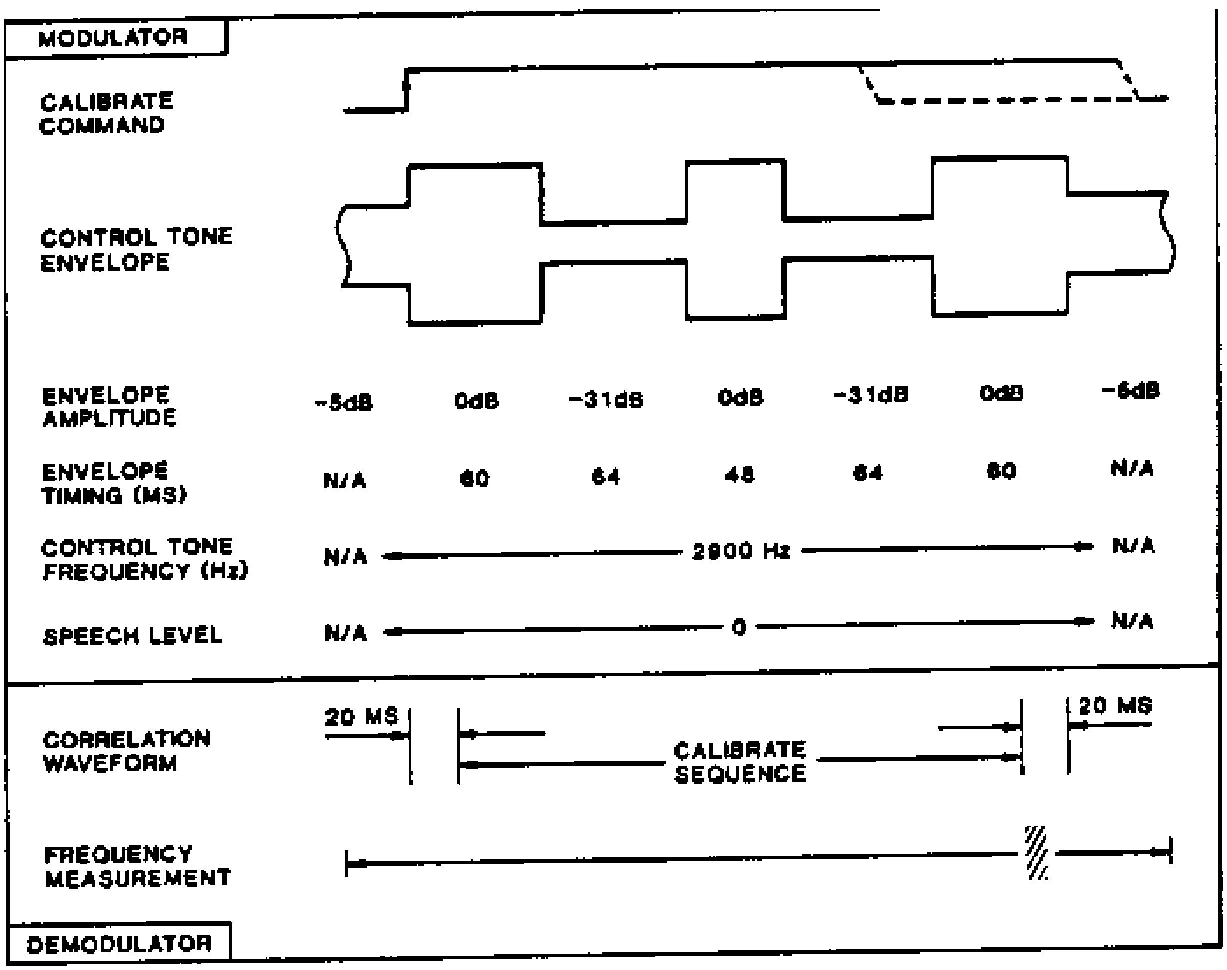
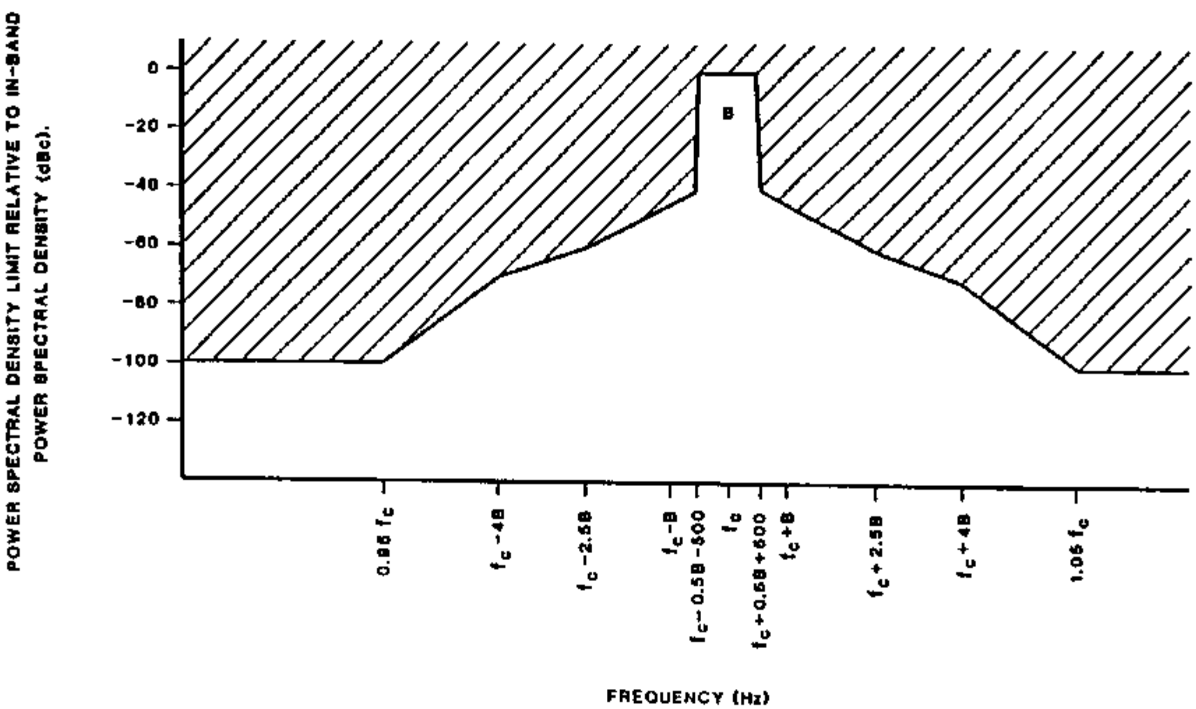


TABLE XXVI. Out-of-band power spectral density limits for radio transmitters

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)
$(f_c + 4.0 \text{ B}) \leq f_m \leq 1.05 f_c$ $0.95 f_c \leq f_m \leq (f_c - 4.0 \text{ B})$	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)	

Figure 39. Out-of-band power spectral density for HF transmitters



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.

20.3.2.2 Discrete frequency spurious emissions. 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:

- between the carrier frequency and 4B (where B = bandwidth), at least 40 dBc (dB referred to the carrier)
- between 4B and ±5 percent of f_c removed from the carrier frequency, at least 60 dBc
- beyond ±5 percent removed from the carrier frequency, at least 80 dBc (See Fig. 40.)

20.3.3 Carrier suppression. The suppressed carrier shall be at least 50 dBc (DO: 60 dBc) below the output level of a single tone modulating the transmitter to rated PEP.

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

20.3.5 Attack and release time delays.

20.3.5.1 Attack-time delay. 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.

20.3.5.2 Release-time delay. 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.

20.3.6 Signal input interface characteristics.

20.3.6.1 Input signal power. Input signal power for microphone or handset input is not standardized. Where provided, the line input signal power range shall be such that the transmitter rated PEP is obtained without manual adjustment of gain controls. For any two-tone signal input, the amplitude can vary from -23 dBm (dB referred to one milliwatt) to 0 dBm per tone; and, for single-tone input, the amplitude can vary from -17 dBm to +6 dBm.

20.3.6.2 Input audio signal interface.

20.3.6.2.1 Unbalanced interface. An unbalanced interface shall be provided with 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 frequency range of 300 Hz to 3050 Hz.

20.3.6.2.2 Balanced interface. 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.

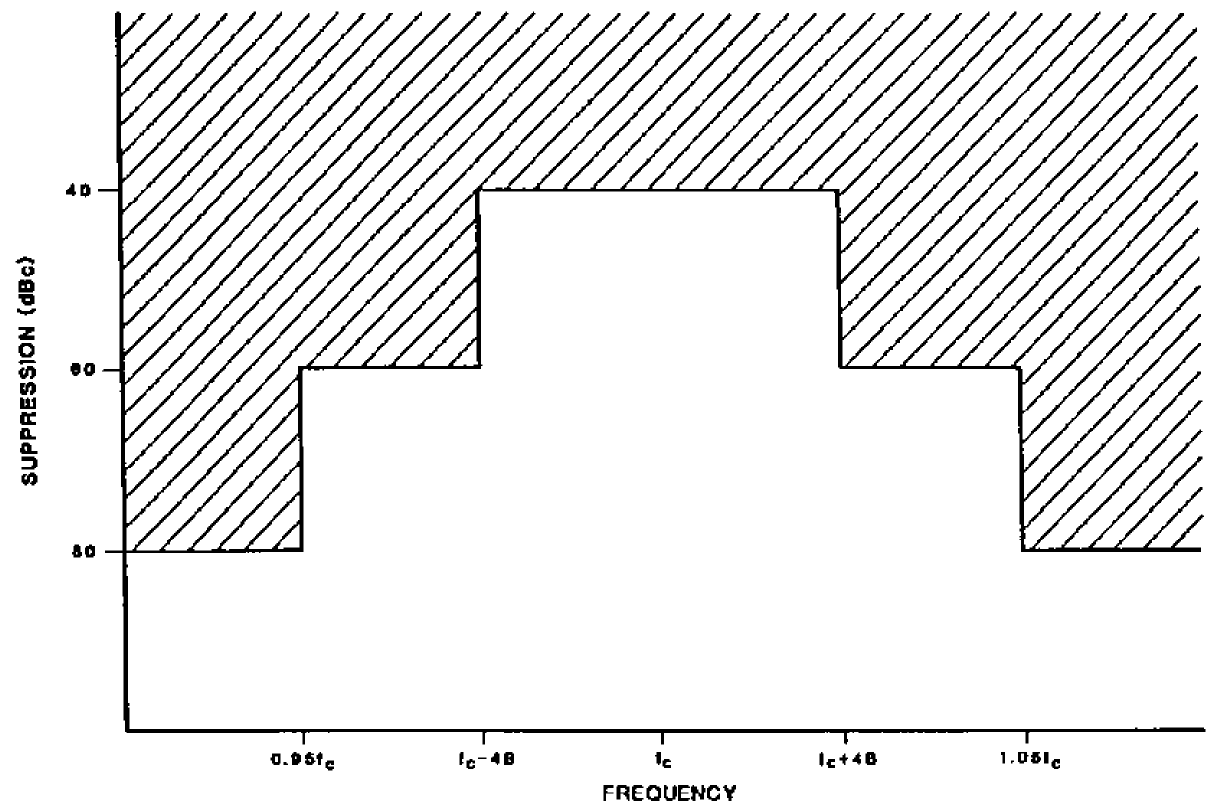
20.3.7 Transmitter output load impedance. The nominal rf output load impedance at interface point B, on Fig. 33, shall be 50 ohms, unbalanced with respect to ground. Transmitters with power output ratings equal to or less than 600 watts shall provide (a) full-rated output power for voltage standing wave ratio (VSWR)s of 2:1 or less, and (b) power output derated by a factor not greater than 1.5/VSWR for VSWRs above 2:1. See Fig. 41A. Transmitters with power output ratings of greater than 600 watts shall derate their output power by a factor of not greater than 1/VSWR. See Fig. 41B. On transmitters using separate exciters, the interface between the exciter and amplifier shall be a nominal 50 ohms, unbalanced, with a maximum VSWR of 1.5:1 over the operating frequency range.

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 nominal 50-ohm load.

20.4 Receiver characteristics.

20.4.1 Receiver rf characteristics. NOTE: All receiver input amplitudes are in terms of available power in dBm from a 50-ohm source impedance signal generator.

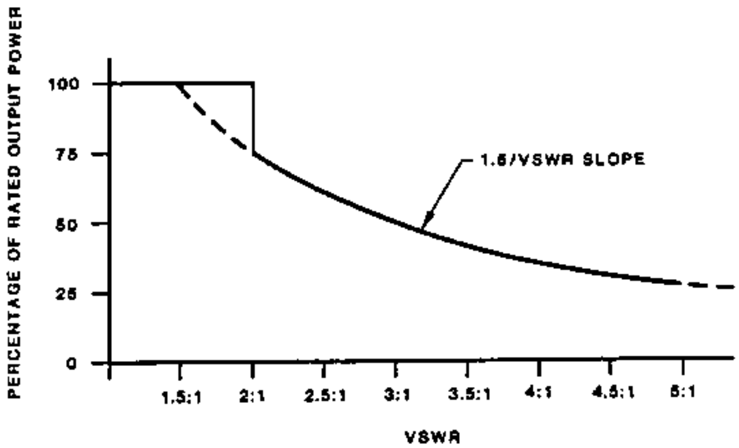
Figure 40. Discrete spurious emissions limit for HF transmitters



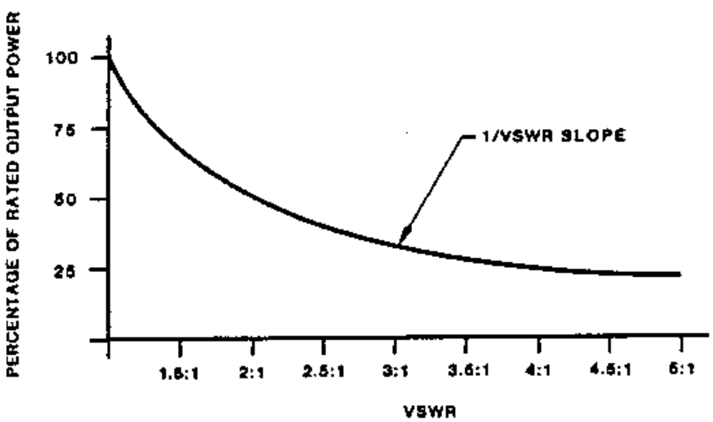
NOTE:

EMISSIONS SHALL FALL WITHIN THE UNSHADED PORTION OF THE CURVE.

Figure 41. Output power vs. VSWR for transmitters with broadband output impedance networks



A. 600 WATTS OR LESS



B. GREATER THAN 600 WATTS

20.4.1.1 Image rejection. The rejection of image signals shall be at least 80 dB for HF receivers (DO: 100 dB).

20.4.1.2 Intermediate frequency (IF) rejection. Signals at the intermediate frequency (frequencies) shall be rejected by at least 80 dB (DO: 100 dB).

20.4.1.3 Adjacent channel rejection. The receiver shall reject any signal in the undesired sideband and adjacent channel in accordance with Fig. 36.

20.4.1.4 Other single-frequency external spurious responses. Receiver rejection of spurious frequencies, other than IF and image, shall be at least 65 dB 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 for frequencies beyond ±30 percent of the center frequency.

20.4.1.5 Receiver protection. The receiver, with primary power on or off, shall be capable of survival without damage with continuously applied signals of up to +43 dBm (DO: 53 dBm) available power delivered from a 50-ohm source.

20.4.1.6 Desensitization dynamic range. The following requirement shall apply to the receiver in an SSB mode of operation with an IF passband setting providing at least 2750 Hz (300 Hz to 3050 Hz) of 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 radios whose frequency determining elements are temperature controlled, the interfering signal is equal to or less than 100 dB above the test signal level

b. for radios whose frequency determining elements are not temperature controlled, the interfering signal is equal to or less than 90 dB above the test signal level.

20.4.1.7 Receiver sensitivity. 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.

20.4.1.8 Receiver out-of-band intermodulation distortion (IMD). Second and higher order responses shall require a two-tone signal amplitude, with each tone at least 80 dB greater than that required for a single-tone input, to produce an output SINAD of 10 dB. This requirement is applicable for equal amplitude input signals with the closest signal spaced 30 kHz or more from the operating frequency.

20.4.1.9 Third-order intercept point. Using test signals within the first IF passband, the worst case third-order intercept point shall not be less than +10 dBm.

20.4.2 Receiver distortion and internally generated spurious outputs.

20.4.2.1 Overall IMD (in-channel). 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. 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 of 0 dBm PEP (-6 dBm/tone) and for any audio output of +12 dBm PEP (+6 dBm/tone) or less. All IMD products shall be at least 35 dB (DO: 45 dB) below the output level of either of the two tones.

20.4.2.2 Adjacent channel IMD. 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.

20.4.2.3 Audio frequency total harmonic distortion. 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.

20.4.2.4 Internally generated spurious outputs. Spurious signals at the output of the receiver, produced in the absence of rf signals by mixing of signals that are generated internally in the receiver, shall not exceed -112 dBm (DO: -122 dBm).

20.4.3 Automatic gain control (AGC) characteristic. 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.

20.4.3.1 AGC attack-time delay (nondata modes). The receiver AGC attack-time delay shall not exceed 30 ms.

20.4.3.2 AGC release time (nondata modes). The receiver AGC release time shall be between 800 and 1200 ms for SSB voice and intermittent continuous wave (ICW) operation. This shall be the time period from rf signal deterioration 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.

20.4.3.3 AGC requirements for data service. In data service, the receiver AGC attack-time shall not exceed 10 ms. The AGC release-time shall not exceed 25 ms.

20.4.4 Receiver linearity. 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 ±10 percent for a linear increase in input signal level until the output SINAD is equal to at least 40 dB (DO: 60 dB). This requirement shall apply over the operating frequency range of the receiver.

20.4.5 Interface characteristics.

20.4.5.1 Input impedance. The receiver rf input impedance shall be nominally 50 ohms, unbalanced with respect to ground. The input VSWR, with respect to 50 ohms, shall not exceed 2.5:1 over the operating frequency range.

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

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

a. requirements for ALE implementation are given in secs. 1 through 5.

b. details on ALE waveform, signal structure protocols, and orderwire messages are contained in secs. 5.1 through 5.5

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

30.1 Intended use. This standard contains requirements to ensure interoperability of new long-haul and tactical radio equipment in the MF and HF bands.

30.2 Issue of DODISS. When this standard is used by the Department of Defense in acquisition, the applicable issue of the DODISS must be cited in the solicitation (see pars. 2.2.1 and 2.3).

30.3 Subject term (key word) listing:

- **Adaptive communications:** Leading redundant word
- **AJ mode:** Lincompex
- **ALE:** Link protection
- **ALE mode:** Link quality analysis (LQA)
- **Automatic link establishment (ALE):** LQA
- **Automatic sounding:** Orderwire data messages
- **Baseline mode:** Radio frequency scanning
- **Deep interleaving:** Selective calling
- **Forward error correction:** Triple redundant words
- **Golay coding:** Word phase reference

30.4 International standardization agreements. Certain provisions of this standard in secs. 10.2, 10.4, 20.2, 20.3, and 20.4, are the subject of international standardization agreements, STANAGs 4203 and 5035 and QSTAG 733. When change notice, revision, or cancellation of this standard is proposed that will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels, including departmental standardization offices, to change the agreement or make other appropriate accommodations.