FEDERAL STANDARD 1052

TELECOMMUNICATIONS:
HF RADIO MODEMS

Prepared By:

National Communications System
Office of Technology & Standards

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FSC TELE

FS-1052: Letter of Promulgation

General Services Administration
Information Resources Management Service
Letter of Promulgation
Federal Standard 1052
Telecommunications: HF Radio Modems

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 1052 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 1052 as the authoritative source for the design and procurement of modulators-demodulators (modems) and 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 modems for HF radio.

2. Requirements and Applicable Documents. The HF radio modem terms, definitions, waveforms, and protocols which constitute this standard are to be applied in the design and procurement of HF radio modems. There is 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 HF radio modems. 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,
701 S. Court House Road
Arlington, Virginia 22204-2198

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FS-1052: Foreword

FOREWORD

FED-STD-1045A, Telecommunications: HF Radio Automatic Link Establishment, October 18, 1993, 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. FED-STD-1045A 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 Message Delivery;
- 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.

FED-STD-1052 contains technical standards and design objectives for minimum interface and performance standards pertinent to modulators-demodulators (modems) which operate in both automatic and manual high frequency radio systems.

This standard shall be used by all Federal departments and agencies in the design and procurement of modems for operation with HF 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:

Federal Telecommunications Standards Committee (FTSC)
National Communications System, N6
701 South Court House Road
Arlington, VA 22204-2198.

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1. SCOPE. This standard is one of a series of standards pertaining to automatic high frequency (HF) radio equipment and operation. The basic standard is Federal Standard (FED-STD) 1045A, Telecommunications: HF Radio Automatic Link Establishment. Other standards in the series are:

- FED-STD-1046, HF Radio Automatic Networking
- Proposed (p) FED-STD-1047, HF Radio Automatic Message Delivery
- pFED-STD-1048, HF Radio Automatic Networking to Multiple-media
- pFED-STD-1049, HF Radio Automatic Operation In Stressed Environments
- pFED-STD-1050, HF Radio Baseline Parameters
- pFED-STD-1051, HF Radio System Controller Interface

1.1 Limitations. This standard establishes technical standards and design objectives (DO) that are necessary to ensure interoperability and to promote performance among modulators-demodulators (modems) used with high frequency (HF) radios. To ensure a minimum level of interoperability, certain waveforms and data rates are prescribed as mandatory. All other waveforms and data rates are optional. However, if any optional waveforms or data rates are to be implemented, the provisions of this document become mandatory for that implementation.

1.2 Application. This standard shall be used by all Federal departments and agencies in the design and procurement of modems for operation with HF radios. This standard is intended to assure interoperability among Federal HF radio systems employing data modems. This 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. This standard is mandatory within the Federal Government in the design and development of new HF radio modems. 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 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-1052: Applicable Documents

2. REFERENCED 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 Governmental.

Federal Standards

- FED-STD-1003 Synchronous Bit Oriented Data Link Control Procedures (Advanced Data Communications Control Procedures)
- FED-STD-1020 Telecommunications: Electrical Characteristics of Balanced Voltage Digital Interface Circuits
- FED-STD-1030 Telecommunications: Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits
- FED-STD-1035 Coding, Modulation and Transmission Requirements for Single Channel Medium and High Frequency Radiotelegraph Systems Used in Government Maritime Mobile Telecommunications
- FED-STD-1037 Glossary of Telecommunication Terms
- FED-STD-1045 Telecommunications: HF Radio Automatic Link Establishment

Military standards

- MIL-STD-188-110 Interoperability and Performance Standards for Data Modems
- MIL-STD-188-115 Interoperability and Performance Standards for Communications Timing and Synchronization Subsystems
- MIL-STD-188-148 (S) Interoperability Standard for Anti-Jam (AJ) Communications in the High Frequency Band (2-30 MHz) (U)

Military specifications

- MIL-C-28883 Military Specification for the Advanced Narrowband Digital Voice Terminal (ANDVT) Tactical Terminal (TACTERM) CV-3591 and Ancillaries

(Those outside the Federal Government may obtain copies of Federal specifications and standards as stated in the Index of Federal Specifications, Standards and Commercial Item Descriptions. The Index, including cumulative supplements issued during the year, is sold on subscription by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.)

(Single copies of Federal specifications and standards required for bidding purposes are available from the General Services Administration Business Service Centers in Boston, MA; New York, NY; Atlanta, GA; Chicago, IL; Kansas City, MO; Fort Worth, TX; Denver, CO; San Francisco, CA; Los Angeles, CA; and Seattle, WA, or from the General

Services Administration Supply Distribution Facility Franconia - Building A, Loisdale Road, Franconia, VA 22105.)

(Federal Government activities may obtain copies of Federal Specifications and Standards from established distribution points in their agencies.) (Unless otherwise indicated, copies of Federal and military specifications, standards, and handbooks are available from the Naval Publications and Forms Center, (ATTN: NPODS), 5801 Tabor Avenue, Philadelphia, PA 19120-5099.)

2.2 Non-governmental.

International Standardization Documents

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

- STANAG 4197 Modulation and coding characteristics that must be common to ensure interoperability of 2400 bps linear predictive encoded digital speech transmitted over HF radio facilities
- STANAG 4198 Parameter and coding characteristics that must be common to ensure interoperability of 2400 bps linear predictive encoded digital speech
- STANAG 4285 Characteristics of 1200/2400/3600 bits per second single tone modulators/demodulators for HF radio links
- STANAG 5031 Minimum standards for naval HF, MF, and LF shore-to-ship broadcast systems
- STANAG 5035 Introduction of an improved system for maritime air communications on HF, LF, and UHF

Quadripartite Standardization Agreements (QSTAG)

- QSTAG-303 Frequency shift standards for HF/RATT and VHF/RATT operation

(Application for copies should be addressed to: Standardization Document Order Desk, 700 Robbins Avenue, Building 4, Section D, Philadelphia, PA 19111.)

International Telecommunication Union (ITU)

- CCIR Radio Report 549: HF Ionospheric Regulations, Channel Simulators Volume III

(Application for copies should be addressed to the General Secretariat, International Telecommunication Union, Place des Nations, CH-1211 Geneva 20, Switzerland or the U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.)

International Organization for Standardization (ISO)

- ISO/IEC 8886.3 Information processing systems - Data communication - Data link service definition for Open Systems Interconnection

National Standardization Documents

American National Standards Institute (ANSI)

- ANSI/EIA-232 Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange
- ANSI/EIA/TIA-562 Electrical Characteristics for An Unbalanced Digital Interface
- ANSI/EIA/TIA-574 9 Position Non-Synchronous Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Interchange

(Applications for copies of ISO and ANSI publications should be addressed to: American National Standards Institute, 11 West 42nd Street, 13th floor, New York, NY 10036.)

Electronic Industries Association (EIA)

- EIA-423 Electrical Characteristics of Unbalanced Voltage Digital Interface Circuits

(Application for copies should be addressed to: Electronic Industries Association, Engineering Department, 2001 Pennsylvania Ave. N.W., Washington, D.C. 20006)

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

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

FS-1052: Definitions

3. DEFINITIONS.

3.1 Terms. Definitions needed for the technical understanding of this standard are found in the current version of FED-STD-1037. For the purposes of this standard, definitions are provided for the following terms, some of which have been repeated from FED-STD-1037 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.

NOTE: 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.

- **Balanced to ground.:** Pertaining to electrical symmetry with respect to a common ground.

- **Clear-to-send (CTS) signal.:** The control signal generated by the transmitting modem on the CTS connection to denote a state of readiness for transmission. The CTS signal is a response to the request-to-send (RTS) signal from the transmitting device.

- **Code rate.:** The ratio of the number of information symbols (k) to the total number of encoded symbols (n) in a code (i.e., the ratio of k/n).

- **Mode.:** An available format in a data modem supporting multi-waveform capability.

- **Narrowband.:** At HF radio frequencies (1.5 - 30 MHz) the nominal voice frequency (VF) bandwidth allocated for single channel radio (i.e., 3 kHz).

- **Nominal bandwidth.:** The widest band of frequencies, inclusive of guard bands, assigned to a channel.

- **Preamble code.:** A short sequence of symbols at the beginning of a coded sequence used to achieve synchronization.

- **Request-to-send (RTS) signal.:** The control signal generated by the transmitting terminal on the RTS connection to denote a request for transmission.

- **Secure voice.:** A voice communication that is protected against compromise through the use of an encryption system.

- **Unbalanced to ground.:** Pertaining to electrical asymmetry with respect to a common ground.

NOTE: Frequently, the term "unbalanced" describes a circuit, one side of which is grounded.

- **Wideband.:** At HF radio frequencies (1.5 - 30 MHz) a bandwidth larger than 3 kHz.

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

- **ABCA:** American, British, Canadian, Australian (armies)
- **ACK:** acknowledgement
- **ALE:** automatic link establishment
- **ANC:** automatic node controller
- **AND:** Logical AND
- **ANDVT:** Advanced Narrowband Digital Voice Terminal
- **ANSI:** American National Standards Institute
- **ARQ:** automatic repeat-request
- **Bd:** baud
- **BER:** bit error ratio
- **bit:** acronym for binary digit
- **b/s:** bits per second
- **BW:** bandwidth
- **CCIR:** International Radio Consultative Committee
- **CRC:** cyclic redundancy check
- **CTS:** clear to send
- **CTX:** clear to transmit
- **dB:** decibel(s)
- **dBm:** dB referred to one milliwatt
- **dBmØ:** noise power in dBm referred to or measured at ØTLP.
- **DCD:** data carrier detect
- **DCE:** data circuit-terminating equipment
- **DO:** design objective
- **DPSK:** differential phase-shift keying
- **DTE:** data terminal equipment
- **EIA:** Electronic Industries Association
- **EOM:** end of message
- **FEC:** forward error correction
- **FED-STD:** Federal Standard
- **freq:** frequency

- **FSK:** frequency-shift keying
- **FTSC:** Federal Telecommunications Standards Committee
- **HF:** high frequency
- **Hz:** hertz
- **IAW:** in accordance with
- **IC Ckt:** Interchange circuit
- **ID:** identification
- **I/O:** input/output
- **ISO:** International Organization for Standardization
- **ITU:** International Telecommunication Union
- **kHz:** kilohertz (1,000 hertz)
- **LF:** low frequency
- **LQA:** link quality analysis
- **LSB:** least significant bit
- **MF:** medium frequency
- **MGD:** modified-Gray decoder
- **MHz:** megahertz (1,000,000 hertz)
- **MIL-STD:** military standard
- **modem:** modulator-demodulator
- **ms:** millisecond(s)
- **MSB:** most significant bit
- **NAK:** negative acknowledgment
- **no.:** number
- **NATO:** North Atlantic Treaty Organization
- **OR:** logical OR
- **OSI:** Open Systems Interconnection
- **PSK:** phase-shift keying
- **PTT:** push-to-talk
- **QDPSK:** quadrature differential phase-shift keying
- **QSTAG:** Quadripartite Standardization Agreement
- **RA:** receive audio
- **RATT:** radio teletypewriter system
- **RC:** receive clock
- **RCE:** radio communications equipment
- **RD:** receive data
- **rf:** radio frequency
- **rms:** root-mean-square
- **RS:** receive (HF radio) signal
- **RTE:** radio terminal equipment
- **RTS:** request to send
- **RTX:** request to transmit
- **R/T:** receiver/transmitter (transceiver)
- **s:** second(s)
- **SNR:** signal-to-noise ratio
- **STANAG:** Standardization Agreement (NATO)
- **sync:** synchronization

- **TA:** transmit audio
- **TACTERM:** tactical terminal
- **TC:** transmit clock
- **TD:** transmit data
- **TIA:** Telecommunications Industry Association
- **TLP:** transmission level point
- **TS:** transmit (HF radio) signal
- **TX:** transmit
- **UHF:** ultra high frequency
- **VF:** voice frequency
- **VHF:** very high frequency

4.1 General system description. Data modulators-demodulators (modems) are employed in both automatic and manual HF radio systems. Data modems employ a variety of techniques for converting digital signals into quasi-analog signals for transmission over analog channels. This section covers general requirements for data modems operating over HF radio channels. Figure 1 shows standard interfaces in a typical system.

4.2 Common parameters. All data modems shall comply with the applicable requirements of pars. 4.2.1 through 4.2.6.

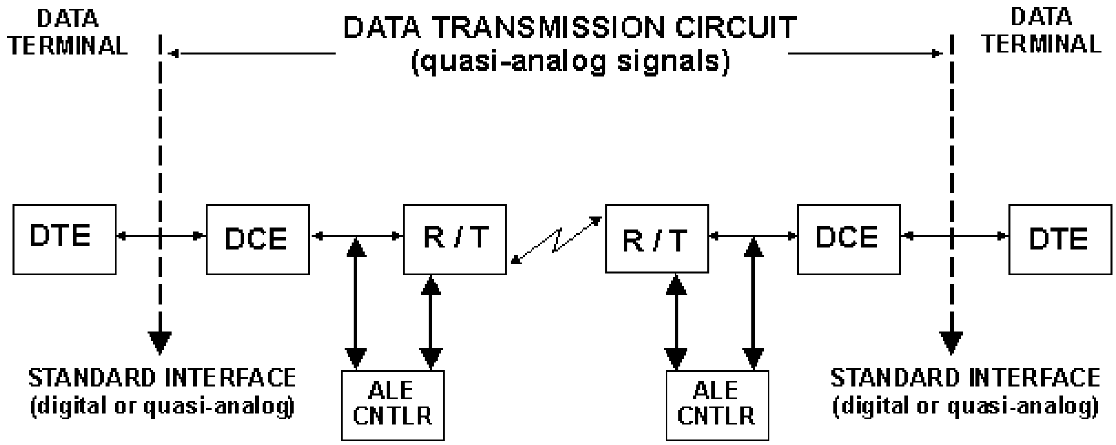
4.2.1 User data rates. The modem shall support user data rates, expressed in bits per second (b/s), of 75, 150, 300, 600, 1200, 2400, and 4800. Except where specified otherwise, signaling rates shall not deviate from the nominal values by more than ±0.01%.

4.2.2 Logic and signaling sense for binary signals. For data and timing circuits, the signal voltage with respect to signal ground shall be negative to represent the MARK condition and positive to represent the SPACE condition. The significant conditions and other logic and signal states shown in Table I shall apply to telegraph and data transmission. An alternative capability shall be provided to interface with equipment that accepts positive MARK and negative SPACE signals.

TABLE I. Logic and signal sense for binary signals

Application	Condition	Condition
Voltage to signal ground	Negative (-)	Positive (+)
Conventional term	MARK	SPACE
Binary digit value	(1)	(0)
Timing signal state	Off	On
FSK signal state	Lower frequency	Higher frequency

4.2.3 Digital interface characteristics. The electrical characteristics of the digital interface at the modulator input and the demodulator output shall be in accordance with the applicable requirements of FED-STD-1020 and FED-STD-1030.



NOTES:

1. DTE = TERMINAL EQUIPMENT
   DCE = DATA CIRCUIT-TERMINATING EQUIPMENT
2. DTE AND DCE MAY INCLUDE DATA ADAPTERS, MODEMS, ERROR CONTROL ALGORITHM, ENCRYPTION DEVICES, CONTROL UNITS AND OTHER EQUIPMENT, AS REQUIRED.
3. DTE AND DCE CAN BE COMBINED IN A SINGLE UNIT DEVICE AS CAN THE OTHER COMPONENTS
4. INTERFACES BETWEEN THE DCE, ALE CONTROLLER, AND RECEIVER / TRANSMITTER ARE VENDOR OR USER DETERMINED
5. MODULATION RATES AND DATA SIGNALING RATES AT THE STANDARD INTERFACE ARE SPECIFIED IN 4.2.1

Figure 1. Typical interface between data terminal equipment and data circuit-terminating equipment

Figure 1. Typical interface between data terminal equipment and data circuit-terminatingequipment

4.2.4 Terminal impedance for quasi-analog signals. (This interface applies to external modem implementations only.) For modems used with radio equipment of single-channel radio subsystems, the terminal impedance at the modulator output shall be 600 ohms, ±10%, balanced to ground. A 150 ohm terminal impedance, unbalanced to ground, is optional. The terminal impedance at the demodulator input shall be 600 ohms, ±10%, balanced to ground. The electrical symmetry shall be sufficient to suppress longitudinal currents to a level which is at least 40 dB below reference level (-40 dBmØ).

4.2.5 Quasi-analog signal levels. Standards for the quasi-analog signal levels of modulators and demodulators are documented in FED-STD-1045A.

4.2.6 Clock equipment, control, and timing. Clock equipment, control, and timing for modems shall be in accordance with the applicable requirements in MIL-STD-188-115. All data modems shall have the capability to accept external timing signals (optional for frequency-shift keying (FSK) modems).

4.3 General design requirements.

4.3.1 Federal maritime interoperability requirements (optional).

Ship-to-ship and shore-to-ship HF radio teletypewriter system (RATT) operation shall be in accordance with the requirements of FED-STD-1035.

4.3.2 International interoperability requirements.

4.3.2.1 Shore-to-ship broadcast systems (optional). For interoperation with North Atlantic Treaty Organization (NATO) member nations, the electrical characteristics of data modems employed in shore-to-ship broadcast systems shall be in accordance with the applicable requirements of NATO Standardization Agreement (STANAG) 5031.

4.3.2.2 Maritime air communications systems (optional). For interoperation with NATO member nations, the electrical characteristics of data modems employed in maritime air communication systems shall be in accordance with the applicable requirements of STANAG 5035.

4.3.2.3 Radio teletypewriter systems (optional). For interoperation among American, British, Canadian, Australian (ABCA) armies, the electrical characteristics of data modems employed in HF RATT operations shall comply with the applicable requirements of Quadripartite Standardization Agreement (QSTAG)-303.

NOTE: The applicable characteristics of data modems standardized in this document comply with STANAG 5031, STANAG 5035, and QSTAG-303.

FS-1052: Detailed Requirements

5. DETAILED REQUIREMENTS.

5.1 HF data modems. Both the frequency-shift keying (FSK) waveform and the serial (single-tone) transmit waveform described in this paragraph establish the minimum essential interoperability and performance requirements for new HF modems.

5.1.1 General requirements.

5.1.1.1 Capability. The HF modems shall be capable of modulating and demodulating serial binary data into/from an FSK waveform or a serial (single-tone) waveform. The waveform is transmitted/received over HF radio operating in a fixed-frequency mode of operation. The minimum acceptable performance and U.S. Government interoperability shall be at 75 b/s using the FSK and phase shift keying (PSK) serial (single-tone) waveforms specified herein. The following optional PSK serial (single-tone) rates, if selected for use, shall be incorporated in accordance with this standard: 150, 300, 600, 1200, 2400, all coded, and 4800 b/s uncoded. As a DO, at the rates above 75 b/s, the modem should have the capability to adapt to circuit conditions. The FED-STD-1052 serial (single-tone) modem (excluding the data link protocol) shall be interoperable with the MIL-STD-188-110A serial (single-tone) modem in the non-frequency hopping modes.

5.1.1.2 Voice digitization. When integrated within the data modem, the minimum mode for voice digitization functions shall be in accordance with (IAW) NATO STANAG 4198.

5.1.1.3 Optional modes. As a DO, the modem should be expandable to include one or more of the following optional modes:

a. NATO mode. If included, this mode shall be in accordance with STANAG 4285.
b. Advanced narrowband digital voice terminal (ANDVT) (thirty-nine-tone library used for secure voice and sixteen-tone subset of the thirty-nine-tone library used for data). If included, this mode shall be in accordance with MIL-C-28883 and STANAG 4197.
c. Thirty-nine-tone DPSK mode. If included, this mode shall be in accordance with appendix A.
d. Sixteen-tone differential phase-shift keying (DPSK) mode. If included, this mode shall be in accordance with appendix C.
e. Frequency hopping mode. If included, this mode shall be in accordance with the PSK serial (single-tone) waveform contained in MIL-STD-188-110A and the data training and timing format provided in MIL-STD-188-148A, Appendix D.

5.2 Interface requirements (optional).

5.2.1 Data terminal equipment (DTE) interface. The electrical characteristics of the digital interface signals shall be IAW FED-STD-1030, which implements EIA Standard 423, or ANSI/EIA/TIA-562. When the modem is provided with a hardware connection to an external DTE, it is recommended that the connectors, pin connections, and digital signal electrical interface signals should be IAW ANSI/EIA-232 (DB-25S connector) or ANSI/EIA/TIA-574 (DE-9S connector).

5.2.1.1 Circuits supported - all modes. The following circuits for both synchronous and nonsynchronous modes shall be supported as defined by FED-STD-1030 and ANSI/EIA-232 or ANSI/EIA/TIA-574:

a. Transmitted Data (input), Interchange Circuit (IC Ckt) BA.
b. Received Data (output), IC Ckt BB.
c. Signal Ground/Common Return, IC Ckt AB.
d. Received Line Signal Detector (carrier detect), IC Ckt CF.

5.2.1.2 Circuits supported - synchronous modes. (Optional for nonsynchronous modes)

a. Request to Send, IC Ckt CA.
b. Clear to Send, IC Ckt CB.
c. DCE Ready (data set ready), IC Ckt CC.
d. DTE Ready (data terminal ready), IC Ckt CD.

(The following are not supported by ANSI/EIA/TIA-574)

e. Transmitter Signal Element Timing (DTE) (external transmit clock), IC Ckt DA.
f. Transmitter Signal Element Timing (DCE) (transmit clock), IC Ckt DB.
g. Receiver Signal Element Timing (DCE) (receive clock), IC Ckt DD

NOTE: Frame or protective ground is not classified as an interchange circuit in the ANSI/EIA-232 standard.

5.2.1.3 Interface features. The following interface features are optional.

5.2.1.3.1 Receive data transmit MARK hold. In a half-duplex modem circuit, the receive data output may be held in the MARK signal condition when the modem is transmitting. This feature is not used when the modem operates in the full-duplex mode.

5.2.1.3.2 Receive data no-signal MARK hold. In a half-duplex modem circuit, the receive data output may be held in the MARK signal condition when the carrier detect (IC Ckt CF) is in the OFF condition.

5.2.2 Analog interface. When the modem provides hardware analog interface connections to external devices, the interface signals shall have the following characteristics.

5.2.2.1 Modulator output. The modulator output shall have an output impedance of 600 ohms (±10%), balanced and isolated, over the frequency range of operation. The modulator output level shall be adjustable over the range of -10 dBm to +3 dBm. A 150 ohm terminal impedance, unbalanced to ground, is optional.

5.2.2.2 Demodulator input. The demodulator input shall have an input impedance of 600 ohms (±10%), balanced and isolated, over the frequency range of operation. Demodulator performance shall be maintained with a nominal input level of -10 dBm to +3 dBm.

5.2.3 Equipment-side characteristics. Modems shall be designed to provide the required performance (see par. 5.4.5) using the single-channel bandwidth and characteristics as given in FED-STD-1045. As a DO, modems should be capable of transmitting and receiving the quasi-analog signals over unconditioned 3-kHz voice frequency (VF) lines while maintaining the performance established in par. 5.4.5.

5.3 Frequency-shift keying (FSK) waveform. The FSK transmit waveform described herein is mandatory. This requirement is intended to assure minimum essential interoperability with existing FSK HF modem equipment. This requirement will expire on 31 December 2001.

5.3.1 Capability. The FSK modems shall be capable of modulating and demodulating serial binary data (asynchronous, synchronous, or bit synchronous) into/from an FSK waveform. This waveform is transmitted/received over HF radio. The minimum acceptable performance and U.S. Government interoperability shall be at 75 Bd. Other data rates, consistent with par. 4.2.1, are optional. The external timing signal requirement (par. 4.2.6) shall be optional for the FSK modem.

5.3.2 Code transparency. The FSK waveform generated by the modulator shall be code transparent. Data input of the MARK state into the modulator shall produce an output of the FSK MARK frequency. Data input in the SPACE state shall produce an output at the FSK SPACE frequency. Reception of the FSK MARK frequency shall be demodulated to produce a MARK output data state. Reception of the SPACE frequency shall be demodulated to produce a SPACE data output state.

5.3.3 FSK tone frequencies. The MARK and SPACE FSK modulator and demodulator tone frequencies shall be independently adjustable over the frequency range of 1000 Hz to 3000 Hz in 5-Hz or less steps.

5.3.4 FSK adaptive tone selection. (Optional). The modem may include the capability to lock-on and adapt to the distant transmit modem MARK/SPACE frequencies.

5.3.4.1 Receive signal requirements. When adaptive tone selection is used, the parameters of the receive signal must be within the following limits:

a. FSK data rate of 75 Bd,
b. Tone frequency range of 1000 Hz to 3000 Hz,
c. FSK shift must be greater than the baud rate.

5.3.4.2 Receive signal polarity, code, and protocol. When adaptive tone selection is used, determination of the received signal's FSK MARK/SPACE polarity, code, and waveform protocol is made by equipment other than the FED-STD-1052 modem.

5.3.4.3 Modulator tone frequencies. When adaptive tone selection is used to set the demodulator FSK filter frequencies, the modulator section of the FED-STD-1052 modem shall be adjusted such that the transmitted MARK and SPACE tone frequencies match those selected for the demodulator.

5.3.4.4 Adaptive tone selection operation. The adaptive tone selection feature shall be selected manually by the operator or by devices external to the FED-STD-1052 modem. Adaptive tone search may be initiated by remote control command, by external signal input, or by a switch on the modem. Upon initiation, a FED-STD-1052 modem equipped for adaptive tone selection shall search the audio frequency spectrum between 1000 Hz and 3000 Hz. If distinctive MARK and SPACE FSK spectral distribution is discovered, the demodulator tone filters and the modulator transmit tones shall be set to the center frequencies of these distributions. Automatic frequency adjust capabilities shall then be disabled and the modem will function as a fixed-frequency FSK modem until the control input is again activated by the operator or external control device.

5.4 Serial (single-tone) mode.

5.4.1 General. This mode shall employ M-ary phase-shift keying (PSK) on a single carrier frequency as the modulation technique for data transmission.

5.4.1.1 Data conversion and modulation. Serial binary information accepted at the line-side input is converted into a single 8-ary PSK-modulated output carrier. The modulation of this output carrier shall be a constant 2400-symbols-per-second waveform regardless of the actual throughput rate. The rate-selection capability shall be as given in par. 5.1.1.1. Selectable interleaver settings shall be provided.

5.4.1.2 Nonsynchronous data operation. (Optional). In addition to bit-synchronous data transmission, a nonsynchronous mode shall also be supported. When operating in the nonsynchronous mode, the modulator shall accept source data in nonsynchronous start/parity/stop character format. The start/parity/stop bits shall be included in the bit stream which is provided to the forward error correction (FEC) encoder. MARK (1) bits shall be inserted in the bit stream as necessary to maintain a bit-synchronous data stream to the FEC encoder. The demodulator will deliver data in nonsynchronous start/parity/stop character format to the receiving data terminal equipment (DTE).

5.4.2 Sequencing of time phases. The PSK waveform (signal structure) has four functionally distinct, sequential transmission phases. These time phases are:

a. Synchronization preamble phase.
b. Data phase.
c. End-of-message (EOM) phase.
d. Coder and interleaver flush phase.

Figure 2 is the functional block diagram.

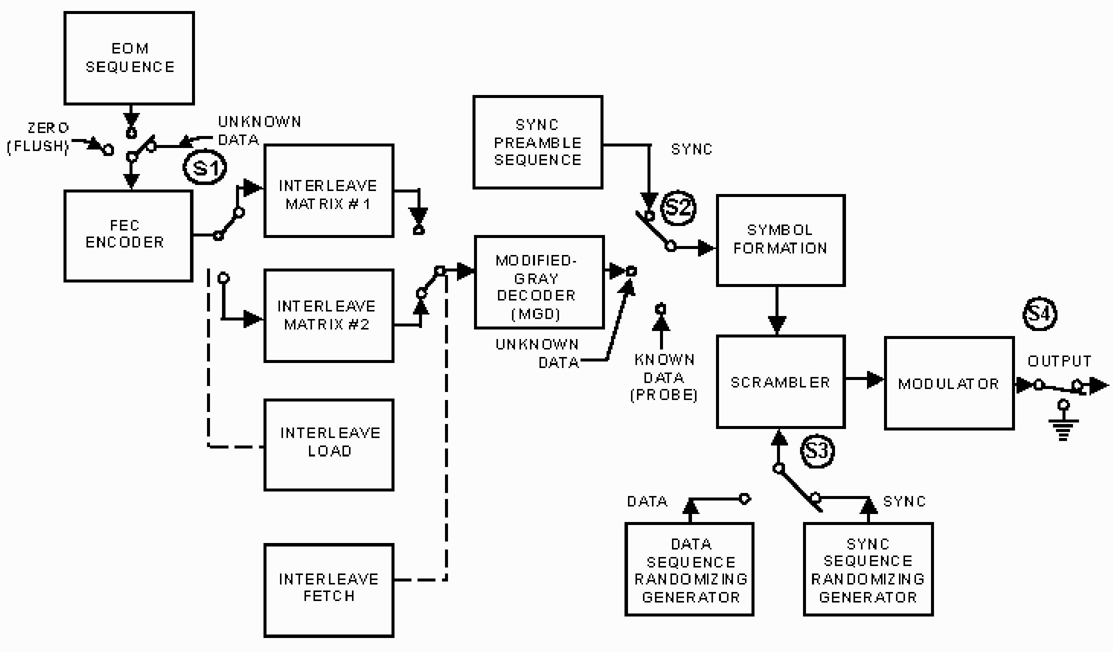


Figure 2. Serial (single-tone) waveform functional block diagram

Figure 2. Serial (single-tone) waveform functional block diagram

5.4.2.1 Synchronization (sync) preamble phase. The duration of the sync preamble phase shall correspond to the exact time required to load the selected interleaver matrix, when an interleaver is present, with one block of data. During this phase, switch S1 (see Fig. 2) shall be in the UNKNOWN DATA position and the encode and load interleave functions shall be active as the modem begins accepting data from the DTE. Switches S2 and S3 shall be in the SYNC position. The transmitting modem shall send the required sync preamble sequence (see par. 5.4.3.7.2) to achieve time and frequency sync with the receiving modem. The length of the sync preamble sequence pattern shall be 0.6 second (s) for the zero interleaver setting (this requires that a 0.6-s buffer be used to delay data traffic during the sync preamble transmission), 0.6 s for the short interleaver setting, and

4.8 s for the long interleaver setting. Switch S4 shall be placed in the through position during fixed-frequency operation. Referring to Fig. 3, the sequence of events for synchronous and asynchronous operation is as follows:

a. For full-duplex data operation, upon receipt of the message request-to-send (RTS) signal from the DTE, the modem shall simultaneously perform the following:

(1) return to the DTE a clear-to-send (CTS) signal,
(2) begin loading the interleaver with data traffic, and
(3) commence sending the special sync preamble pattern described in pars. 5.4.3.7.2 and 5.4.3.8.2.

b. For half-duplex (one-way reversible) data operation using radio equipment without automatic link establishment (ALE) capability, the radio set transmitter shall be keyed first, then the sequence of events shall be identical to that given for full-duplex operation.

c. Half-duplex data operation using ALE radio equipment shall incorporate a method of delaying the data CTS signal until radio link confirmation. In an example of this operation, upon receipt of the RTS signal from the user data terminal, the controller first initiates and confirms linking with the called station. During this link confirmation period, the RTS signal is controlled and delayed in the controller until the link is confirmed. After link confirmation, the controller sends the RTS signal to the modem. (In effect, the delaying of the RTS signal provides the needed delay of the data CTS signal.) Upon receipt of the RTS signal from the controller, the modem shall simultaneously perform the following:

(1) key the radio,
(2) return to the DTE a CTS signal,
(3) begin loading the interleaver with data traffic, and
(4) commence sending the special sync pattern described in pars. 5.4.3.7.2 and 5.4.3.8.2.

Figure 3. An example of equipment interface block diagram

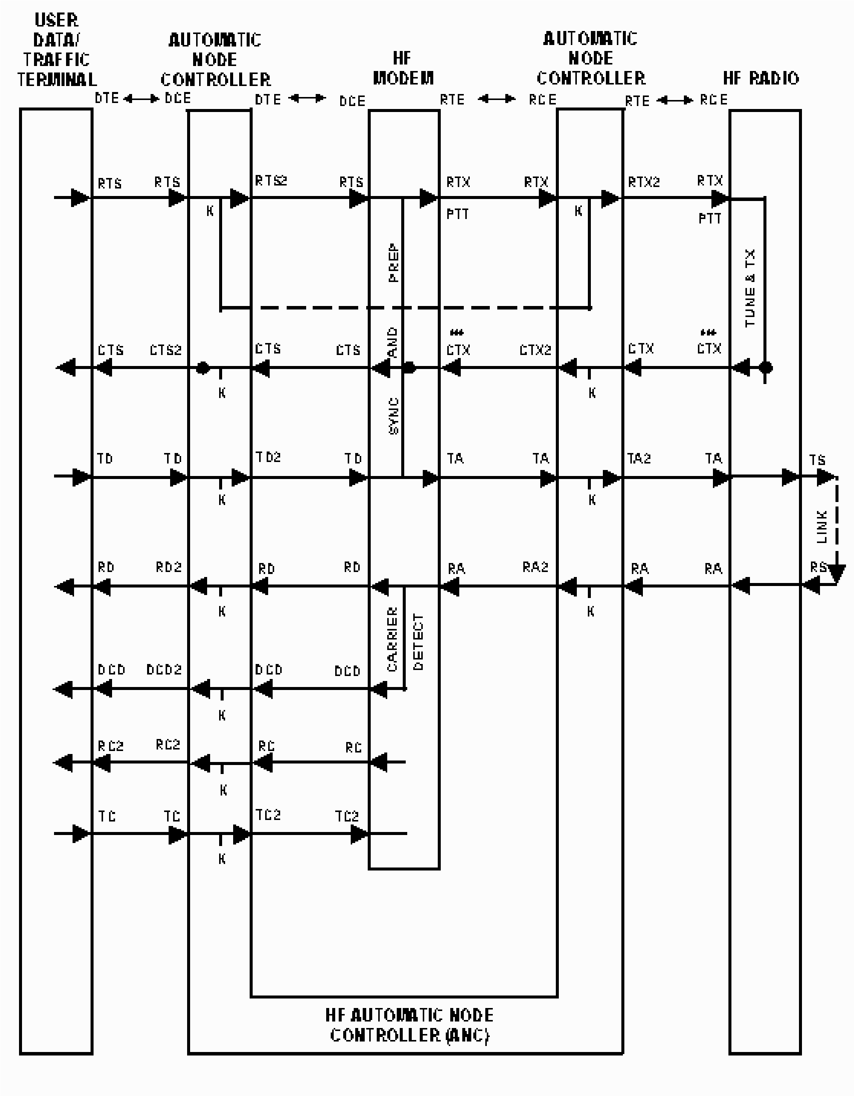


Figure 3. An example of equipment interface block diagram

LEGEND:

- *****:** Indicates a necessary interface which is not presently defined and required in present equipments and standards, and must be incorporated.
- **ANC:** Automatic node controller
- **AND:** Logical AND, all (available) inputs must be true to obtain a true output
- **CTS:** Clear to send
- **CTX:** Clear to transmit (transmitter tuned and on)
- **CTX2:** CTX controlled through ANC
- **DCD:** Data Carrier Detect (received data carrier detection)
- **DCD2:** DCD controlled through ANC

- **DCE:** Data circuit-terminating equipment
- **DTE:** Data terminal equipment
- **K:** Indicates HF ANC control, which may also include monitoring and/or injection
- **Link:** HF radio link, including distant station and propagation
- **OR:** Logical OR, some (available) inputs must be true to obtain a true output
- **Prep:** Preparation to accept and send data, and key transmitter
- **PTT:** Push to talk (key transmitter on)
- **RA:** Receive audio
- **RA2:** RA controlled through ANC
- **RC:** Receive clock
- **RC2:** Receive clock controlled through ANC
- **RCE:** Radio communications equipment
- **RD:** Receive data
- **RD2:** RD controlled through ANC
- **RS:** Receive (HF radio) signal
- **RTE:** Radio terminal equipment
- **RTS:** Request to send
- **RTS2:** RTS controlled through ANC
- **RTX:** Request to transmit
- **RTX2:** RTX controlled through ANC
- **Sync:** Synchronization for data transmission
- **TA:** Transmit audio
- **TA2:** TA controlled through ANC
- **TC:** Transmit clock
- **TC2:** Transmit clock controlled through ANC
- **TD:** Transmit data
- **TD2:** TD controlled through ANC
- **TS:** Transmit (HF radio) signal
- **Tune:** Tuning of the transmitter system before transmit
- **TX:** Transmit (HF radio on and ready to send data)

5.4.2.2 Data phase. During the data phase, the transmit waveform shall contain both message information (UNKNOWN DATA) and channel probes (KNOWN DATA), that is, training bits reserved for channel equalization by the distant receive modem. Function switches S1 and S3 (fig. 2) are in the UNKNOWN DATA and DATA position, respectively, and switch S2 toggles between the UNKNOWN DATA (modified-Gray decoder (MGD) output) and the KNOWN DATA (probe) positions. The probe shall consist of zeros, D1, and D2 (D1 and D2 are defined in par. 5.4.3.7.2.1). The period of dwell in each switch position shall be a function of bit rate only. At 2400 and 4800 b/s, there shall be a 32-symbol duration in the UNKNOWN DATA position followed by a 16-symbol duration in the KNOWN DATA position. At 150, 300, 600, and 1200 b/s, the two durations shall be 20 symbols in each position. At 75 b/s, switch S2 shall remain in the UNKNOWN DATA position. Data transfer operation shall be terminated by removal of the RTS signal by the input DTE.

NOTE: In all cases, switch S2 is placed in the UNKNOWN DATA position first, following the end of the sync preamble phase.

5.4.2.3 EOM phase. When the last UNKNOWN DATA bit prior to the absence of the RTS signal has entered the forward error correction (FEC) encoder, S1 (fig. 2) shall be switched to the EOM position. This shall cause a fixed 32-bit pattern (see par. 5.4.3.1) to be sent to the FEC encoder. Function switches S2 and S3 shall continue to operate as established for the data phase.

5.4.2.4 FEC coder and interleaver flush phase. Immediately upon completion of the EOM phase, S1 (fig. 2) shall be switched to the FLUSH position causing input of flush bits (see par. 5.4.3.2) to the FEC encoder.

5.4.3 Functional descriptions. The following subparagraphs provide Fig. 2 block descriptions.

5.4.3.1 EOM sequence. The EOM sequence shall be represented by the eight-digit hexadecimal number, 4B65A5B2. The bits shall be transmitted with the most significant digit first. Thus the first eight bits are, left to right, 0100 1011.

5.4.3.2 Interleaver flush. If an interleaver is used, the duration of the flush phase shall be 144 bits (for coder flush) plus enough bits to complete transmission of the remainder of the interleaver matrix data block containing the last coder flush bit (see par. 5.4.3.4 for data block size). Flush bits shall be set to "Ø". If the interleaver is in a bypass (0.0 s) state, only the coder flush bits are transmitted.

NOTE: This causes the transmission of enough flush bits to allow effective flushing of the FEC decoder and the deinterleaver at the receiving modem.

5.4.3.3 FEC encoder. The FEC encoder shall be used for data rates up to and including 2400 b/s. The FEC encoder block diagram for fixed-frequency operation is shown on Figure 4. The FEC encoder function shall be accomplished by a single rate 1/2 constraint length 7 convolutional decoder with repeat coding used at 150 and 300 b/s. The two summing nodes on the figure represent modulo 2 addition. For each bit input to the encoder, two bits shall be taken as output from the encoder, the upper output bit $T_1(x)$ being taken first. Coded bit streams of 4800, 2400, and 1200 b/s shall be generated for input data rates of 2400, 1200, and 600 b/s, respectively. For 300-b/s and 150-b/s input data rates, a 1200-b/s coded bit stream shall be generated by repeating the pairs of output bits the appropriate number of times. The bits shall be repeated in pairs rather than repetitions for the first, $T_1(x)$, followed by repetitions of the second $T_2(x)$. At 75 b/s, a different transmit format (see par. 5.4.3.7.1.1) is used and the effective code rate of 1/2 shall be employed to produce a 150-b/s coded stream. Error-correction coding shall be in accordance with Table II. For 4800-b/s fixed-frequency operation, the FEC encoder shall be bypassed.

TABLE II. Error-correcting coding

DATA RATE (b/s)	EFFECTIVE CODE RATE	METHOD FOR ACHIEVING THE CODE RATE
4800	(no coding)	(no coding)
2400	1/2	Rate 1/2
1200	1/2	Rate 1/2 code
600	1/2	Rate 1/2 code
300	1/4	Rate 1/2 code, repeated 2 times
150	1/8	Rate 1/2 code, repeated 4 times
75	1/2	Rate 1/2

[Figure 4](#). FEC encoder block diagram

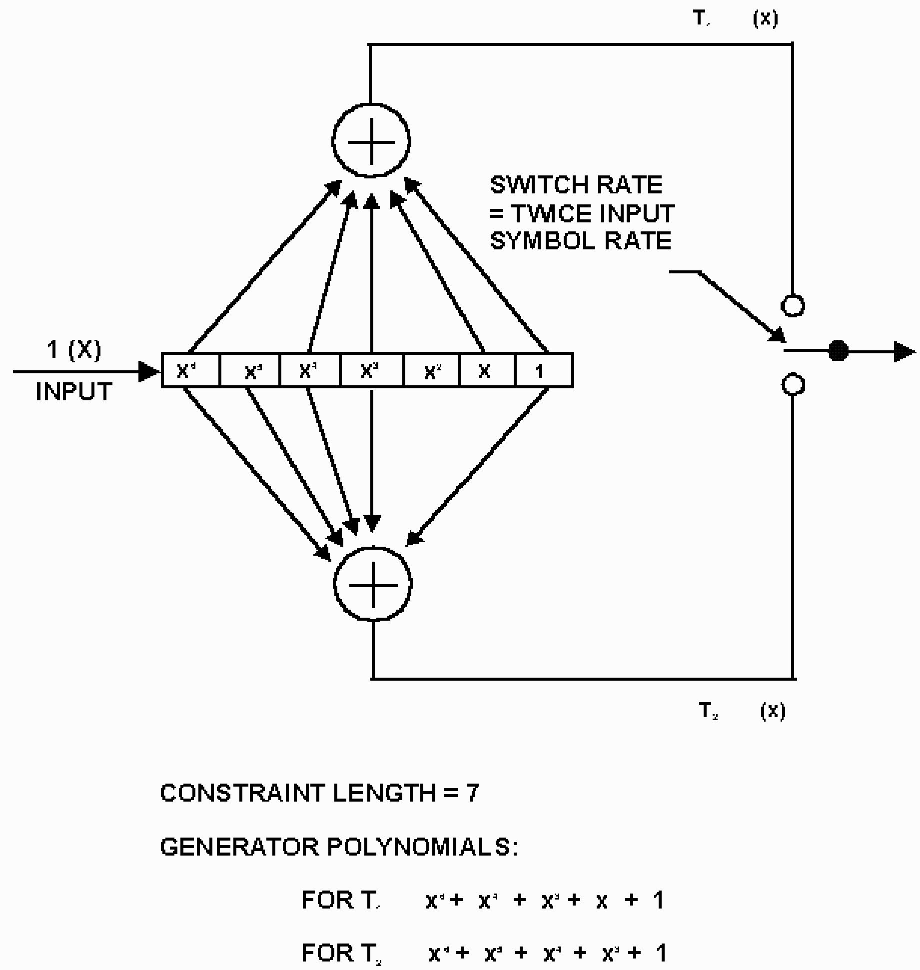


Figure 4. FEC encoder block diagram

5.4.3.4 <u>Interleaver load</u>. The interleaver, when used, shall be a matrix block type which operates upon input bits. The matrix size shall accommodate block storage of 0.0, 0.6, or 4.8 s of receiving bits (depending on whether the zero, short, or long interleave setting is chosen) at all required data rates. Because the bits are loaded and fetched in different orders, two distinct interleave matrices shall be required.

NOTE: This allows one block of data to be loaded while the other is being fetched. The selection between the long and short interleaver is contained in the transmitted sync pattern (par. 5.4.3.7.2). The short interleaver shall be switch selectable to be either 0.0 or 0.6 s (see par. 5.4.3.7.2.1).

To maintain the interleave delay at a constant value, the block size shall be scaled by bit rate. Table III lists the interleave matrix dimensions (rows and columns) that shall be allocated for each required bit rate and interleave delay.

NOTE: At the rates of 300 and 150 b/s, the number of bits required for a constant time delay is the same as that for 600 b/s due to repeat coding.

Unknown data bits shall be loaded into the interleaver matrix starting at column zero as follows: the first bit is loaded into row 0, the next bit is loaded into row 9, the third bit is loaded into row 18, and the fourth bit into row 27. Thus, the row location for the bits increases by 9 modulo 40. This process continues until all 40 rows are loaded. The load then advances to column 1 and the process is repeated until the matrix block is filled. This procedure shall be followed for both long and short interleave settings.

NOTE: The interleaver shall be bypassed for 4800-b/s operation.

For operation at 75 b/s only, the following changes to the above description shall apply:

a. When the interleave setting is on long, the procedure is the same, but the row number shall be advanced by 7 modulo 20.
b. When the interleave setting is on short, the row number shall be advanced by 7 modulo 10. If the short interleaver is selected and the short interleaver setting is 0.0 s, the interleaver shall be bypassed.

5.4.3.5 Interleaver fetch. The fetching sequence for all rates shall start with the first bit being taken from row zero, column zero. The location of each successive fetched bit shall be determined by incrementing the row by one and decrementing the column number by 17 (modulo number of columns in the interleaver matrix). Thus, for 2400 b/s with a long interleaver setting, the second bit comes from row 1, column 559, and the third bit from row 2, column 542. This interleaver fetch shall continue until the row number reaches the maximum value. At this point, the row number shall be reset to zero, the column number is reset to be one larger than the value it had when the row number was last zero, and the process continued until the entire matrix data block is unloaded. For operation at the 75-b/s rate, the interleaver fetch is similar except the decrement value of the column number shall be 7 rather than 17. The bits obtained from the interleaver matrix shall be grouped together as one-, two-, or three-bit entities that will be referred to as channel symbols. The number of bits that must be fetched per channel symbol shall be a function of bit rate as given in Table IV.

TABLE III. Interleaver matrix dimensions

LONG INTERLEAVER			SHORT INTERLEAVER	
Bit rate (b/s)	Number of rows	Number of columns	Number of rows	Number of columns
2400	40	576	40	72
1200	40	288	40	36
600	40	144	40	18
300	40	144	40	18
150	40	144	40	18
75	20	36	10	9

5.4.3.6 Modified-Gray decoder (MGD). At 4800 and 2400 b/s, the channel bits are effectively transmitted with 8-ary channel symbols. At 1200 b/s and 75 b/s, the channel bits are effectively transmitted with 4-ary channel symbols.

NOTE: The purpose of decoding the bits from the interleaver matrix (through the MGD) is to guarantee that only one bit is in error when symbol errors involving adjacent phases are made at the receiving demodulator.

Modified-Gray decoding of the 4800-b/s, 2400-b/s (tribit), and the 1200-b/s, 75-b/s (dibit) channel symbols shall be IAW tables V and VI respectively. When one-bit channel symbols are used (600-150 b/s), the MGD does not modify the unknown data bit stream.

TABLE IV. Bits-per-channel symbol

Data rate (b/s)	Number of bits fetched per channel symbol
2400	3
1200	2
600	1
300	1
150	1
75	2

TABLE V. Modified-Gray decoding at 4800 b/s and 2400 b/s

INPUT BITS	

First bit	Middle bit	Last bit	Modified-Gray decoded value
0	0	0	000
0	0	1	001
0	1	0	011
0	1	1	010
1	0	0	111
1	0	1	110
1	1	0	100
1	1	1	101

TABLE VI. Modified-Gray decoding at 1200 b/s and 75 b/s

INPUT BITS		
First bit	Last bit	Modified-Gray decoded value
0	0	00
0	1	01
1	0	11
1	1	10

5.4.3.7 Symbol formation. The function of symbol formation is one of mapping the one-, two-, or three-bit channel symbols from the MGD or from the sync preamble sequence into tribit numbers compatible with transmission using an 8-ary modulation scheme. The mapping process is discussed separately for data and preamble transmissions.

5.4.3.7.1 Symbol formation for data transmission. Channel symbols shall be fetched from the interleaver only during the portion of time that unknown symbols are to be transmitted. For all data rates, the output of the symbol formation shall be scrambled with pseudorandom three-bit numbers. This scrambled waveform shall appear to be 8-ary tribit numbers regardless of operational throughput bit rates. The relationship of tribit numbers (0-7) to the transmitted phase of the waveform is further defined in par. 5.4.3.9.

5.4.3.7.1.1 Unknown data. At all rates above 75 b/s, each one-, two-, or three-bit channel symbol shall map directly into one of the 8-ary tribit numbers as shown on the state constellation diagram, Fig. 5. When one-bit channel symbols are used (600-150 b/s), the symbol formation output shall be tribit numbers 0 and 4. At the 1200-b/s rate, the dibit channel symbol formation shall use tribit numbers 0, 2, 4, and 6. At the 4800-b/s and

2400-b/s rates, all the tribit numbers (0-7) shall be used for symbol formation. At 75 b/s, the channel symbols shall consist of two bits for 4-ary channel symbol mapping. Unlike the higher rates, no known symbols (channel probes) shall be transmitted and no repeat coding shall be used. Instead, the use of 32 tribit numbers shall be used to represent each of the 4-ary channel symbols. The mapping that shall be used is given in Table VII. The mapping in Table VIIa shall be used for all sets of 32 tribit numbers with the exception of every 45th set (following the end of the sync pattern) if short interleave is selected, and every 360th set (following the end of the sync pattern) if long interleave is selected. These exceptional sets, every 45th set for short interleave and every 360th set for long interleave, shall use the mappings of Table VIIb. In any case, the resultant output is one of four orthogonal waveforms produced for each of the possible dibits of information. These values will be scrambled later to take on all 8-phase states.

NOTE: Each set consists of 32 tribit numbers. The receive modem, at rates 150 b/s and above, shall use the modification of the known data at interleaver boundaries to synchronize without a preamble and determine the correct data rate and mode of operation. At the 75-b/s rate, the receive modem shall use the exceptional set at interleaver boundaries to synchronize without a preamble and determine the correct data rate and mode of operation.

[Figure 5](#). State constellation diagram

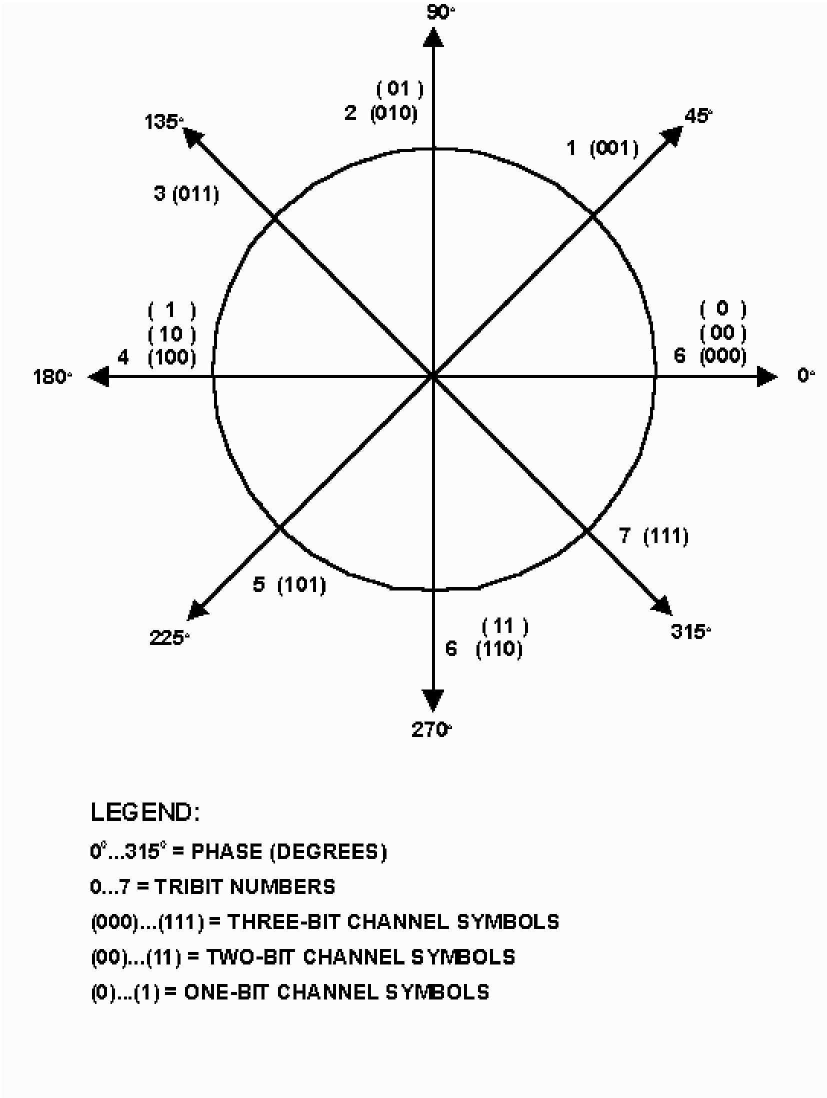


Figure 5. State constellation diagram

TABLE VII. Channel symbol mapping for 75 b/s

CHANNEL SYMBOL	TRIBIT NUMBERS
a. Mapping for normal sets.	
00	(0000) repeated 8 times
01	(0404) repeated 8 times
10	(0044) repeated 8 times
11	(0440) repeated 8 times

b. Mapping for exceptional sets.	
00	(0000 4444) repeated 4 times
01	(0404 4040) repeated 4 times
10	(0044 4400) repeated 4 times
11	(0440 4004) repeated 4 times

5.4.3.7.1.2 Known data. During the periods where known (channel probe) symbols are to be transmitted, the channel symbol formation output shall be set to 0 (000) except for the two known symbol patterns preceding the transmission of each new interleaver block. The block length shall be 1440 tribit channel symbols for short interleave setting and 11520 tribit channel symbols for the long interleave setting. When the two known symbol patterns preceding the transmission of each new interleaver block are transmitted, the 16 tribit symbols of these two known symbol patterns shall be set to D1 and D2, respectively, as defined in Table VIII of par. 5.4.3.7.2.1 and Table X of par. 5.4.3.7.2.2. The two known symbol patterns are repeated twice rather than four times as they are in Table X to produce a pattern of 16 tribit numbers. In cases where the duration of the known symbol pattern is 20 tribit symbols, the unused last four tribit symbols shall be set to 0 (000).

NOTE: When zero interleaver setting is selected, the pattern associated with the 0.6-s block is used. When 4800-b/s operation is selected, the pattern associated with the short interleaver setting is selected.

5.4.3.7.2 Sync preamble sequence.

5.4.3.7.2.1 General. The waveform for synchronization is essentially the same for all data rates. The synchronization pattern shall consist of either three or twenty-four 200-millisecond (ms) segments (depending on whether zero, short, or long interleave periods are used). Each 200-ms segment shall consist of a transmission of 15 three-bit channel symbols as described in par. 5.4.3.7.2.2. The sequence of channel symbols shall be:

0, 1, 3, 0, 1, 3, 1, 2, 0, D1, D2, C1, C2, C3, 0.

The three-bit values of D1 and D2 shall designate the bit rate and interleave setting of the transmitting modem. Table VIII gives the assignment of these values. Again, the short interleave can be selected as either 0.0 (bypassed) or 0.6 s.

NOTE: The short interleave generally should be set to 0.6 s. If the 0.0-s interleave is selected, coordination with the distant terminal must be made before transmitting data. An automatic feature of selection between the 0.0-s and 0.6-s interleaver for both transmitter and receiver is a DO.

The three count symbols C1, C2 and C3 shall represent a count of the 200-ms segments starting at 2 for the zero and short sync (interleave) setting cases and 23 for the long sync (interleave) case. The count in either case shall start at the value established by the sync case setting and count down each segment to zero. The values shall be read as a six-bit word (C1, C2, C3), where C1 contains the most significant two bits. The two-bit values of each C (C1, C2, C3) shall be converted to three-bit values. This is done by adding a "1" before the two-bit value so that this "1" becomes the most significant bit. This conversion shall be as shown in Table IX.

NOTE: The converted count of 23 (010111) would have values of 5, 5, and 7 for C1, C2, and C3, respectively.

TABLE VIII. Assignment of designation symbols D1 and D2

	SHORT INTERLEAVE		LONG INTERLEAVE	
BIT RATE	D1	D2	D1	D2
4800	7	6	-	-
2400 (secure voice)	7	7	-	-
2400 (data)	6	4	4	4
1200	6	5	4	5
600	6	6	4	6
300	6	7	4	7
150	7	4	5	4
75	7	5	5	5

TABLE IX. Conversion of two-bit count value to three-bit symbol

Two-bit count value	Three-bit sync symbol
00	4 (100)
01	5 (101)
10	6 (110)
11	7 (111)

5.4.3.7.2.2 Preamble pattern generation. The sync preamble pattern shall be a sequence of channel symbols containing three bits each (see par. 5.4.3.7.2.1). These channel symbols shall be mapped into 32 tribit numbers as given in Table X.

NOTE: When the two known symbol patterns preceding the transmission of each new interleaver block are transmitted, the patterns in Table X are repeated twice rather than four times to produce a pattern of 16 tribit numbers.

TABLE X. Channel symbol mapping for sync preamble

CHANNEL SYMBOL	TRIBIT NUMBERS
000	(0000 0000) repeated 4 times
001	(0404 0404) repeated 4 times
010	(0044 0044) repeated 4 times
011	(0440 0440) repeated 4 times
100	(0000 4444) repeated 4 times
101	(0404 4040) repeated 4 times
110	(0044 4400) repeated 4 times
111	(0440 4004) repeated 4 times

5.4.3.8 Scrambler. The tribit number supplied from the symbol formation function for each 8-ary transmitted symbol shall be modulo 8 added to a three-bit value supplied by either the data sequence randomizing generator or the sync sequence randomizing generator.

5.4.3.8.1 Data sequence randomizing generator. The data sequence randomizing generator shall be a 12-bit shift register with the functional configuration shown on Fig. 6. At the start of the data phase, the shift register shall be loaded with the initial pattern shown in Fig. 6 (101110101101 (binary) or BAD (hexadecimal)) and advanced eight times. The resulting three bits, as shown, shall be used to supply the scrambler with a number from 0 to 7. The shift register shall be shifted eight times each time a new three-bit number is required (every transmit symbol period). After 160 transmit symbols, the shift register shall be reset to BAD (hexadecimal) prior to the eight shifts.

NOTE: This sequence produces a periodic pattern 160 transmit symbols in length.

Figure 6. Randomizing shift register functional diagram

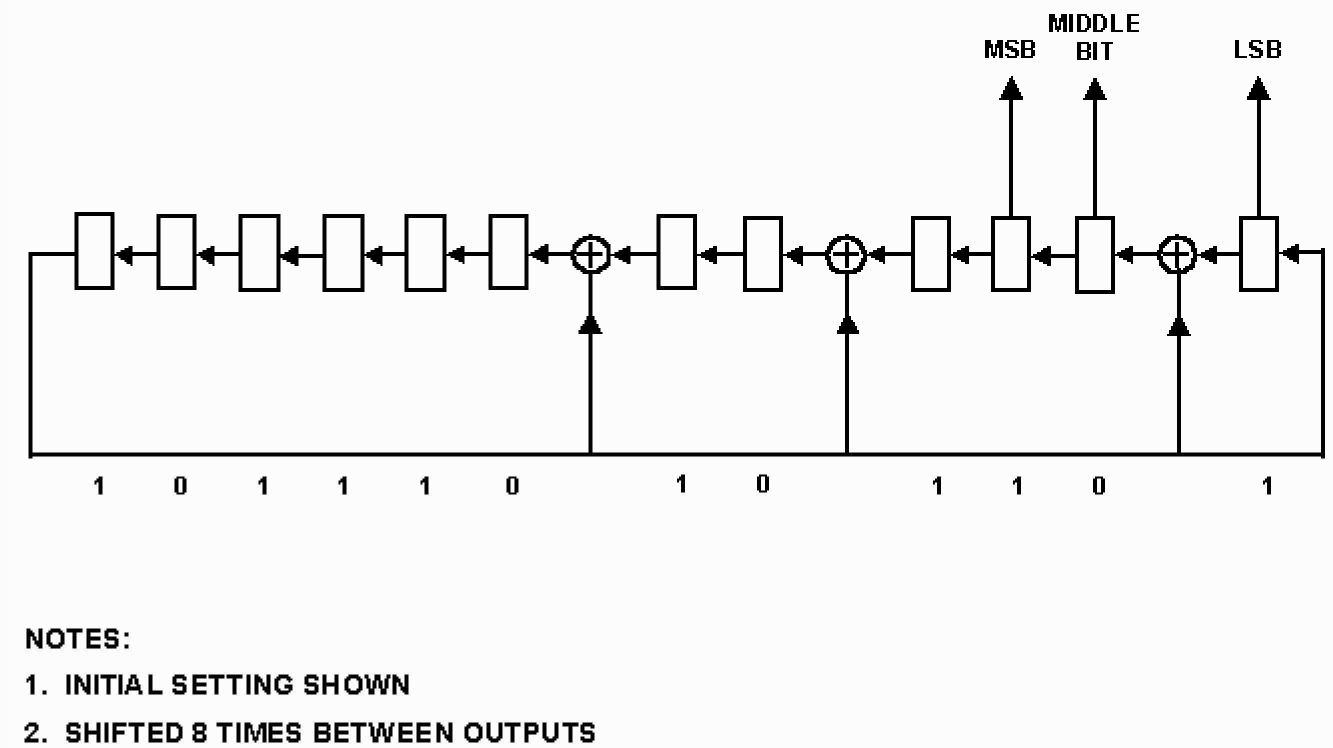


Figure 6. Randomizing shift register functional diagram

5.4.3.8.2 Sync sequence randomizing generator. The following scrambling sequence for the sync preamble shall repeat every 32 transmitted symbols:

7 4 3 0 5 1 5 0 2 2 1 1 5 7 4 3 5 0 2 6 2 1 6 2 0 0 5 0 5 2 6 6

where 7 shall always be used first and 6 shall be used last. The sequences in par. 5.4.3.8.1 and this paragraph shall be modulo 8 added to the output of the symbol formation function.

5.4.3.9 PSK modulation.

a. The eight-phase modulation process shall be achieved by assigning the tribit numbers from the scrambler to 45-degree increments of an 1800-Hz sinewave. Thus, 0 (000) corresponds to 0 degrees, 1 (001) corresponds to 45 degrees, 2 (010) corresponds to 90 degrees, etc. Figure 5 shows the assignment and pattern of output waveform generation.

NOTE: Since the transmit channel symbol duration is less than one cycle of the 1800-Hz carrier, the waveforms controlling the sine and cosine components must be filtered to prevent severe aliasing.

b. Clock accuracy for generation of the 1800-Hz carrier shall be within ±1 Hz.

5.4.4 Waveform summary. Table XI summarizes the data phase characteristics of the transmitted formats that shall be used for each bit rate.

5.4.5 Performance requirements. The measured performance of the serial (single-tone) mode, employing the maximum interleaving period, shall be equal to or better than the coded BER performance in Table XII. Performance verification shall be tested using a baseband HF simulator patterned after the Watterson Model in accordance with International Radio Consultative Committee (CCIR) 549-2. The modeled multipath spread values and fading (two sigma) bandwidth (BW) values in Table XII shall consist of two independent but equal average power Rayleigh paths. The specified values shown represent HF modem performance under ideal test conditions. To identify the minimum acceptable performance available to users, many factors, including operational test and evaluation, must be considered.

TABLE XI. Data phase waveform characteristics

Information rate	Coding rate	Channel rate	Bits/channel symbol	8-phase symbols/ channel symbol	No. of unknown 8-phase symbols	No. of known 8-phase symbols
4800	(no coding)	4800	3	1	32	16
2400	1/2	4800	3	1	32	16
1200	1/2	2400	2	1	20	20
600	1/2	1200	1	1	20	20
300	1/4	1200	1	1	20	20
150	1/8	1200	1	1	20	20
75	1/2	150	2	32	all	0

TABLE XII. Serial (single-tone) mode minimum performance.

User bit rate	Channel paths	Multipath (ms)	Fading BW (Hz) [1]	SNR (dB) [2]	Coded BER
4800	1 Fixed	-	-	17	1.0×10^{-3}
4800	2 Fading	2	0.5	27	1.0×10^{-3}
2400	1 Fixed	-	-	10	1.0×10^{-5}
2400	2 Fading	2	1	18	1.0×10^{-5}
2400	2 Fading	2	5	30	1.0×10^{-3}
2400	2 Fading	5	1	30	1.0×10^{-5}
1200	2 Fading	2	1	11	1.0×10^{-5}
600	2 Fading	2	1	7	1.0×10^{-5}
300	2 Fading	5	5	7	1.0×10^{-5}
150	2 Fading	5	5	5	1.0×10^{-5}
75	2 Fading	5	5	2	1.0×10^{-5}

NOTES:
1. Per CCIR 549-2
2. Both signal and noise powers are measured in a 3-kHz bandwidth

FS-1052: Appendix A

APPENDIX A
39-TONE PARALLEL MODE

10. GENERAL.

10.1 Scope. This appendix describes the 39-tone parallel mode.

10.2 Applicability. This appendix is a nonmandatory part of FED-STD-1052; however, when the optional 39-tone parallel mode is used, it shall be implemented in accordance with this appendix.

20. APPLICABLE DOCUMENTS. See section 2.

30. DEFINITIONS. See section 3.

40. GENERAL REQUIREMENTS. The mode specified herein uses 39 orthogonal subcarrier tones in the audio frequency band with quadrature differential phase-shift keying (QDPSK) modulation for bit-synchronous data transmission. In the transmit direction, this mode (see Fig. 7);

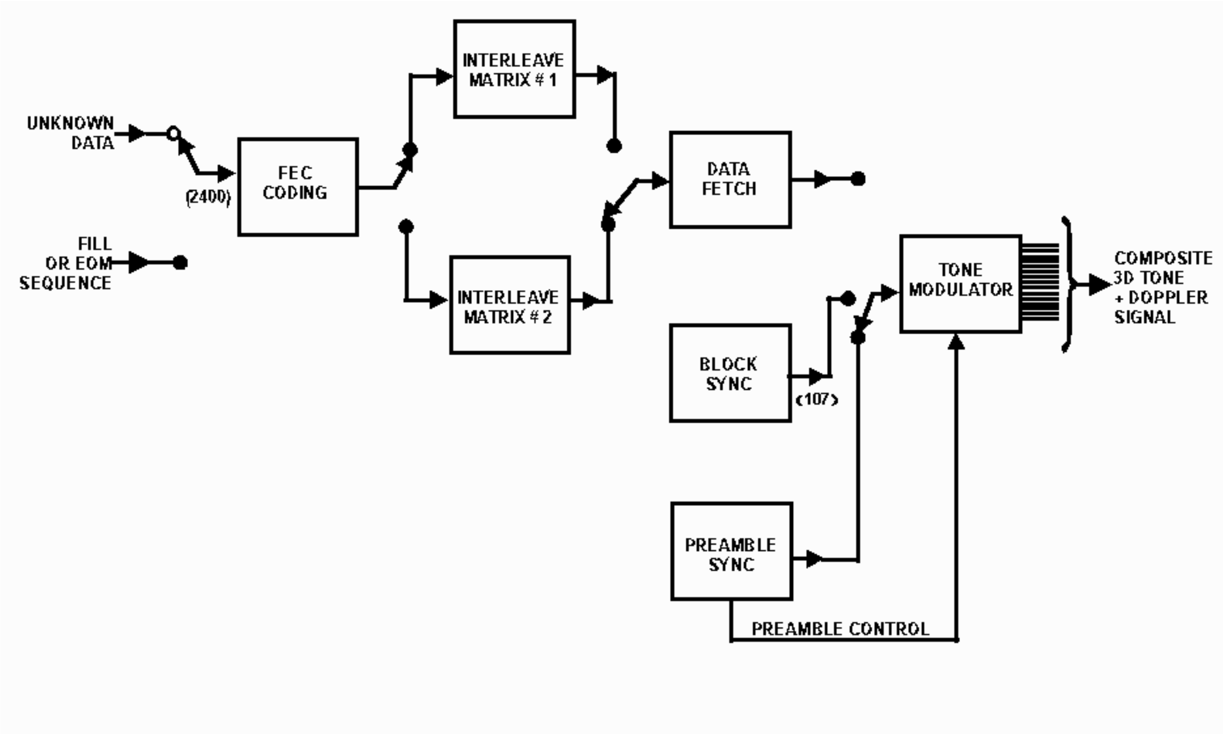


Figure 7. Transmit direction functional diagram

a. accepts UNKNOWN serial binary data at its line-side data input port,
b. performs forward error correction (FEC) encoding and interleaving, and
c. converts the resulting coded serial bit stream into QDPSK data tones at the modulator output port.

The modulation rate of the modulator output is constant for all data rates. In-band diversity of varying degrees is used at data rates below 1200 bits per second (b/s). A means is provided for synchronization of the signal element and interleaved data block timing. A 40th unmodulated tone is used for correcting frequency offsets introduced by doppler shift or radio equipment instability. In a like manner, the receive direction;

a. accepts QDPSK data tones at its demodulator input port,
b. converts them back into the transmitted coded serial bit stream,
c. performs deinterleaving and FEC decoding, and
d. makes the resulting serial binary data stream available at its line-side output port.

Figure 7. Transmit direction functional diagram

50. DETAILED REQUIREMENTS.

50.1 Characteristics. In this section, detailed requirements are given for the waveform characteristics for which knowledge is needed to achieve over-the-air interoperability. These characteristics are error-correction coding, interleaving, synchronization, modulator output signal, in-band time/frequency diversity, and asynchronous data operation.

50.2 Error-correcting coding. All UNKNOWN input data shall have redundant bits added to it, prior to modulation, for the purpose of correcting errors introduced by the transmission medium. The added bits shall be computed by a shortened Reed-Solomon (15,11) block code, whose generator polynomial is:

$$g(x) = x^4 + a^{13}x^3 + a^6x^2 + a^3x + a^{10};$$

where a is a nonzero element of the Galois field (GF)(2^4) formed as the field of polynomials over GF(2) modulo $x^4 + x + 1$.

For input signaling rates of 2400 b/s, the code shall be shortened to (14,10). Otherwise, the code shall be shortened to (7,3).

50.3 Interleaving. The mode shall perform block interleaving for the purpose of providing time separation between contiguous symbols of a code word. Selectable interleaving degrees for the data rates as shown in Table XIII shall be provided. For a data signaling rate of 2400 b/s, the selection shall consist of eight degrees. At data signaling rates below 2400 b/s, four degrees for each bit rate shall be provided as shown in Table XIII. The input data stream shall be loaded into the interleaver buffer as described by figures 8 and 9.

TABLE XIII. Selectable interleaving degrees

Data rate (b/s)	75	150	300	600	1200	2400	
Interleaving Degree	1	1	1	1	1	1	1
	4	9	17	33	63	9	72
	12	25	47	99	189	18	144
	36	81	153	297	567	27	288

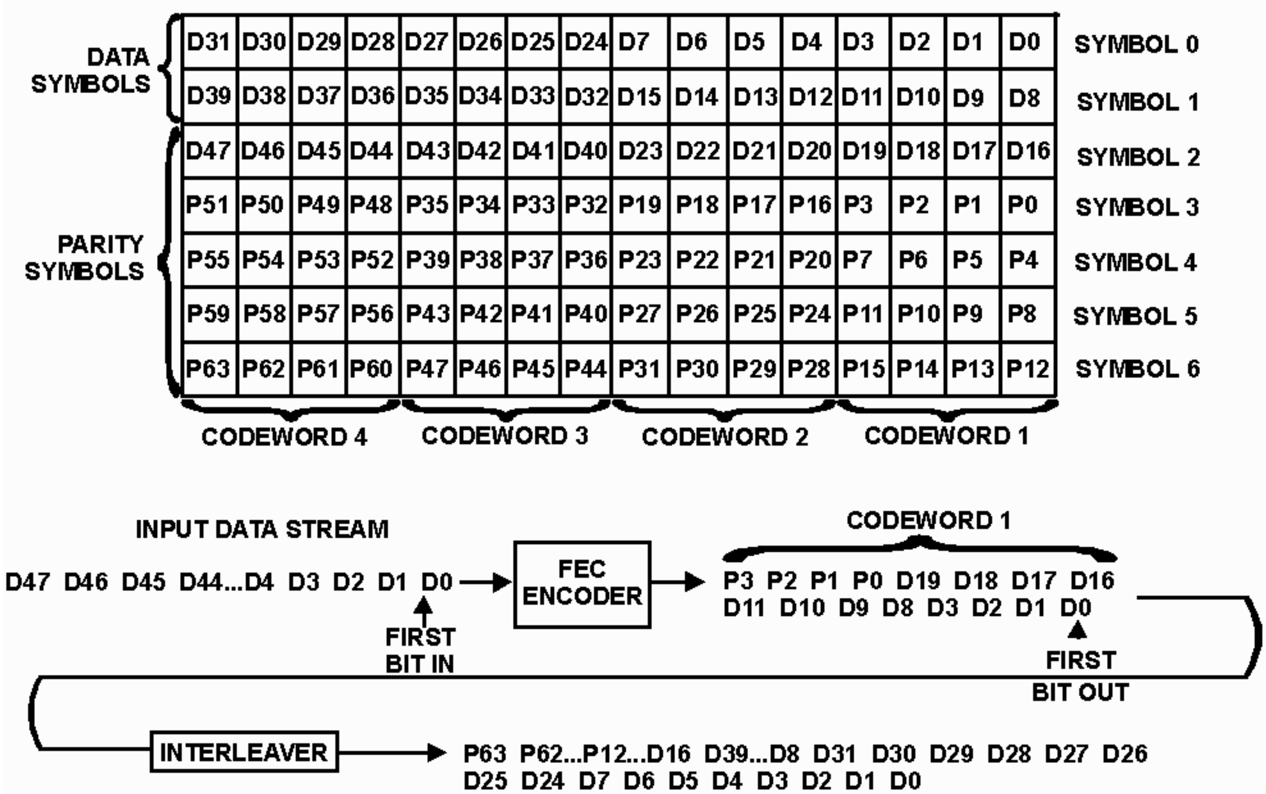


Figure 8. Data flow through encoder and interleaver for an interleaver containing an even number of code words

Figure 8. Data flow through encoder and interleaver for an interleaver containing an even number of code words

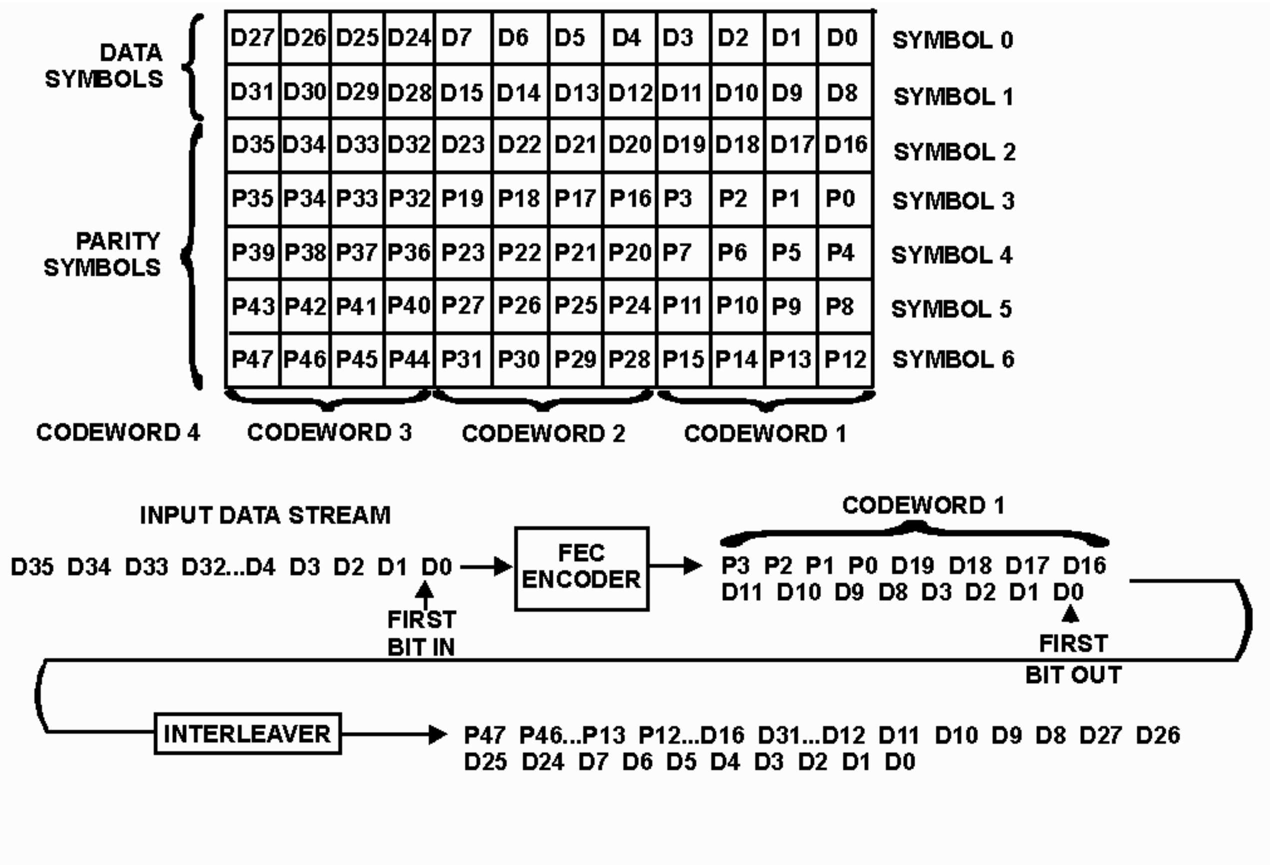


Figure 9. Data flow through encoder and interleaver for an interleaver containing an odd number of code words

Figure 9. Data flow through encoder and interleaver for an interleaver containing an odd number of code words

50.4 Synchronization. A means shall be provided whereby the receive demodulator process achieves time alignment with both signal element and code-word timing. Frame synchronization shall be acquired within 680 milliseconds (ms). The transmit sequence of events is shown on Figure 10.

50.4.1 Preamble. Prior to the transmission of data, a three-part preamble shall be transmitted. Part one shall last for 14 signal-element periods and consist of four equal-amplitude unmodulated data tones of 787.5, 1462.5, 2137.5, and 2812.5 hertz (Hz). Part two shall last for 8 signal-element periods and consist of three modulated data tones of 1125.0, 1800.0, and 2475.0 Hz. The three data tones of part two shall be advanced 180 degrees at the boundary of each data signal element. Part three shall last for one signal-element period and consist of all 39 data tones plus the doppler correction tone. This last part establishes the starting phase reference for subsequent signal-element periods. During all parts of the preamble, the transmitted level of the composite signals shall have a root-mean-square (rms) value within ±1 decibel (dB) of the rms value of the modulator output (39-tone) levels occurring during subsequent data transmission. The tone phases at the onset of each part of the preamble, along with their normalized amplitudes, shall be in accordance with Table XIV.

50.4.2 Extended preamble. To improve the probability of synchronization and signal presence detection in low signal-to-noise ratio situations, the ability to select an extended preamble shall be provided. Part one of the extended preamble shall last for 58 signal-element periods, part two shall last for 27 signal-element periods, and part three shall last for 12 signal-element periods. In parts one and two, the data tones shall be as described in the nonextended preamble given above. In part three, the phase of each data tone shall be set at the onset of each signal element to the phase that it had at the onset of the first signal element in this part.

NOTE: When operating with the extended preamble, the minimum doppler correction shall be ±20 Hz and frame synchronization shall be acquired within 2.5 seconds (s).

50.4.3 Data block synchronization. A set of interleaved code words is known as a super block. Block synchronization (framing) is the process whereby a receiving demodulator locates super block boundaries. This synchronization process must occur before proper deinterleaving and decoding can commence. Framing shall be established and maintained by periodically inserting into the encoded unknown data bit stream a known pseudorandom sequence. The required sequence is defined by the primitive polynomial,

$$f(x) = x^9 + x^7 + x^6 + x^4 + 1,$$

when used in the feedback shift register configuration shown in Figure 11. The first insertion of the block framing sequence shall start on the first signal element following the synchronization preamble. Upon transmission of the last bit of the sequence, the first bit of the first super block shall be transmitted without interruption. Thereafter, the framing sequence shall be inserted each time the number of super blocks specified in Table XV has been transmitted. Upon transmission of the last bit of the framing sequence, transmission of data bits shall resume without interruption. The number of framing bits to be transmitted per insertion varies with data rate and interleaving degree, and is specified in Table XV. However, the final bit of the framing sequence shall always be the first SPACE bit which follows a contiguous block of nine MARK bits. Equivalently, the final sequence bit shall be the bit generated by the shift register when its present state is 111111111 (binary) or 511 (decimal).

Figure 10. Transmit sequence of events

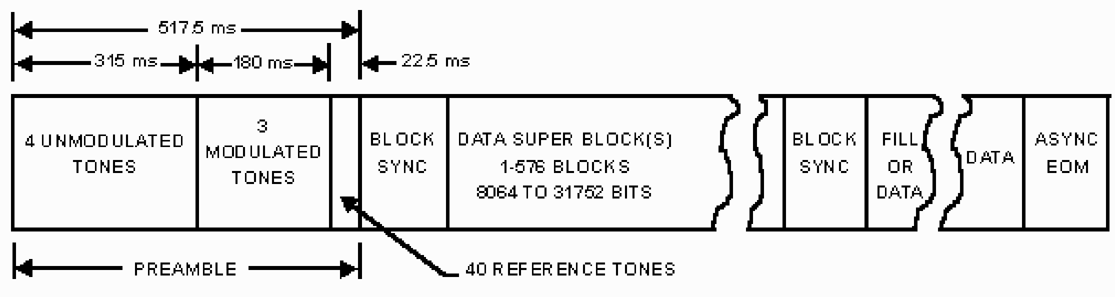


Figure 10. Transmit sequence of events

TABLE XIV. Tone set application, amplitude, and phase

Preamble part number	Tone freq (Hz)	Function	Normalized amplitude	Initial phase (degrees)
1	787.50	Data tone 3	3	0.0
1	1462.50	Data tone 15	3	103.7
1	2137.50	Data tone 27	3	103.7
1	2812.50	Data tone 39	3	0.0
2	1125.00	Data tone 9	4	0.0
2	1800.00	Data tone 21	4	90.0
2	2475.00	Data tone 33	4	0.0
3	393.75	Doppler	2	0.0
3	675.00	Data tone 1	1	0.0
3	731.25	Data tone 2	1	5.6
3	787.50	Data tone 3	1	19.7
3	843.75	Data tone 4	1	42.2

3	900.00	Data tone 5	1	73.1
3	956.25	Data tone 6	1	115.3
3	1012.50	Data tone 7	1	165.9
3	1068.75	Data tone 8	1	225.0
3	1125.00	Data tone 9	1	295.3
3	1181.25	Data tone 10	1	14.1
3	1237.50	Data tone 11	1	101.3
3	1293.75	Data tone 12	1	199.7
3	1350.00	Data tone 13	1	303.8
3	1406.25	Data tone 14	1	59.1
3	1462.50	Data tone 15	1	185.6
3	1518.75	Data tone 16	1	317.8
3	1575.00	Data tone 17	1	101.3
3	1631.25	Data tone 18	1	253.1
3	1687.50	Data tone 19	1	56.3
3	1743.75	Data tone 20	1	225.0
3	1800.00	Data tone 21	1	45.0
3	1856.25	Data tone 22	1	236.3
3	1912.50	Data tone	1	73.1

		23		
3	1968.75	Data tone 24	1	281.3
3	2025.00	Data tone 25	1	137.8
3	2081.25	Data tone 26	1	5.6
3	2137.50	Data tone 27	1	239.1
3	2193.75	Data tone 28	1	123.8
3	2250.00	Data tone 29	1	19.7
3	2306.25	Data tone 30	1	281.3
3	2362.50	Data tone 31	1	194.1
3	2418.75	Data tone 32	1	115.3
3	2475.00	Data tone 33	1	45.0
3	2531.25	Data tone 34	1	345.9
3	2587.50	Data tone 35	1	295.3
3	2643.75	Data tone 36	1	253.1
3	2700.00	Data tone 37	1	222.2
3	2756.25	Data tone 38	1	199.7
3	2812.50	Data tone 39	1	185.6

Figure 11. Framing sequence feedback shift register generator

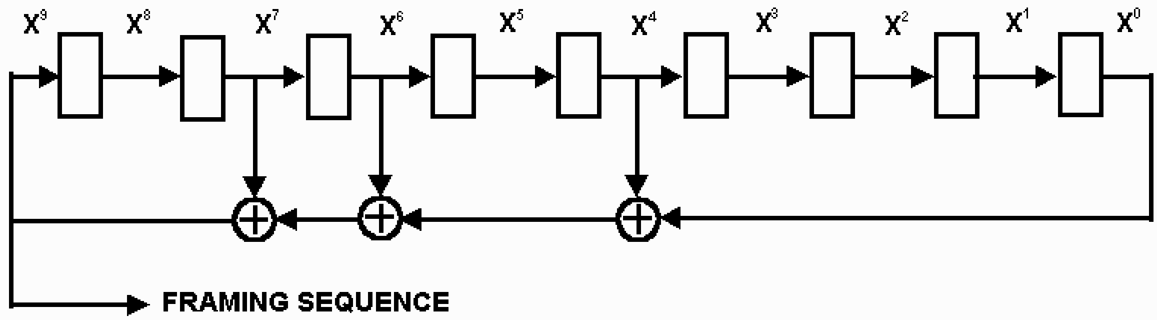


Figure 11. Framing sequence feedback shift register generator

50.5 Modulator output signal. The modulator output shall contain 39-QDPSK data tones (see Table XVI). The 39 data tones shall be simultaneously keyed to produce a signal-element interval of 22.5 ms for each data tone. The composite modulator output shall have a constant modulation rate of 44.44 baud (Bd) for all standard input data signaling rates from 75 to 2400 b/s. At input signaling rates less than 2400 b/s, information carried on data tones 1 through 7 shall also be carried on data tones 33 through 39. The modulator shall also provide the required special preamble tone combinations used to initiate synchronization and doppler correction. During data transmission, the unmodulated doppler correction tone shall be 6 dB (±1 dB) higher than the normal level of any data tone. All tone frequencies shall maintain an accuracy of ±0.05 Hz. At the onset of each signal element, every data tone shall experience a phase change relative to its phase at the onset of the previous signal element. The modulator shall partition the bit stream to be transmitted into 2-bit symbols (dibits) and map them into a phase change of the appropriate data tone according to Table XVII.

50.6 In-band diversity. Two selectable methods of in-band diversity for data rates of 75-600 b/s shall be incorporated in each modem as follows: a modern method containing both time and frequency diversity, and a frequency-only diversity method for backward compatibility with older modems. The requirements given for these methods in the following subparagraphs apply to diversities of order d, where d = 1200/(data signaling rate).

50.6.1 Time/frequency diversity. Disregarding the redundant data carried on data tones 33 through 39, 64 bits, equally partitioned into d data words, shall be transmitted during each 22.5-ms signal element. Each data word and its d-1 copies shall be transmitted on 32/d unique data tones in d different signal elements. If data word i is being transmitted in a given signal element, the other data words that are to be transmitted in the same signal element are given by i - k(16/d), where k ranges from 1 through d-1 (see Table XVIII).

50.6.2 Frequency diversity. In-band diversity shall be characterized by transmitting a data word and its (d-l) copies in one signal element (e.g., 22.5-ms time interval). This characterization is according to the tone/bit assignments shown in Table XIX.

TABLE XV. Framing sequence insertion intervals and lengths

Data rate (b/s)	Interleaving degree	Insertion interval		Sequence length (bits)
		(super blocks)	(bits)	
75	1	567	15876	252
75	4	234	26208	416
75	12	75	25200	400
75	36	16	16128	256
150	1	576	16128	256
150	9	100	25200	400
150	25	36	25200	400
150	81	8	18144	288
300	1	567	15876	252
300	17	54	25704	408
300	47	18	23688	376
300	153	4	17136	272
600	1	567	15876	252
600	33	30	27720	440
600	99	10	27720	440
600	297	2	16632	264
1200	1	567	15876	252
1200	63	14	24696	392
1200	189	6	31752	504
1200	567	1	15876	252
2400	1	144	8064	256

2400	9	16	8064	256
2400	18	12	12096	384
2400	27	9	13608	432
2400	36	7	14112	448
2400	72	3	12096	384
2400	144	1	8064	256
2400	288	1	16128	512
NOTE: Insertion interval does not include framing sequence bits.				

TABLE XVI. Data-tone frequencies and bit locations

Tone freq (Hz)	Function	Bit Locations			
		2400 b/s		1200 b/s	
393.75	Continuous Doppler				
675.00	Data tone 1	1	2	1	2
731.25	Data tone 2	3	4	3	4
787.50	Data tone 3	5	6	5	6
843.75	Data tone 4	7	8	7	8
900.00	Data tone 5	9	10	9	10
956.25	Data tone 6	11	12	11	12
1012.50	Data tone 7	13	14	13	14
1068.75	Data tone 8	15	16	15	16
1125.00	Data tone 9	17	18	17	18
1181.25	Data tone 10	19	20	19	20
1237.50	Data tone 11	21	22	21	22
1293.75	Data tone 12	23	24	23	24
1350.00	Data tone 13	25	26	25	26
1406.25	Data tone 14	27	28	27	28

1462.50	Data tone 15	29	30	29	30
1518.75	Data tone 16	31	32	31	32
1575.00	Data tone 17	33	34	33	34
1631.25	Data tone 18	35	36	35	36
1687.50	Data tone 19	37	38	37	38
1743.75	Data tone 20	39	40	39	40
1800.00	Data tone 21	41	42	41	42
1856.25	Data tone 22	43	44	43	44
1912.50	Data tone 23	45	46	45	46
1968.75	Data tone 24	47	48	47	48
2025.00	Data tone 25	49	50	49	50
2081.25	Data tone 26	51	52	51	52
2137.50	Data tone 27	53	54	53	54
2193.75	Data tone 28	55	56	55	56
2250.00	Data tone 29	57	58	57	58
2306.25	Data tone 30	59	60	59	60
2362.50	Data tone 31	61	62	61	62
2418.75	Data tone 32	63	64	63	64
2475.00	Data tone 33	65	66	1	2
2531.25	Data tone 34	67	68	3	4
2587.50	Data tone 35	69	70	5	6
2643.75	Data tone 36	71	72	7	8
2700.00	Data tone 37	73	74	9	10
2756.25	Data tone 38	75	76	11	12
2812.50	Data tone 39	77	78	13	14

TABLE XVII. Modulation characteristics of the 39-tone HF modem

Logic sense of dibits		Phase change (degrees)
Later bit	Earlier bit	
MARK (1)	SPACE (0)	+45
SPACE (0)	SPACE (0)	+135
SPACE (0)	MARK (1)	+225
MARK (1)	MARK (1)	+315

50.7 Asynchronous data operation. In addition to bit-synchronous data transmission, an asynchronous mode shall also be supported. When operating in the asynchronous mode, the modulator shall accept source data in asynchronous start/stop character format, convert it to bit synchronous data, and replace the start, stop, and parity bits with SPACE bits prior to FEC encoding. Conversely, after FEC decoding, the demodulator shall restore the converted bit synchronous data back into asynchronous format and re-generate the start, stop, and parity bits before placing the characters in the output data stream. Otherwise, the mode operates as specified in pars. 50.1 through 50.6 above.

50.7.1 Character length. A means shall be provided whereby the modulator will accept, and the demodulator will generate, any of the data characters shown in Table XX.

50.7.2 Data signaling rate constraint. A means shall be provided whereby the selected data signaling rate of the modem is constrained to not exceed the nominal bit rate of the data input source.

50.7.3 Data-rate adjustment. A means shall be provided whereby differences between data signaling rates of the data input source and the modem are accommodated with no loss of data or introduction of extraneous data in the demodulated output.

50.7.3.1 Input data source rate greater than modem rate. The modem shall maintain a control path to the data source for the purpose of stopping the flow of data into the modulator. When the modem senses that continued flow of input data will result in data loss, it shall cause the data source to suspend the transfer of data. Upon sensing that the threat of data loss has passed, the modem shall allow the transfer of data to resume.

TABLE XVIII. In-band time/frequency diversity

Tone no.	600 b/s	Data word	300 b/s	Data word	150 b/s	Data word	75 b/s	Data word
1	1 2		1 2		1 2		1 2	i
2	3 4		3 4		3 4	i	3 4	
3	5 6		5 6		5 6		1 2	i-1

4	7 8		7 8	i	7 8		3 4	
5	9 10		9 10		1 2		1 2	i-2
6	11 12		11 12		3 4	i-2	3 4	
7	13 14		13 14		5 6		1 2	i-3
8	15 16	i	15 16		7 8		3 4	
9	17 18		1 2		1 2		1 2	i-4
10	19 20		3 4		3 4	i-4	3 4	
11	21 22		5 6		5 6		1 2	i-5
12	23 24		7 8	i-4	7 8		3 4	
13	25 26		9 10		1 2		1 2	i-6
14	27 28		11 12		3 4	i-6	3 4	
15	29 30		13 14		5 6		1 2	i-7
16	31 32		15 16		7 8		3 4	
17	1 2		1 2		1 2		1 2	i-8
18	3 4		3 4		3 4	i-8	3 4	
19	5 6		5 6		5 6		1 2	i-9
20	7 8		7 8	i-8	7 8		3 4	
21	9 10		9 10		1 2		1 2	i-10
22	11 12		11 12		3 4	i-10	3 4	
23	13 14		13 14		5 6		1 2	i-11
24	15 16	i-8	15 16		7 8		3 4	
25	17 18		1 2		1 2		1 2	i-12
26	19 20		3 4		3 4	i-12	3 4	
27	21 22		5 6		5 6		1 2	i-13
28	23 24		7 8	i-12	7 8		3 4	
29	25 26		9 10		1 2		1 2	i-14

30	27 28		11 12		3 4	i-14	3 4	
31	29 30		13 14		5 6		1 2	i-15
32	31 32		15 16		7 8		3 4	
33	1 2		1 2		1 2		1 2	i
34	3 4		3 4		3 4	i	3 4	
35	5 6		5 6		5 6		1 2	i-1
36	7 8	i	7 8	i	7 8		3 4	
37	9 10		9 10		1 2		1 2	i-2
38	11 12		11 12		3 4	i-2	3 4	
39	13 14		13 14		5 6		1 2	i-3

TABLE XIX. In-band frequency diversity

Tone freq (Hz)	Function	600 b/s	300 b/s	150 b/s	75 b/s
393.75	Continuous doppler				
675.00	Data tone 1	1 2	1 2	1 2	1 2
731.25	Data tone 2	3 4	3 4	3 4	3 4
787.50	Data tone 3	5 6	5 6	5 6	1 2
843.75	Data tone 4	7 8	7 8	7 8	3 4
900.00	Data tone 5	9 10	9 10	1 2	1 2
956.25	Data tone 6	11 12	11 12	3 4	3 4
1012.50	Data tone 7	13 14	13 14	5 6	1 2
1068.75	Data tone 8	15 16	15 16	7 8	3 4
1125.00	Data tone 9	17 18	1 2	1 2	1 2
1181.25	Data tone 10	19 20	3 4	3 4	3 4
1237.50	Data tone 11	21 22	5 6	5 6	1 2
1293.75	Data tone 12	23 24	7 8	7 8	3 4
1350.00	Data tone 13	25 26	9 10	1 2	1 2

1406.25	Data tone 14	27 28	11 12	3 4	3 4
1462.50	Data tone 15	29 30	13 14	5 6	1 2
1518.75	Data tone 16	31 32	15 16	7 8	3 4
1575.00	Data tone 17	1 2	1 2	1 2	1 2
1631.25	Data tone 18	3 4	3 4	3 4	3 4
1687.50	Data tone 19	5 6	5 6	5 6	1 2
1743.75	Data tone 20	7 8	7 8	7 8	3 4
1800.00	Data tone 21	9 10	9 10	1 2	1 2
1856.25	Data tone 22	11 12	11 12	3 4	3 4
1912.50	Data tone 23	13 14	13 14	5 6	1 2
1968.75	Data tone 24	15 16	15 16	7 8	3 4
2025.00	Data tone 25	17 18	1 2	1 2	1 2
2081.25	Data tone 26	19 20	3 4	3 4	3 4
2137.50	Data tone 27	21 22	5 6	5 6	1 2
2193.75	Data tone 28	23 24	7 8	7 8	3 4
2250.00	Data tone 29	25 26	9 10	1 2	1 2
2306.25	Data tone 30	27 28	11 12	3 4	3 4
2362.50	Data tone 31	29 30	13 14	5 6	1 2
2418.75	Data tone 32	31 32	15 16	7 8	3 4
2475.00	Data tone 33	1 2	1 2	1 2	1 2
2531.25	Data tone 34	3 4	3 4	3 4	3 4
2587.50	Data tone 35	5 6	5 6	5 6	1 2
2643.75	Data tone 36	7 8	7 8	7 8	3 4
2700.00	Data tone 37	9 10	9 10	1 2	1 2
2756.25	Data tone 38	11 12	11 12	3 4	3 4
2812.50	Data tone 39	13 14	13 14	5 6	1 2

TABLE XX. Asynchronous character set

Nr. of bits	Character bit designation and location											
	1	2	3	4	5	6	7	8	9	10	11	12
7	Start	Data	Data	Data	Data	Data	Stop					
8	Start	Data	Data	Data	Data	Data	+Par	Stop				
8	Start	Data	Data	Data	Data	Data	-Par	Stop				
8	Start	Data	Data	Data	Data	Data	Stop	Stop				
8	Start	Data	Data	Data	Data	Data	Data	Stop				
9	Start	Data	Data	Data	Data	Data	+Par	Stop	Stop			
9	Start	Data	Data	Data	Data	Data	-Par	Stop	Stop			
9	Start	Data	Data	Data	Data	Data	Data	+Par	Stop			
9	Start	Data	Data	Data	Data	Data	Data	-Par	Stop			
9	Start	Data	Data	Data	Data	Data	Data	Stop	Stop			
9	Start	Data	Data	Data	Data	Data	Data	Data	Stop			
10	Start	Data	Data	Data	Data	Data	Data	+Par	Stop	Stop		
10	Start	Data	Data	Data	Data	Data	Data	-Par	Stop	Stop		
10	Start	Data	Data	Data	Data	Data	Data	Data	+Par	Stop		
10	Start	Data	Data	Data	Data	Data	Data	Data	-Par	Stop		
10	Start	Data	Data	Data	Data	Data	Data	Data	Stop	Stop		
10	Start	Data	Data	Data	Data	Data	Data	Data	Data	Stop		
11	Start	Data	Data	Data	Data	Data	Data	Data	+Par	Stop	Stop	
11	Start	Data	Data	Data	Data	Data	Data	Data	-Par	Stop	Stop	
11	Start	Data	Data	Data	Data	Data	Data	Data	Data	+Par	Stop	
11	Start	Data	Data	Data	Data	Data	Data	Data	Data	-Par	Stop	
11	Start	Data	Data	Data	Data	Data	Data	Data	Data	Stop	Stop	
12	Start	Data	Data	Data	Data	Data	Data	Data	Data	+Par	Stop	Stop
12	Start	Data	Data	Data	Data	Data	Data	Data	Data	-Par	Stop	Stop

NOTE: +Par = Positive parity, -Par = Negative parity

50.7.3.2 Input data source rate less than modem rate. When the modem senses that it is about to exhaust its supply of source data, it shall insert a special "null" character into the source data bit stream prior to encoding. The null character shall be formed by making each of its bits a SPACE, and the start, stop, and parity bits a MARK. The demodulator shall recognize this bit pattern as a null character, and discard it from its data output.

50.7.4 End-of-message (EOM) indication. Upon reception of the source's final data character, the modulator shall insert a series of EOM characters into the source data bit stream prior to encoding. The EOM character shall be formed by making each of its bits a MARK. The number of EOM characters inserted shall range from a minimum of ten to the number greater than ten required to fill a super block. The demodulator shall use the arrival of the EOM characters to terminate its data output.

50.7.5 Asynchronous mode interleaving and block framing. The degree of interleaving and the framing sequence length used in the asynchronous mode vary with data signaling rate and character length. With each data rate and character length, four selectable interleaving degrees shall be provided as shown in tables XXI thru XXVI, along with the corresponding framing sequence length.

50.7.6 Bit packing. An integral number of data characters shall be transmitted between framing sequence transmissions. Therefore, the number of bits encoded will not always equal the number of bits received from the data source. In such cases, the modulator shall insert into the source data a number of fill bits equal to the difference between the number of bits encoded and the number of bits received (see tables XXI thru XXVI). The fill bits shall be located in the bit stream so that they are the first bits encoded, thereby permitting the remainder of the data transmission to carry an integral number of data characters.

60. PERFORMANCE REQUIREMENTS. The minimum performance of the 39-tone mode employing soft-decision decoding and maximum interleaving, as measured using a baseband HF simulator patterned after the Watterson Model for channel simulation, shall be as shown in table XXVII.

TABLE XXI. 75-b/s asynchronous operational parameters

Data rate (b/s)	Char length (bits)	Interleaver degree	Super blocks	Nr. of bits encoded	Nr. of source bits	Fill bits	Seq nr. length (bits)
75	7	1	567	6804	6804	0	252
75	7	5	189	11340	11340	0	420
75	7	12	84	12096	12096	0	448

75	7	35	18	7560	7560	0	280
75	8	1	576	6912	6912	0	256
75	8	4	234	11232	11232	0	416
75	8	12	75	10800	10800	0	400
75	8	36	16	6912	6912	0	256
75	9	1	567	6804	6804	0	252
75	9	4	252	12096	12096	0	448
75	9	12	84	12096	12096	0	448
75	9	36	16	6912	6912	0	256
75	10	1	585	7020	7020	0	260
75	10	4	242	11616	11610	6	416
75	10	12	75	10800	10800	0	400
75	10	35	18	7560	7560	0	280
75	11	1	594	7128	7128	0	264
75	11	4	260	12480	12474	6	448
75	11	11	99	13068	13068	0	484
75	11	33	18	7128	7128	0	264
75	12	1	567	6804	6804	0	252
75	12	4	261	12528	12528	0	464
75	12	12	84	12096	12096	0	448
75	12	36	16	6912	6912	0	256

TABLE XXII. 150-b/s asynchronous operational parameters

Data rate (b/s)	Char length (bits)	Interleaver degree	Super blocks	Nr. of bits encoded	Nr. of source bits	Fill bits	Seq nr. length (bits)
150	7	1	567	6804	6804	0	252
150	7	9	112	12096	12096	0	448

150	7	27	35	11340	11340	0	420
150	7	81	7	6804	6804	0	252
150	8	1	576	6912	6912	0	256
150	8	9	100	10800	10800	0	400
150	8	25	36	10800	10800	0	400
150	8	81	8	7776	7776	0	288
150	9	1	567	6804	6804	0	252
150	9	9	112	12096	12096	0	448
150	9	25	38	11400	11394	6	408
150	9	81	7	6804	6804	0	252
150	10	1	585	7020	7020	0	260
150	10	9	110	11880	11880	0	440
150	10	25	36	10800	10800	0	400
150	10	75	9	8100	8100	0	300
150	11	1	594	7128	7128	0	264
150	11	9	110	11880	11880`	0	440
150	11	27	33	10692	10692	0	396
150	11	77	9	8316	8316	0	308
150	12	1	567	6804	6804	0	252
150	12	9	110	11880	11880	0	440
150	12	27	33	10692	10692	0	396
150	12	81	7	6804	6804	0	252

TABLE XXIII. 300-b/s asynchronous operational parameters

Data rate (b/s)	Char length (bits)	Interleaver degree	Super blocks	Nr. of bits encoded	Nr. of source bits	Fill bits	Seq nr. length (bits)
300	7	1	567	6804	6804	0	252

300	7	15	63	11340	11340	0	420
300	7	49	18	10584	10584	0	392
300	7	145	5	8700	8694	6	308
300	8	1	576	6912	6912	0	256
300	8	17	54	11016	11016	0	408
300	8	47	18	10152	10152	0	376
300	8	153	4	7344	7344	0	272
300	9	1	567	6804	6804	0	252
300	9	17	54	11016	11016	0	408
300	9	47	18	10152	10152	0	376
300	9	153	4	7344	7344	0	272
300	10	1	585	7020	7020	0	260
300	10	17	49	9996	9990	6	356
300	10	45	22	11880	11880	0	440
300	10	153	5	9180	9180	0	340
300	11	1	594	7128	7128	0	264
300	11	19	43	9804	9801	3	356
300	11	45	22	11880	11880	0	440
300	11	161	4	7728	7722	6	272
300	12	1	567	6804	6804	0	252
300	12	17	54	11016	11016	0	408
300	12	49	18	10584	10584	0	392
300	12	153	4	7344	7344	0	272

TABLE XXIV. 600-b/s asynchronous operational parameters

Data rate (b/s)	Char length (bits)	Interleaver degree	Super blocks	Nr. of bits encoded	Nr. of source bits	Fill bits	Seq nr. length (bits)

600	7	1	567	6804	6804	0	252
600	7	35	27	11340	11340	0	420
600	7	105	9	11340	11340	0	420
600	7	315	2	7560	7560	0	280
600	8	1	576	6912	6912	0	256
600	8	33	30	11880	11880	0	440
600	8	99	10	11880	11880	0	440
600	8	297	2	7128	7128	0	264
600	9	1	567	6804	6804	0	252
600	9	33	30	11880	11880	0	440
600	9	99	10	11880	11880	0	440
600	9	297	2	7128	7128	0	264
600	10	1	585	7020	7020	0	260
600	10	33	30	11880	11880	0	440
600	10	99	10	11880	11880	0	440
600	10	315	2	7560	7560	0	280
600	11	1	594	7128	7128	0	264
600	11	33	30	11880	11880	0	440
600	11	99	10	11880	11880	0	440
600	11	297	2	7128	7128	0	264
600	12	1	567	6804	6804	0	252
600	12	33	30	11880	11880	0	440
600	12	99	10	11880	11880	0	440
600	12	297	2	7128	7128	0	264

TABLE XXV. 1200-b/s asynchronous operational parameters

Data rate	Char length	Interleaver degree	Super blocks	Nr. of bits encoded	Nr. of source	Fill bits	Seq nr. length

(b/s)	(bits)				bits		(bits)
1200	7	1	567	6804	6804	0	252
1200	7	63	15	11340	11340	0	420
1200	7	189	6	13608	13608	0	504
1200	7	567	1	6804	6804	0	252
1200	8	1	576	6912	6912	0	256
1200	8	63	14	10584	10584	0	392
1200	8	189	6	13608	13608	0	504
1200	8	576	1	6912	6912	0	256
1200	9	1	567	6804	6804	0	252
1200	9	63	15	11340	11340	0	420
1200	9	189	6	13608	13608	0	504
1200	9	567	1	6804	6804	0	252
1200	10	1	585	7020	7020	0	260
1200	10	63	15	11340	11340	0	420
1200	10	195	6	14040	14040	0	520
1200	10	585	1	7020	7020	0	260
1200	11	1	594	7128	7128	0	264
1200	11	65	16	12480	12474	6	448
1200	11	203	5	12180	12177	3	444
1200	11	619	1	7428	7425	3	268
1200	12	1	567	6804	6804	0	252
1200	12	63	15	11340	11340	0	420
1200	12	189	6	13608	13608	0	504
1200	12	567	1	6804	6804	0	252

TABLE XXVI. 2400-b/s asynchronous operational parameters

Data rate (b/s)	Char length (bits)	Interleaver degree	Super blocks	Nr. of bits encoded	Nr. of source bits	Fill bits	Seq nr. length (bits)
2400	7	1	145	5800	5796	4	252
2400	7	36	7	10080	10080	0	448
2400	7	73	3	8760	8757	3	385
2400	7	282	1	11280	11277	3	497
2400	8	1	144	5760	5760	0	256
2400	8	36	7	10080	10080	0	448
2400	8	72	3	8640	8640	0	384
2400	8	288	1	11520	11520	0	512
2400	9	1	144	5760	5760	0	256
2400	9	36	7	10080	10080	0	448
2400	9	72	3	8640	8640	0	384
2400	9	288	1	11520	11520	0	512
2400	10	1	144	5760	5760	0	256
2400	10	36	7	10080	10080	0	448
2400	10	72	3	8640	8640	0	384
2400	10	288	1	11520	11520	0	512
2400	11	1	151	6040	6039	1	267
2400	11	33	9	11880	11880	0	528
2400	11	71	3	8520	8514	6	370
2400	11	297	1	11880	11880	0	528
2400	12	1	144	5760	5760	0	256
2400	12	36	7	10080	10080	0	448
2400	12	72	3	8640	8640	0	384
2400	12	288	1	11520	11520	0	512

TABLE XXVII. Probability of bit error vs signal-to-noise ratio

Signal-to-noise ratio (dB in 3-kHz bandwidth)	Probability of bit error	
	2400 b/s	1200 b/s
5	8.6×10^{-2}	6.4×10^{-2}
10	3.5×10^{-2}	4.4×10^{-3}
15	1.0×10^{-2}	3.4×10^{-4}
20	1.0×10^{-3}	9.0×10^{-6}
30	1.8×10^{-4}	2.7×10^{-6}
Signal-to-noise ratio (dB in 3-kHz bandwidth)	Probability of bit error	
	300 b/s	75 b/s
0	1.8×10^{-2}	4.4×10^{-4}
2	6.4×10^{-3}	5.0×10^{-5}
4	1.0×10^{-3}	1.0×10^{-6}
6	5.0×10^{-5}	1.0×10^{-6}
8	1.5×10^{-6}	1.0×10^{-6}
NOTE: Two independent equal average-power Rayleigh fading paths, with 2-Hz fading bandwidth and 2-ms multipath spread.		

FS-1052: Appendix B

APPENDIX B
DATA LINK PROTOCOL

10. GENERAL.

10.1 Scope. This appendix describes the characteristics, interoperability requirements and performance requirements of the FED-STD-1052 data link protocol (DLP). The DLP supports a data link layer protocol as defined by the International Organization for Standardization (ISO) network reference model. This protocol, when used in conjunction with an appropriate modem, provides a method for transmitting error-free data over an HF radio circuit.

10.2 Applicability. This appendix is a nonmandatory part of FED-STD-1052, however, when the optional data link protocol is used, it shall be implemented in accordance with this appendix.

20. APPLICABLE DOCUMENTS. See section 2.

30. DEFINITIONS. See section 3 and definitions below.

30.1 Terms. When used in this appendix, the following terms have the meanings indicated.

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

becomes the transmit terminal. Note: this terminal is not necessarily the same as the "Destination" (user).

- **Transmit terminal:** The terminal sending the herald and data frames. When the link is reversed, this becomes the receive terminal. Note: this terminal is not necessarily the same as the "Source" (user)

30.2 Abbreviations and acronyms. (Not defined in section 3).

- **DLP:** data link protocol
- **MDP:** message delivery protocol
- **p/o:** part of

40. GENERAL REQUIREMENTS.

40.1 Modes. The DLP, defined in this appendix, provides three (one has two forms) modes of operation. These provide a variety of data transfer methods intended to meet the requirements of most data transfer applications over the HF channel. Although the DLP has been optimized for operation with the FED-STD-1052 serial (single-tone) waveform, it has been designed to operate with any arbitrary modem waveform. The modes within this DLP are designed to provide a wide range of performance with varying degrees of implementational complexity.

40.1.1 ARQ mode. The primary mode of operation (mandatory) is the automatic repeat request (ARQ) mode, which provides for error-free point-to-point data transfer. One alternative of this mode uses fixed-length control frames and a minimum of link reversals. The other alternative provides additional functionality and flexibility by employing variable length control frames. Both alternatives employ a control frame acknowledgment scheme.

40.1.2 Broadcast mode. A secondary mode of operation (mandatory) is the Broadcast (non-ARQ) mode. The Broadcast mode allows unidirectional data transfer using fixed-length frames to multiple (as well as to single) receivers. No transmissions from the receiving terminal are desired or required. See par. 50.4.3.2.

40.1.3 Circuit mode. The other secondary mode, the Circuit mode (optional), allows a link to be established and maintained in the absence of traffic. The ARQ variable-length frame protocol is used along with a technique to maintain the data link connection in the absence of user data. See par. 50.4.3.3.

40.2 Implementation. The protocol modes defined in this appendix are nonmandatory modes of FED-STD-1052. However, all terminals (message processors) that provide the DLP shall, as a minimum, fully implement the ARQ mode and the Broadcast mode. The Circuit mode is optional in all terminals.

40.3 Functionality.

40.3.1 Open Systems Interconnection (OSI) compatibility. The DLP provides the functionality required to support a data link service defined in ISO/IEC 8886.3. The DLP defined in this appendix does not provide this service directly.

40.3.2 Physical circuit. Implementations of the DLP shall operate over both simplex and duplex physical circuits. The DLP was developed for the serial (single-tone) waveform described in sec. 5.4, but is usable over other physical circuits as well.

40.3.3 Priority. The DLP provides a means for users to unambiguously resolve the relative priority of messages and transfer higher priority messages before transferring lower priority messages. The DLP allows two users to transfer messages of equal priority in both directions over either simplex or duplex links on an equal basis (see pars. 50.1.6.6 and 50.4.1.4).

40.3.4 Preemption. The DLP provides mechanisms for preemption (in either the forward or reverse direction) of a lower-priority message to transfer a higher-priority message (mandatory), and the resumption of the transfer of the lower-priority message after the complete transfer of the higher-priority message (optional). The protocol provides a means for the receive terminal to specify the resumption point within the preempted message, or to request complete retransmission if the preemption resulted in the disposal of the preempted message (see sec. 50.4.1.5).

40.3.5 Flow control. The FED-STD-1052 message delivery protocol (MDP) provides a method for the receive terminal to control the rate at which the transmit terminal sends the messages. The MDP allows the receive terminal to suspend transfer of messages from the transmit terminal for an indefinite period of time and resume transfer from an arbitrary position in the interrupted message (see pars. 50.1.4.2.1.2 and 50.4.3.1.4).

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

40.3.7 Synchronization. The MDP provides a method of ensuring that the terminals are in compatible states prior to attempting the transfer of data, a means for the terminals to be returned to a defined state, and synchronization of the activities of the two terminals (see sec. 50.4.2).

40.3.8 Order of transmission. Data and control fields shall be transmitted least-significant bit (LSB) first in all cases. Control fields that contain multi-byte data, such as addresses, shall be transmitted least-significant byte first. User data bytes shall be sent in the order received from the user (or higher-layer protocol). In this standard, bit and byte sequences are shown with the most significant bit (MSB) to the left and the LSB to the right, unless otherwise noted.

50. DETAILED REQUIREMENTS.

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

50.1.1 General frame format. The MDP frame format shall be as shown on figure 12.

50.1.1.1 Frame sync pattern. Each new transmission over the physical channel shall begin with a three byte (24-bit) frame synchronization pattern to identify the following traffic as DLP processed traffic. The frame synchronization sequence in hexadecimal format, shall be "**5C5C5C**". The sync pattern shall be transmitted such that the first eight bits in order of transmission are "00111010". Note: As shown here in transmission sequence, the left-most bits are the LSBs. If a transmission contains more than one frame, a two-byte sync sequence shall be inserted between each pair of adjacent frames. This pattern (hexadecimal) shall be "**5C5C**".

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

50.1.1.3 Frame Type bit. In each frame, the bit following the Sync Mismatch Bit shall be the Frame Type indicator bit. This bit shall be set to logic Ø to indicate that the current frame is a data frame, or set to logic 1 to indicate that the current frame is a control frame.

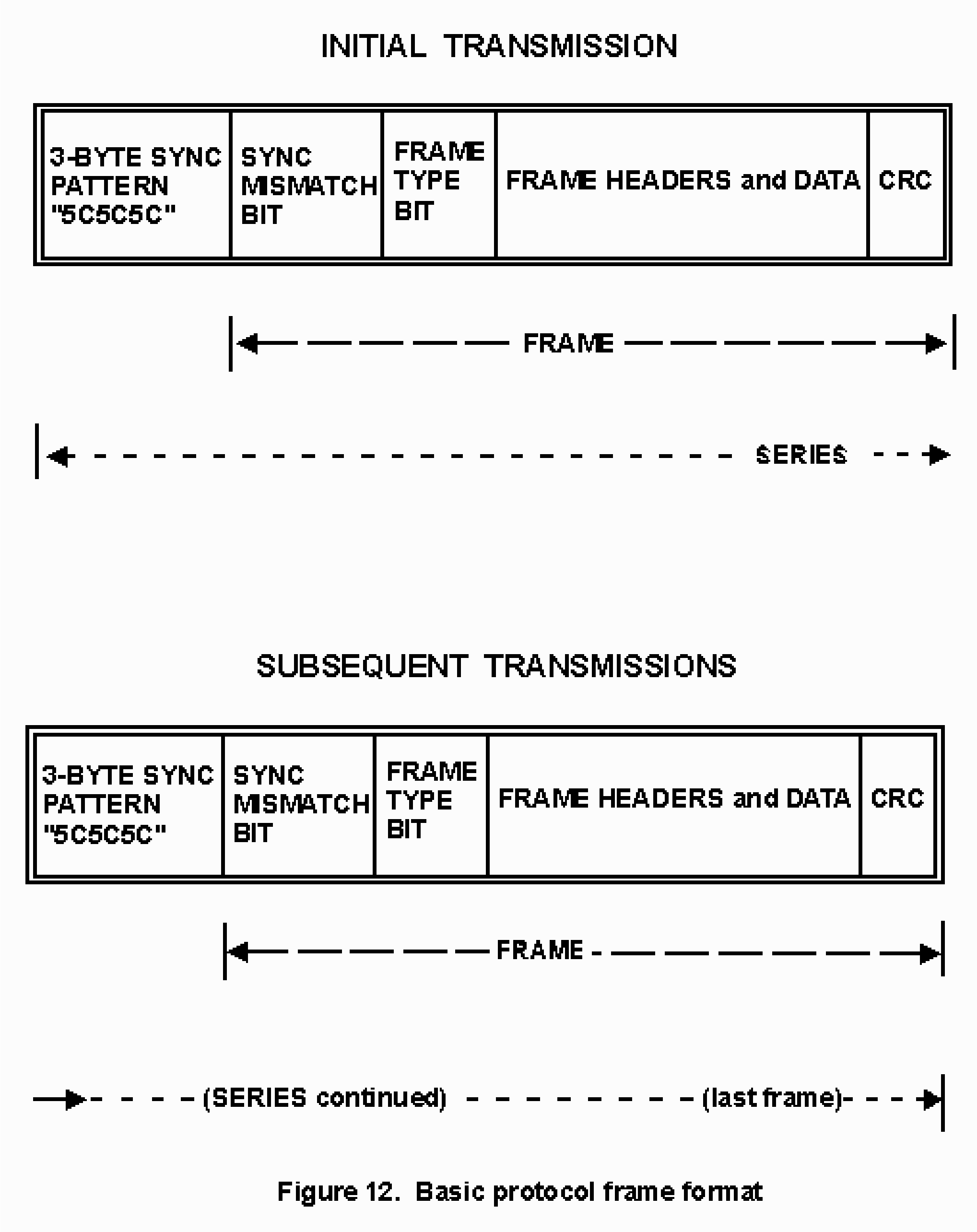


Figure 12. Basic protocol frame format

50.1.1.4 Frame Headers and Data. The Frame Headers and Data field shall immediately follow the Frame Type bit and shall contain either control frame headers or data frame headers and data. The length of the Frame Headers and Data field for control frames is either fixed at 486 bits or variable, depending on the number of header fields contained within the control frame (see par. 50.1.2.1.2). The length of the Frame Headers and Data field (number of data bytes per data frame) shall be specified in the herald announcing the data frame series.

50.1.1.5 CRC error control checksum. A 32-bit CRC following the Frame Headers and Data field shall conclude each protocol frame. After initially setting all 32 bits to one, the CRC shall be calculated using all bits of the frame starting with the Sync Mismatch bit and ending with the last bit of the Frame Headers and Data field. The generator polynomial for the CRC calculation shall be:

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

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

50.1.2 Control frame format. Figure 13 defines the format of the DLP control frames. The fields of the control frame are described in the following paragraphs.

50.1.2.1 Control frame header fields. The control frame header fields follow the Frame Header fields (Sync Mismatch Bit and Frame Type) in control frames, and are described below.

50.1.2.1.1 Protocol Version. The Protocol Version field shall contain a 2-bit code representing the version of the DLP implemented on the terminal sending the frame. Implementations based on this DLP version shall set the field to zero (ØØ).

50.1.2.1.2 Control Mode. The Control Mode field shall be used to specify the mode under which the data link will operate after establishment. Three control modes are supported: (a) ARQ mode with two alternatives, one for variable-length control frames and the other for fixed-length control frames, (b) Broadcast mode, and (c) the optional Circuit mode.

a. ARQ. A value of Ø in the Control Mode field shall indicate the ARQ mode with variable-length control frames. In this mode, the control frames may be of variable lengths of up to 520 bits (see sec. 50.2).

b. Broadcast. A value of 1 in the Control Mode field shall indicate the Broadcast mode (see sec. 50.4.3.2). In this mode, the receive terminal(s) shall send no acknowledgment of the control or data frames transmitted. The transmit terminal shall send only 520-bit fixed-length control frames.

c. Circuit. A value of 2 in the Control Mode field shall indicate that the terminal is operating in the Circuit mode with variable-length control frames (see par. 50.4.3.3).

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

Header field name	Field name	Length (bits)	Possible values
Frame Header	Sync Mismatch Bit	1	1 (always 1)
	Frame Type	1	Ø = Data frame 1 = Control frame
Control Frame	Protocol Version	2	Set to Ø for this DLP version

Header	Control Mode	2	Ø = ARQ mode with variable-length control frames 1 = Broadcast mode, no ARQ, fixed-length control frames 2 = Circuit mode, ARQ, variable-length control frames 3 = ARQ mode with fixed-length control frames
	Negotiation Mode	1	Ø = negotiate only when there are changes 1 = negotiate before every data series
	Extended Addressing	1	Ø = 2 byte addressing 1 = 18 byte addressing
	Source Address	16	0000 through FFFF hexadecimal representing two least significant bytes of source terminal address
	Destination Address	16	0000 through FFFF hexadecimal (see above)
Link Management	Link State	2	Ø = Calling 1 = Call acknowledge 2 = Linked up 3 = Dropping link
	Link Timeout	4	Maximum retry time (see text)
Data Transfer	ACK/NAK Type	2	Ø = Null-ACK 1 = Data-ACK 2 = Data-ACK request 3 = Herald-ACK
	ACK Bit-Map/Extended Address	256	Ø = Retransmit associated frame 1 = Error-free frame
	Alternating Data-ACK Frames	1	Changes state for each new data-ACK frame
H e	Data Rate Format	1	Ø = Absolute data rate 1 = Relative rate
	Data Rate	3	Code / Absolute format / Relative format

	r			Ø	75 b/s	÷8
	a			1	150 b/s	÷4
	l			2	300 b/s	÷2
	d			3	600 b/s	No change
				4	1200 b/s	×2
				5	2400 b/s	×4
				6	4800 b/s	×8
				7	No recommendation	
		Interleaver Length	1	Ø = Short interleaver 1 = Long interleaver		
		Number of Bytes in Data Frames	10	56 through 1023 decimal (see par. 50.1.5.4)		
		Number of Frames in Next Series	8	1 through 255 decimal. Ø denotes null-herald (see par. 50.1.5.5)		
Message Management		Transmit Message ID	8	Ø through 255 decimal		
		Transmit Connection ID	8	Ø through 255 decimal		
		Transmit Message Size	24	Message size in bits		
		Transmit Message Next Byte Location	21	Position of next byte in message		
		Reserved	3	Reserved for future use (set to Ø)		
		Transmit Message Priority	8	Ø through 255; Ø is lowest priority message		
		Receive Message Next Byte Location	21	Position of next byte required by receive terminal		
		Reserved	3	Reserved for future use (set to Ø)		

Extended Function	User ID	14	Orderwire flag/Free format user ID
	Function Bits	50	Orderwire data/Reserved
(p/o Frame header)	CRC	32	(see par. 50.1.1.5)

Figure 13. Control frame format

50.1.2.1.3 Negotiation Mode. By default, terminals are required to send a herald to re-negotiate the parameters for data transfer only when those parameters will change for the following data series (see par. 50.4.3.1.1). However, if a terminal receives a control frame with the Negotiation Mode flag set to logic 1, it shall send a herald before every data series subsequently sent on that link until it receives a control frame with the Negotiation Mode flag set to logic Ø.

50.1.2.1.4 Extended Addressing. The Extended Addressing flag shall be used to define the format of the source and destination addresses within the control frame. This flag shall be set to logic Ø when an ACK bit-map is required (i.e., when the ACK/NAK type is data-ACK).

a. When set to logic Ø, the Extended Addressing flag shall indicate that the addresses are restricted to two bytes each, and are contained in the message management header, Source Address field and Destination Address field. In this case, the 256 bits of the ACK Bit-Map/Extended Address field are available for data frame acknowledgments and flow control (see sec. 50.1.4.2).

b. When set to logic 1, the Extended Addressing flag shall indicate that extended source and destination addressing is being used. In this condition, the source and destination addresses can each be up to eighteen bytes long (see par. 50.1.4.2.1.3).

50.1.2.1.5 Source Address. When the Extended Addressing flag (par. 50.1.2.1.4) in the data transfer header is set to logic Ø, the Source Address field shall contain a two-byte message source address. When the Extended Addressing flag is set to logic 1, the Source Address field shall contain the two least-significant bytes of the extended message source address (see par. 50.1.4.2.1.3). Up to 16 most-significant bytes of the extended address will be contained in the ACK Bit-Map/Extended Address field of the data transfer header.

50.1.2.1.6 Destination Address. When the Extended Addressing flag (par. 50.1.2.1.4) in the data transfer header is set to logic Ø, the Destination Address field shall contain a two-byte message destination address. When the Extended Addressing flag is set to logic 1, the Destination Address field shall contain the two least-significant bytes of the extended message destination address (see par. 50.1.4.2.1.3). Up to 16 most-significant bytes of the extended address will be contained in the ACK Bit-Map/Extended Address field of the data transfer header. A destination address of all ones shall indicate a broadcast address.

50.1.3 Link management header fields.

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

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

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

c. Linked up. A value of 2 in the Link State field shall indicate that the terminal has successfully concluded the link establishment protocol and is linked to the other terminal.

d. Dropping link. A value of 3 in the Link State field shall indicate that the terminal is dropping an established link.

50.1.3.2 Link Timeout. The Link Timeout field contains four bits to indicate the time that the terminal sending the control frame will wait for a valid response to the frame before dropping the link. This field shall be computed before the initial transmission of each control frame, taking into consideration the number of retries the terminal is willing to perform and any data-rate reductions that will be used for retries (see par. 50.4.4.3). This computed time shall be rounded up to the next multiple of 30 s, and encoded as the number of 30-second intervals minus one. Thus a timeout of 25 s is encoded as Ø, and 78 s is encoded as 2. All transmissions of a control frame (including retries) shall carry the same link-timeout value.

50.1.4 Data transfer header fields.

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

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

b. Data acknowledgment (data-ACK). A value of 1 indicates that the control frame contains an acknowledgment of a data transfer series. In this case the ACK Bit-Map (see sec. 50.1.4.2.1) is active and contains the ARQ bits.

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

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

50.1.4.2 ACK Bit-Map/Extended Address.

50.1.4.2.1 ACK Bit-Map field. The ACK Bit-Map field shall be used to specify which frames of the prior data transfer series were received error free and which frames require retransmission. A position-based relationship is employed in the definition of this field. The least-significant bit of this field (first bit sent) is bit number 255. The most-significant bit of this field (last bit sent) is bit number Ø.

50.1.4.2.1.1 ACK Bit-Map. When the ACK/NAK Type field (par. 50.1.4.1) is set to logic 1 (data-ACK), bits 1 through 255 of the ACK Bit-Map/Extended Address field compose an ACK bit-map, with each bit corresponding to the data frame having the same data frame sequence number (par. 50.3.2.1) as that bit (e.g., bit 1 corresponds to data frame 1 and so on).

a. A logic Ø in the ACK Bit-Map field shall indicate that the associated data frame was missed or received with errors and should be retransmitted.

b. A logic 1 in the ACK Bit-Map field shall indicate that the frame was received error free and does not require retransmission. All bits numbered higher than the number of data frames in the previous data transfer series shall be set to logic Ø.

When acknowledging a series of data frames sent at 4800 b/s, each bit in the ACK Bit-Map field shall correspond to two frames of data. Bit 1 of the ACK Bit-Map field corresponds to the first two data frames in the data series, bit 2 to the third and fourth data frames in the series, etc.

50.1.4.2.1.2 Flow Control. Bit Ø of the ACK Bit-Map field shall be used as a flow control flag when the Extended Addressing flag (par. 50.1.2.1.4) is set to logic Ø (addresses restricted and ACK bit-map active). When the Flow Control flag (bit Ø of the ACK Bit-Map field) is set to logic 1, it signifies that "No new frames" type flow control is in effect. The transmit terminal shall retransmit only unacknowledged data frames (no new data frames) until flow control is lifted IAW par. 50.4.3.1.4.

50.1.4.2.1.3 Extended Address. The Extended Address field becomes active when the Extended Addressing flag (par. 50.1.2.1.4) is set to logic 1 indicating that extended source and destination addressing is being used. The source address and the destination address fields of the message management header shall contain the two least-significant bytes of the extended address. Up to sixteen of the most-significant bytes (128 bits) of the addresses shall be contained in the ACK Bit-Map/Extended Address field. The source address shall be placed in the first (least significant) 128 bits of the field and the destination address shall be placed in the last (most significant) 128 bits of the field. If addresses are shorter than eighteen characters, the ASCII NULL character shall be used to stuff or fill the remaining bytes in the most significant bytes position. See Fig. 14 for an extended address example.

50.1.4.3 Alternating Data-ACK Frames bit. This bit shall be set to alternate (toggle) between Ø and 1 to indicate successive different ACK bit-maps. In the first Data-ACK frame for each message (and the first Data-ACK frame after resumption of a message) this bit shall be set to Ø. Each subsequent different ACK bit-map shall cause this bit to alternate between Ø and 1. If an ACK bit-map is retransmitted, the state of the Alternating Data-ACK Frames bit shall not change. This bit shall be active when the ACK/NAK Type field (par. 50.1.4.1) is set to data-ACK (value 1). This Alternating Data-ACK Frames bit shall be set to Ø for all other type control frames.

50.1.5 Herald header fields. The herald header fields are included in the data transfer header, and are used to negotiate parameters of subsequent data series. They are described in the following paragraphs.

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

50.1.5.2 Data Rate. This field shall be used in Herald and Data-ACK frames to specify the data rate of the following data series, and in Herald-ACK or Data-ACK frames with null-heralds, to recommend a data rate for the next data series. If the Herald-ACK frame contains such a recommendation for a data-rate change, the transmit terminal may, if in agreement, immediately transmit a new herald, updated as required in regard to the data rate. If not in agreement, the transmit terminal shall proceed with sending data frames at the previously announced data rate. The code definitions for each of the data-rate formats are listed in table XXVIII and are shown on Fig. 14. In the absence of higher order control information and the ability to detect baud rate from the waveform preamble, a default data rate of 600 b/s is recommended.

Figure 14. Extended addressing example: from ABCD to WXYZ

Header field name	Field name	Length (bits)	Extended Address Contents
Frame Header	Sync Mismatch Bit	1	
	Frame Type	1	
Control Frame Header	Protocol Version	2	
	Control Mode	2	
	Negotiation Mode	1	
	Extended Addressing	1	1
	Source Address	16	D C
	Destination Address	16	Z Y
Link Management	Link State	2	
	Link Timeout	4	
Data Transfer	ACK/NAK Type	2	
	(ACK Bit-Map/Extended Address)		
	Source Extended Address Characters	128	B A . .
	Destination Extended Address Characters	128	X W . .
	Alternating Data-ACK Frames	1	0
Herald	Data Rate Format	1	
	Data Rate	3	
	Interleaver Length	1	
	Number of Bytes in Data Frames	10	
	Number of Frames in Next Series	8	
Message Management	Transmit Message ID	8	
	Transmit Connection ID	8	
	Transmit Message Size	24	
	Transmit Message Next Byte Location	21	
	Reserved	3	
	Transmit Message Priority	8	
	Receive Message Next Byte Location	21	
	Reserved	3	
Extended Function	User ID	14	
	Function bits	50	
(p/o Frame header)	CRC	32	

TABLE XXVIII. Code definitions for data-rate formats

Code	Absolute format	Relative format
0	75 b/s	÷8
1	150 b/s	÷4
2	300 b/s	÷2
3	600 b/s	No change
4	1200 b/s	×2
5	2400 b/s	×4
6	4800 b/s	×8
7	No recommendation (no change)	

50.1.5.3 Interleaver Length. This bit is used by the transmit terminal to distinguish between the short interleaver and the long interleaver mode of the FED-STD-1052 serial (single-tone) waveform (see pars. 5.4.3.4 and 5.4.3.5). The announcement convention shall be the same as defined for data rate,and if the Data Rate field makes no recommendation, the Interleaver Length field shall not be changed. For the purpose of this standard, the short interleaver setting specifies the 0.6 second interleaver. When this protocol is used with any other waveform, the interleaver length field has no defined meaning, and shall be set to logic Ø.

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

50.1.5.5 Number of Frames in Next Series. This field shall be used by the transmit terminal to specify the number of data frames contained in the next data series following this herald. The maximum number of data frames in a series shall be a function of data rate as defined in Table XXIX. For a 4800 b/s data rate, this field shall be the number of data frames divided by 2. When the number of frame repeats plus the number of remaining frames is equal to or greater than 255, set the value to 255 (see par. 50.4.3.1.1. for details). When the data rate changes, the number of frames in the next series shall change by the same proportion. If this field is set to value Ø, the entire herald is a null-herald.

TABLE XXIX. Maximum series size

Data rate (b/s)	Maximum number of frames in series
75	8
150	16
300	32
600	64
1200	128
2400	255
4800	510

50.1.6 Message management header fields. The message management header fields contain data that identify and specify the user message being transferred.

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

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

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

a. If the Transmit Message Size field has the value of zero, the remainder of the message management transmit header fields shall be ignored.

b. If the Transmit Message Size field contains the value of 16,777,215 (all binary 1s), the size of the message is unbounded. Use of this code places the DLP into "bit pipe" mode. Subsequent use of any other message size terminates this mode.

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

50.1.6.5 Reserved (transmit). The three bits following the 21 bits of the Transmit Message Next Byte Location field are reserved for future use and shall be set to zero for this DLP version.

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

50.1.6.7 Receive Message Next Byte Location. The Receive Message Next Byte Location value shall be used by the receiving terminal to specify to the transmitting terminal the required starting byte position in the message being offered. This byte position shall be the first byte of the earliest frame not received. Upon resumption of an interrupted or preempted message, this value shall be used to specify the restart position of the interrupted message. For new messages, this field shall be set to zero. The receive terminal shall set this field to the value specified in the Transmit Message Size field (divided by eight to convert to bytes) if it has already received the entire message being offered. The receive terminal shall set this field to a value greater than that specified in the Transmit Message Size field (divided by eight) if it is unwilling to accept the message being offered. For all other cases during the reception of a message, when this field is present in a control frame from a receive terminal, it shall specify;

a. the first byte of the earliest frame not yet received correctly, to continue the message transfer, or

b. a value greater than or equal to the Transmit Message Size field (divided by eight) to abort the message transfer.

50.1.6.8 Reserved (receive). The three bits following the 21 bits of the Receive Message Next Byte Location field are reserved for future use and shall be set to zero for this DLP version.

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

50.1.7.1 User ID. The User ID field shall contain a manufacturer identification code or the interoperable mode code zero. When the User ID code is set to zero, the Function Bit field may contain the orderwire seven-bit ASCII data characters. The User ID field can also be used to identify closed system terminals. Note: Closed systems are not necessarily interoperable with other users. A User ID code other than zero shall indicate an operating version that is specialized to the designated user(s) and is not necessarily interoperable with other users. The terminal shall ignore all unknown user IDs received. It is recommended that manufacturers register their code with the custodian of this standard for the purposes of interoperability, identification, and non-duplication of codes.

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

50.2 Control frame lengths.

50.2.1 Variable-length control frames. Control frames shall be one of four possible lengths depending on the operating mode and the contents of the control frame. The value set for the Control Mode bits of the control frame header indicates whether the control frames will be fixed (520 bits) or variable (80, 360, or 456 bits). The Control Mode field value 1 indicates Broadcast mode with fixed-length control frames and value 3 indicates ARQ mode, also with fixed-length control frames. The Control Mode field value Ø indicates ARQ mode with variable-length control frames, and value 2 indicates Circuit mode, also with variable length-control frames. The allowable frame lengths and the control fields available in each frame are shown on Fig. 15. Shaded areas in the figure indicate control fields that are not present in the control frame for the frame type listed.

a. Type 1 control frames are the shortest frames allowable. These frames contain frame, control frame, and link management headers defining the link operating mode, the link state of the transmit terminal, the ACK type indicator, and whether or not extended addressing is to be used. Type 1 control frames can be used to send null-ACKs, data-ACK requests, and herald-ACKs.

b. Type 2 control frames contain all fields of the type 1 frame plus the full data transfer header with the herald fields. The ACK Bit-Map/Extended Address field and the Alternating Data-ACK Frames indicator are included. The herald fields provide information on the data rate, interleaver length, the number of frames in the next series, and the number of bytes in the data frames. In addition to the uses of the type 1 frames, these type 2 frames can be used for data-ACKs, heralds, and null-heralds.

c. Type 3 control frames add the message management header fields to the type 2 control frames. In addition to the source and destination addresses, these fields contain accounting information about the message to be transmitted -- message and connection identification, message size, location of an interrupted message restart position, message priority, and the receive terminal's desired restart position. The type 3 control frames can be used to implement all operational capabilities of the protocol, with the exception of the extended functions.

d. Type 4 control frames are 520 bits long and contain all control fields. The extended function header fields of User ID and Function Bits are the added capability. The type 4 control frames can be used to implement all operational capabilities of the protocol.

Header field name	Field name	Length (bits)	Type 1	Type 2	Type 3	Type 4
Frame header	Sync Mismatch Bit	1				
	Frame Type	1				
Control Frame header	Protocol Version	2				
	Control Mode	2				
	Negotiation Mode	1				
	Extended Addressing	1				
	Source Address	16				
	Destination Address	16				
Link Management	Link State	2				
	Link Timeout	4				
Data Transfer	ACK/NAK Type	2				
	ACK Bit-Map/Extended Address	256				
	Alternating Data-ACK Frames	1				
H	Data Rate Format	1				
e	Data Rate	3				
r	Interleaver Length	1				

a	Number of Bytes in Data Frames	10				
l d	Number of Frames in Next Series	8				
Message Management	Transmit Message ID	8				
	Transmit Connection ID	8				
	Transmit Message Size	24				
	Transmit Message Next Byte Location	21				
	Reserved	3				
	Transmit Message Priority	8				
	Receive Message Next Byte Location	21				
	Reserved	3				
Extended Functions	User ID	14				
	Function Bits	50				
p/o Frame header	CRC	32				
Total frame size			80	360	456	520
Note: Shaded areas (Herald and below) indicate fields not included in header						

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Figure 15. Control frames

50.2.2 Fixed-length control frames. All control frames transferred over the HF data link in the ARQ mode with fixed-length control frames or in the Broadcast mode shall be type 4 (520 bits) and shall contain all of the control fields described in the previous paragraph.

50.3 Data frame format. Data frames transferred over the HF data link, shall be formatted in accordance with Figure 16. Data frames may be variable in length as specified in the herald control frame that announces one or more data series.

50.3.1 Reverse channel control frame fields. These fields shall be used by the transmit terminal to recommend the data-ACK control frames data rate and interleaver length to the receive terminal. (See pars. 50.1.5.1, 50.1.5.2, and 50.1.5.3 for descriptions of the

Data Rate Format, Data Rate, and Interleaver Length fields, and par. 30.1 for the definitions of "receive terminal" and "transmit terminal").

50.3.2 Data frame header fields. The data frame header fields are described below.

50.3.2.1 Data Frame Sequence Number. The transmit terminal shall sequentially number each data frame within a data transfer series, starting at the value specified in the Number of Frames in Next Series field of the data transfer header or herald, and decrementing to one in the last frame of the series. The transmit terminal shall place this number in the Data Frame Sequence Number field of the data frame. The receive terminal shall use this number to construct the position-based ACK bit-map (sec. 50.1.4.2) for the data acknowledgment reply. When the modem is operating at 4800 b/s, the sequence number remains the same for the first two frames and counts down in pairs of frames after that.

Header field name	Field name	Length (bits)	Possible values		
Frame Header	Sync Mismatch Bit	1	1 (always 1)		
	Frame Type	1	Ø = Data frame		
Reverse Channel Control Frame	Data Rate Format	1	Ø = Absolute data rate 1 = Relative rate		
	Data Rate	3	Code	Absolute format	Relative format
			Ø	75 b/s	÷8
			1	150 b/s	÷4
			2	300 b/s	÷2
			3	600 b/s	No change
			4	1200 b/s	×2
			5	2400 b/s	×4
			6	4800 b/s	×8
			7	No recommendation	
	Interleaver Length	1	Ø = Short interleaver 1 = Long interleaver		
	Reserved	1	Reserved for future use. Set to Ø.		

Data Frame Header	Data Frame Sequence Number	8	255 through 1 (counts down); identifies data frame within series.
	Message Byte Offset	21	Position of frame in message (byte Ø is first byte)
	Reserved	3	Reserved for future use. Set to Ø.
Data	Data	Vari-able	User data. Variable size as defined in herald control frame.
P/O Frame header	CRC	32	(see par. 50.1.1.5)

Figure 16. Data frame format

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

50.3.2.3 Reserved. Reserved for future use. Set to Ø for this DLP version.

50.3.3 Data field. The Data field shall contain the message data. The length of the Data field shall be as specified in the Number of Bytes in Data Frames field of the data transfer header of the most recent herald.

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

50.4.1 Message management protocol. DLP terminals shall use the message management protocol to coordinate the transfer of data messages, priority preemption of message transfer, and resumption of preempted messages. The message management protocol shall be implemented through an exchange of control frames containing the message management header fields (par. 50.1.6). The message management header fields contain a complete definition of the message to be transferred or resumed. Terminals shall be able to selectively accept or reject messages over the data link based upon the message source, priority, length, or connection number.

50.4.1.1 Message announcement. A terminal shall announce a message to be transferred over the HF data link by transmitting a control frame with a message management header that defines the parameters of the offered message. Within the message management header, the terminal shall specify the source address and the destination address as well as specifying the message identification number, connection identification, total message size, the relative starting point within the message, and the message priority. Terminals that support multiple data connections shall specify the connection number of the offered message in the announcing message management header. All others shall set the Transmit Connection ID field to Ø. Terminals shall specify a starting point of zero for all new messages. Transmit terminals may specify an arbitrary start position for messages restarted after a link interruption (due to preemption or link failure), however the start position specified by the receive terminal shall override the position specified by the transmit terminal. Message announcement control frames shall also contain a herald describing the first data series to be transferred (see par. 50.1.2.1.3).

50.4.1.2 Message acceptance. A terminal operating in one of the ARQ modes shall signify its acceptance of an announced message by sending a control frame containing a herald-ACK in response to the herald frame. If other than a type 1 (48 bits) control frame is sent (e.g., in ARQ mode with fixed-length control frames), the message management header fields should duplicate the corresponding fields in the announcing frame. (See par. 50.4.1.5.2 for the case of a receive terminal with higher-priority traffic, and par. 50.4.1.6 for negotiation of starting byte offset in a resumed message). The receive terminal may request a change in the parameters announced in the herald (see par. 50.4.3.1.1.2). For Immediate mode, see par. 50.4.2.4.

50.4.1.3 Message refusal. To refuse an announced message, a terminal operating in one of the ARQ modes shall return a control frame with the Receive Message Next Byte Location field of the message management header set to a value greater than or equal to the value announced in the Transmit Message Size field (divided by eight) of the announcing message management header. However, see par. 50.4.2.4 for Immediate mode.

50.4.1.4 Priority resolution. Terminals shall resolve data link contention by exchanging message management headers announcing the highest priority traffic available for transfer. The terminal with the highest priority traffic shall be allowed to use the data link first. Thus, a terminal receiving announcement of a lower-priority message shall preempt that incoming message IAW par. 50.4.1.5.2, except that the message management header shall be sent with a null-ACK to refuse the first data series (rather than the data-ACK needed when preempting a message in progress). If both terminals have traffic of equal priority, the terminals may share the data link on an equal basis. In such sharing, the two terminals alternate the transmission of data series. Each data-ACK includes a herald. The terminal receiving the data-ACK/herald responds with a herald-ACK. The terminal receiving this herald-ACK responds by transmitting its data series. The terminal receiving the data series responds with a data-ACK/herald, and the link direction reverses again.

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

50.4.1.5.1 Forward preemption. A transmit terminal shall preempt the ongoing transfer of a message with a higher-priority message, by sending a new message management header announcing the new message. This message management header should be sent at the first logical opportunity for a control frame transfer. The receive terminal can refuse the offered message as previously described (par. 50.4.1.3). Upon acceptance of the preempting message, the transmit terminal shall suspend transfer of the preempted message until the higher-priority traffic is transferred. Terminals shall only preempt ongoing-message transfers in the forward direction with messages of higher priority than the preempted message. Nested preemption is allowed, provided that the preemption meets this requirement for relative priority. If a terminal resumes preempted messages, it shall resume them in the reverse order of preemption, i.e., the most recently preempted message shall be resumed first. This ensures that the requirement for relative priority is maintained throughout the preemption and resumption process.

50.4.1.5.2 Reverse preemption. A receive terminal shall preempt the transfer of an incoming message by sending a message management header announcing a higher-priority message at the first available opportunity. The transmit terminal can refuse the offered message as previously described in pars. 50.4.1.3 and 50.4.1.5.1 above. Upon acceptance, the terminals shall reverse the link direction and transfer the higher-priority message until completion. Transfer of the preempted message may then be resumed.

50.4.1.6 Message resumption. A terminal shall resume the transfer of a preempted message after the completion of the higher-priority traffic (or of an interrupted message after link recovery) by sending a message management header announcing the resumption of the preempted message. The message management header shall contain the same message identification data as the original announcement of the message with the exception of the Transmit Message Next Byte Location field. The transmit terminal, upon resumption of the message, shall specify the starting location within the message. This would typically be the first byte of the first frame not acknowledged by the receive terminal prior to the preemption (or link failure). The receive terminal may override this starting position by sending a message management header specifying the desired start position in the Receive Message Next Byte Location field. A value of zero in this field shall compel a message restart instead of a message resumption.

50.4.1.7 Null message management headers. When none of the above conditions apply, no message management header need be sent. If a full-length control frame is sent in this case, the message management header fields shall be set to all Øs by the transmit terminal. The receive terminal shall ignore message management headers with the Transmit Message Size field set to the value of zero.

50.4.2 Link establishment protocol. DLP terminals employ the optional link establishment protocol to coordinate the terminals' status (state) and resolve access contention prior to initiating the transfer of data over the link. The link establishment protocol is implemented through an orderly exchange of control frames containing the link management header fields. During the link establishment phase, the two terminals attempting to link shall exchange terminal addresses and link state information in accordance with the protocol rules. This is to ensure that both terminals are fully aware of the link state of the other terminal and therefore do not attempt to transfer data before the other terminal is ready to accept that data. The link establishment protocol is optional and can be bypassed. When the link establishment protocol is bypassed, the terminal shall set the Link State field in all control frames to the linked up state (value 2). This bypass condition is that of the "Immediate mode", described in par. 50.4.2.4.

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

Note: In the descriptions that follow, the potential transmit terminal and receive terminal are shown in parentheses to emphasize that until "negotiations" are complete (especially forward and reverse priorities), either terminal can become the transmit terminal and the other, of course, will become the receive terminal.

50.4.2.1.1 Idle. The idle state of the link establishment protocol is the resting state of the protocol. The terminal shall reside in this state whenever it has no traffic to send and is not being called by another terminal. The terminal shall return to the idle state if there has been a link failure or a time out. However, as an option, either terminal may automatically attempt to reestablish the link to continue the data transfer, rather than returning directly to the idle state.

50.4.2.1.2 Calling. A terminal shall enter the calling state when it has data traffic for another (receive) terminal or is requested to establish a link with that (receive) terminal by one of the data link users (source) associated with the (transmit) terminal. When in the calling state, the (transmit) terminal shall send type 4 (520 bit) control frames containing the following:

a. the control frame header (par. 50.1.2.1) with the Control Mode (par. 50.1.2.1.2), Negotiation Mode (par. 50.1.2.1.3), Extended Addressing flag (par. 50.1.2.1.4), message Source Address (par. 50.1.2.1.5), and the message Destination Address (par. 50.1.2.1.6) fields set,
b. the link management header (par. 50.1.3) with the Link State (par. 50.1.3.1) and Link Timeout (par. 50.1.3.2 and 50.4.4.3) fields set,
c. the data transfer header (par. 50.1.4) with the ACK Bit-Map/Extended Address (sec. 50.1.4.2) field set,
d. the herald header of the data transfer header (par. 50.1.5) with the Data Rate Format (par. 50.1.5.1), Data Rate (par. 50.1.5.2), and Interleaver Length (par. 50.1.5.3) fields set,
e. the message management header (par. 50.1.6) will announce the (first) message that it wishes to transfer to the destination (pars. 50.1.6.1 through 50.1.6.6, and
f. the extended function header (par. 50.1.7) containing the User ID (par. 50.1.7.1) of the calling (transmit) terminal.

After sending the control frame, the (transmit) terminal shall wait for a response from the called (receive) terminal. Upon reception of a valid control frame from the (receive) terminal containing a link management header acknowledging the link request, the (transmit) terminal shall advance to the linked up state. If the (transmit) terminal does not receive a timely call acknowledgment frame, it shall retry the call. See sec. 50.4.4 for timeout calculations. As an option, a terminal should enter the calling mode when a link, that has been established, is interrupted. If node contention is possible, the (transmit) terminal should wait a random time interval before resending the link establishment header, in order to reduce the probability of collision.

50.4.2.1.3 Call acknowledge. A (receive) terminal shall enter the call acknowledge state upon reception of a valid control frame containing a link management header, indicating that a (transmit) terminal is attempting to establish a link with it. When in the call acknowledge state, the (receive) terminal shall send control frames in response to the (transmit) terminal's control frames. These response control frames indicate the local (receive terminal) link state, link timeout, and the accepted link modes and characteristics. If the (transmit) terminal accepts variable-length control frames, a type 1 (48 bits) control frame may be returned to accept the announced message. Note: Overrides to the Control Mode field and to the Negotiation Mode field may be included in control frames of any size. If a longer control frame (types 2, 3, or 4) is sent, refer to Fig. 15 and the descriptions of the other protocols for contents of the message management and data transfer headers. The extended function header (type 4), if present, shall contain a User ID field (par. 50.1.7.1) set to one of the following:

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

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

After sending the control frame, the (receive) terminal shall wait for a response from the calling (transmit) terminal. If the acknowledging (receive) terminal does not receive a timely valid reply to its response and it has higher-priority traffic (i.e., it initiated reverse preemption), it shall retransmit the call acknowledge announcing this traffic after the response timeout IAW sec. 50.4.4. If it (receive terminal) does not have higher priority traffic, it shall await a repetition of the call. If it (receive terminal) has not received a repeated call within the link timeout specified in the call frame, it shall return to the idle state.

50.4.2.1.4 Linked up state. The linked up state is the fully operational state of the terminal. The terminal may begin the data transfer protocol once it has reached the linked up state. The terminal shall enter the linked up state upon receipt of a valid control frame indicating that the other terminal is in either the call acknowledge or the linked up state, or upon receipt of a local request for Immediate mode message transfer when it is in the idle state (see par. 50.4.2.4). When in the linked up state, the terminal shall include a link management header in all control frames sent indicating its link state is linked up (see par. 50.1.3.1). The terminal may implement any operational feature of the data transfer and message management protocols when in this state. The terminal shall remain in the linked up state until the link is dropped (or fails) whereupon it shall return to the idle state. As an option, in the case of a link failure, the terminal shall attempt to reestablish the link to continue the data transfer, rather than returning directly to the idle state.

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

50.4.2.3 Link termination. The link may be dropped due to a local request, a link timeout, or the absence at both terminals of messages to be sent (when not in Circuit mode). Terminals should send a control frame with the Link State field set to dropping link (value 3) before dropping the link.

50.4.2.4 Immediate mode. An Immediate mode message transfer bypasses link establishment and the initial data transfer negotiation. The first transmission shall begin with a type 4 (520 bit) control frame with the Link State field of the link management header set to linked up (value 2), a message management header announcing a message, and a herald describing the characteristics of the first data series, with the User ID field normally set to Ø. This control frame shall be immediately followed by two sync bytes (par. 50.1.1.1), then the first data series of the announced message, with no change in data rate. Following this first data series, the data transfer protocol shall use either the ARQ mode or the ARQ Circuit mode.

50.4.2.5 State sequence rules. Figure 17 summarizes the state actions and transition rules of the link establishment protocol.

50.4.3 Data transfer protocol. HF data link terminals shall use the following data transfer protocol to deliver data over an established data link connection. The data transfer protocol is implemented through the exchange of control frames and data frames over the data link. The data transfer protocol includes three different transfer modes; (a) ARQ mode, (b) Broadcast mode, and (c) Circuit mode. Each of these modes is defined in the following paragraphs.

50.4.3.1 ARQ mode. The ARQ mode is made up of three phases; (a) the negotiation phase, (b) the data transfer phase, and (c) the data acknowledgment phase. Negotiation may be combined with data acknowledgment (e.g., to reverse the link for high-priority reverse-channel traffic).

State	Action	Transition criteria	Next state
Idle	None	Receive link request from local operator or connection (normal)	Calling
		Receive link request from local operator or connection (Immediate)	Linked up
		Receive valid control frame with proper address link state = calling	Call acknowledge
		Receive valid control frame with proper address, link state = linked up	Linked up
Calling	Emit link establishment header with link state = 'Calling'	Response timeout expired	Same state
		Neighbor link state = calling	Call acknowledge
		Neighbor link state = call acknowledge	Linked up
		Neighbor link state = linked up	Same state
		Link attempt time expired	Idle
Call acknowledge	Emit link establishment header with link state = 'Call acknowledge'	Response timeout expired	Same state
		Neighbor link state = calling	Same state
		Neighbor link state = call acknowledge	Linked up
		Neighbor link state = linked up	Linked up
		Arrival of data series heralded in call	Linked up
		Link timeout expired	Idle
Linked up	Emit link establishment header with link state =	Neighbor link state = calling	Call acknowledge

	'Linked up'	Neighbor link state = call acknowledge	Linked up
		Neighbor link state = linked up	Same state
		Transmit terminal timeout expired (repeat countdown >0)	Linked up (retransmit)
		Neighbor link state = dropping link	Idle
		No more traffic to send	Idle
		Link timeout expired	Idle or calling*
* Idle state aborts transfer; calling state continues message after link recovery			

.

Figure 17. State sequence, link establishment protocol

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

The negotiation phase is required in the following circumstances:

a. Before the first data frames are sent over a link (except Immediate mode message transfers; see par. 50.4.2.4).
b. Before any change in previously-negotiated values in the herald fields. The exceptions are that no negotiation is required to (1) send a data series to finish a message or to (2) change only the data rate and the number of frames in next series if the following rules are followed:
(1) If the data rate increases by 2^n, the Number of Frames in Next Series field value must increase by the same factor, thus keeping the ratio of the number of frames in next series to data rate constant. If this would result in a Number of Frames in Next Series field value greater than 255, the Number of Frames in Next Series field shall be set to 255, but the ratio of the number of frames in the next series to data rate without this limiting operation shall be stored for future reference.
(2) If the data rate decreases by 2^n, the Number of Frames in Next Series field value must decrease by the same factor (then rounded down to the nearest integer), thus keeping the

ratio of the number of frames in next series to data rate constant, except that if the previous Number of Frames in Next Series field value was 255, the new Number of Frames in Next Series field value shall be computed from the new data rate using the previously stored ratio of the number of frames in next series to data rate (see above), constrained as before to be no greater than 255.
c. Before each data series, if the most recent control frame from the terminal that will receive the data frames contained the Negotiation Mode field set to 1.
d. When flow control prevents the transfer of any data frames.

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

a. a herald-ACK signifying acceptance of the offered data series,
b. a null-ACK indicating that the receive terminal cannot accept the offered data series, or
c. a herald and message management header of its own, announcing a higher-priority data series in the reverse direction.

The transmit terminal shall retransmit the herald if it does not receive a valid response within the response timeout period (see sec. 50.4.4). Note that a transmit terminal may respond to a herald-ACK by immediately transmitting a new, different herald (e.g., for forward preemption). The receive terminal must, therefore, treat each herald received as if it contained new information and not merely as an identical repetition of a previously-received herald.

50.4.3.1.1.2 Acceptance. A receive terminal shall signify its acceptance of the data series offered in a herald frame by responding with a herald-ACK frame. The herald-ACK frame may be type 1 (48 bits) if not otherwise constrained by the need to negotiate data transfer characteristics or by control mode. The receive terminal may negotiate (override) any of the herald fields, except that the Number of Bytes in Data Frames field may not be changed if any data frames from a previous data series are to be resent in the current data series. Upon receipt of the herald-ACK frame, the transmit terminal will normally transition to the data transfer phase and begin transferring the data frames of the accepted series.

50.4.3.1.1.3 Data refusal. To refuse an offered data series, a DLP terminal shall send a null-ACK frame in response to a herald frame announcing a new data series. If the cause for refusal is a temporary lack of local buffer space, the receive terminal shall set the Flow Control flag (par. 50.1.4.2.1.2) in the null-ACK. In this case, the transmit terminal should periodically retransmit the herald frame in order to determine when the flow control restriction is lifted (see par. 50.4.3.1.4).

50.4.3.1.2 Data transfer phase. Upon transition to the data transfer phase, the transmit terminal shall transmit the data frames announced in the acknowledged herald. The transmit terminal shall transmit the total number of data frames announced in the herald without delay or interruption, except for preemption (see par. 50.4.1.5). All data frames shall be of the same size as was announced in the herald. This implies that the last data frame of a message may need to be padded with fill bits. The receive terminal will use the transmit message size information (par. 50.1.6.3) to determine where the message is to be truncated in order to remove the fill bits from its output data stream.

50.4.3.1.3 Data acknowledgment phase. The data acknowledgment phase shall begin after the last data frame of the data series has been transmitted. The transmit terminal shall stop transmission and wait for the data-ACK frame from the receive terminal. The data-ACK frame shall contain the data-ACK bit-map indicating which data frames were received error free and which frames, if any, require retransmission. The transmit terminal shall prepare a new data series containing all prior frames requiring retransmission and enough new data frames to fill the data series. Unless negotiation is required (see par. 50.4.3.1.1.b - d), the terminals shall return to the data transfer phase upon completion of the data acknowledgment phase. If the transmit terminal fails to receive a data-ACK frame from the receive terminal within the response timeout period (see sec. 50.4.4), it shall transmit a data-ACK request frame to inform the receive terminal that a data-ACK was not received. Receipt of a data-ACK request by a receive terminal shall cause it to resend the last data-ACK frame that it had previously sent. If the ACK sequence number received by the transmit terminal is incorrect, the receive terminal must have missed the entire preceding data series, which should, therefore, be resent by the transmit terminal.

50.4.3.1.4 Flow control. A receive terminal may impose flow control by returning a control frame (null-ACK, data-ACK, or herald-ACK) with the Flow Control flag (bit Ø of the ACK Bit-Map field)(see par. 50.1.4.2.1.2) set to 1. Note: The Flow Control flag is present only when the Extended Addressing flag (par. 50.1.2.1.4) is set to Ø. If the ACK Bit-Map field in a data-ACK control frame, with the Flow Control flag (bit Ø) set to 1, indicates that some data frames would be retransmitted, the transmit terminal shall resend those data frames. In no case shall a transmit terminal send new data frames in response to a control frame containing the Flow Control flag set to 1. A receive terminal shall lift flow control by responding to a frame from the transmit terminal with a control frame containing the Flow Control flag set to Ø. The type of control frame sent to lift flow control shall be an appropriate response to the frame from the transmit terminal (e.g., a herald-ACK for a herald, or a data-ACK for re-sent data frames).

50.4.3.2 Broadcast mode. The Broadcast mode shall be used for one-way transfers of data from a single transmit terminal to one or more receive terminals. Since multiple terminals can receive the data, acknowledgments of the data frames are not allowed. A terminal shall initiate a broadcast transmission by transmitting a type 4 (520 bits) control frame containing appropriate data transfer and message management header fields. The control frame header, Control Mode field (par. 50.1.2.1.2) shall be set to Broadcast mode (value 1), and the link management header, Link State field (par. 50.1.3.1) shall be set to linked up (value 2). The terminal shall immediately follow the control frame with data frames. Receive terminal(s) shall not respond with data-ACK control frames to a Broadcast mode transmission. This process shall be repeated until the entire data series is transmitted. All parameters shall remain fixed for the entire data series. Herald frames between each data series are optional. Although the Broadcast mode is non-ARQ, it is very similar to the ARQ mode with fixed-length control frames, except that no acknowledgments are allowed or accepted.

50.4.3.3 Circuit mode. The Circuit mode shall operate identically to the variable-length control frame ARQ mode, except that terminals shall maintain the link in the absence of user data, until directed to drop the link by the user. Terminals shall maintain the data link connection in the absence of data, by sending null-herald and null-ACK control frames that announce no message. Terminals shall respond to this null-herald by sending a null-ACK control frame along with their own null-herald. Terminals should use the error statistics of the null-herald/null-ACK exchange to maintain a valid estimate of the supportable data rate of the data link. When available, new user data shall be announced according to the requirements of the ARQ data transfer mode. Note that the Circuit mode does not include a fixed-length control frame option.

50.4.4 Timeouts. Timeouts serve two functions in the DLP; they ensure that terminals do not wait indefinitely for responses, and that transmissions from terminals that simultaneously attempt to link with each other have a low probability of colliding at every retransmission and therefore failing to link.

50.4.4.1 Turn-around times. After reception of a valid transmission, a terminal shall initiate the responding rf transmission no sooner than 1 second and no longer than 10 seconds after cessation of the received rf signal.

50.4.4.2 Response timeout. After each valid reception, the terminal shall establish a time at which it will take action if further valid receptions are not forthcoming. These times are different for transmit terminals and receive terminals. A further distinction must be made between acknowledged transmit terminals and prospective transmit terminals. When a receive terminal determines that it has traffic to send that is of equal or higher priority than the current transmit terminal (e.g., when such higher-priority traffic is delivered to it by a local user), it heralds this event following the next legitimate reception from the transmit terminal (see sec. 50.4.3.1). Until this receive terminal receives an acknowledgment of its new status, this terminal is a prospective transmit terminal. A terminal that has received acknowledgment of its transmit terminal status is an acknowledged transmit terminal. (Note that under certain conditions, there may be no acknowledged transmit terminal). During link establishment, terminals in the call acknowledge state act as either receive terminals (if not attempting reverse preemption) or as prospective transmit terminals (if preempting). Timeout values shall be set as follows for the interoperable mode (User ID = Ø)(par. 50.1.7.1):

a. After each legitimate reception, an acknowledged transmit terminal shall set a response timeout equal to the ending time of its responding transmission plus 25.4 s.
b. Following each retransmission (or the initial transmission of a data-ACK request), an acknowledged transmit terminal shall set its response timeout to the starting time of that transmission plus 48.8 s.

c. A prospective transmit terminal shall set its response timeout to 48.8 s after the starting time of its transmission, whether this transmission follows a legitimate reception or was a retransmission following a missed response.
d. A receive terminal shall set its response timeout following each legitimate reception from the transmit terminal to a value equal to the ending time of its transmission in response to the reception plus the estimated ending time of its next reception plus the most recent link timeout value received (Link Timeout field (par. 50.1.3.2) of the link management header) from the transmit terminal during the current link. If expecting a control frame, 25.4 s shall be allowed for the next transmission; otherwise (data series expected), the time allowed for the next transmission shall be the sum of a 10 s turnaround time plus N+1 interleaver times, where N is the number of interleavers of the size required to hold the announced data series.
e. After a call (or immediate mode transmission) a terminal shall set its timeout to be 25.4 s after the end of the first transmission. If no valid reception has occurred prior to this timeout, the terminal shall act IAW par. 50.4.4.4, below. After retransmissions, the timeout shall be set to the starting time of the retransmission plus either 48.8 s, 63.8 s, or 78.8 s. The choice among these three values shall be randomly generated in such a manner that each has approximately equal probability of being selected, with little correlation among the choices either at a single terminal or between pairs of terminals.

Terminals may use timings different from those above only if they have negotiated a non-zero User ID field code which is associated with different timing rules.

50.4.4.3 Link timeout. The link timeout shall be computed as the time from the end of the first transmission of a frame until all retransmissions that would result from no response to that frame have been completed, including the response timeout after the last retransmission, and accounting for any automatic data rate or interleaver changes that would be performed by that station.

50.4.4.4 Action following timeout. The action taken by a terminal when no legitimate response is received shall be as follows:

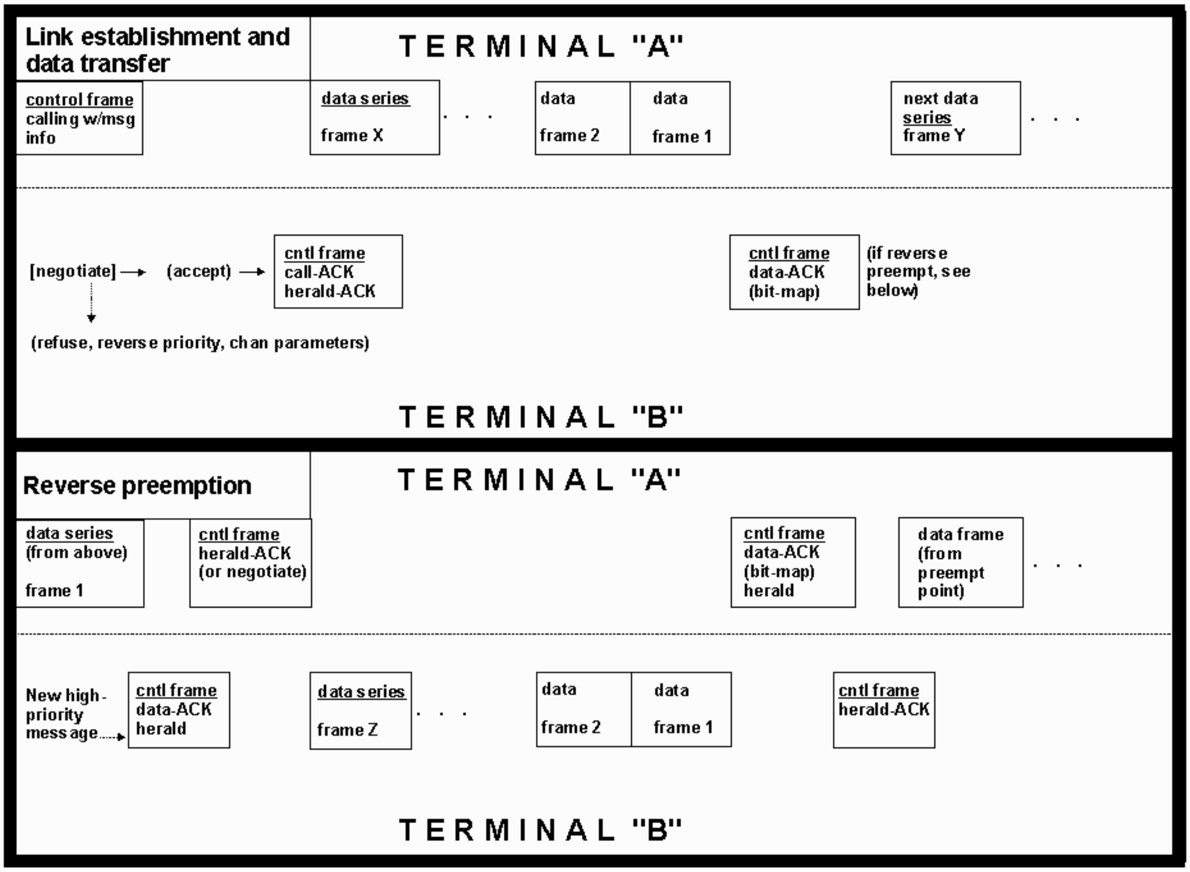
a. If a transmit terminal (acknowledged or prospective) has received no signal by the time specified by the response timeout, it shall decrement its internal retry countdown and transmit a frame that requests a retransmission from the other terminal. If the missing response is a data-ACK frame, the transmit terminal shall send a frame with the ACK/NAK Type field (par. 50.1.4.1) set to data-ACK request (value 2). If the missing response is a herald-ACK, it shall repeat the herald frame. If the missing response is that associated with a call (or an Immediate mode transmission), the repeated frame shall be the call (or the control frame with the ACK/NAK Type field set to data-ACK request (value 2) and the same herald that was transmitted at the start of the Immediate mode transmission).
b. If a transmit terminal (acknowledged or prospective) receives a transmission with an invalid CRC, including a transmission that begins before but concludes after the response timeout, it shall take the actions specified in the preceding paragraph, except that the transmission shall take place as soon as possible within the constraints imposed by par.

50.4.4.1.
c. Upon expiration of the link timeout, a transmit terminal shall either return to the idle state, discarding any unfinished message with notification to the (local) source of that message, or request re-establishment of the physical-layer link (possibly through an ALE controller) with the intent to resume the message if re-linking is successful.
d. A receive terminal that has not received a valid transmission prior to the expiration of its response timeout shall drop the link IAW par. 50.4.2.2. A receive terminal may respond immediately (within the constraints imposed by par. 50.4.4.1) to signals resulting in an invalid CRC, but the operator must be able to disable this function if provided. If the receive terminal is in the process of reception when the timeout expires, it shall complete the reception but shall drop the link if no valid CRC is obtained.
e. In general, whenever a terminal receives a valid transmission, it shall reset the response timeout as specified in par. 50.4.4.2.

50.4.5 Duplex operation. The formats and protocols for duplex operation shall be identical to those specified for simplex operations except that timeouts and retransmissions for one traffic direction must work around the data series transferred in the other direction. Simultaneous traffic should be supported whenever traffic of any priority exists at both terminals. Note that reverse link preemption is not needed in duplex operation.

50.5 Examples. Figure 18 illustrates typical data transfers over the data link. Each square on the figure represents a control or data frame.

[Figure 18](#). Examples of data transfers over the data link during DLP operation



Notes: Time moves from left to right (not to scale). Blocks indicate transmissions from each terminal.

Figure 18. Examples of data transfers over the data link during DLP operation

60. NOTES.

60.1 Implementation guidelines. Although the DLP has been designed to operate with any arbitrary modem waveform, it has been optimized to operate over HF radio channels with the inherent high error rate encountered on these channels. It is expected that the protocol will be most often used with the FED-STD-1052 serial (single-tone) waveform. The following paragraphs provide insight and guidance in implementing the DLP using the FED-STD-1052 serial (single-tone) modem waveform.

60.1.1 Adapting data rate. A simple but effective algorithm for adapting the data rate of the modem during data link operation is as follows:

a. If all of the frames are transferred without error, the data rate should be raised.

b. If fewer than 50% of the frames are transferred without error, the data rate should be lowered.

60.1.2 FED-STD-1052 serial (single-tone) interleaver capacity. Table XXX lists the capacity of the serial (single-tone) modem interleaver buffers as a function of interleaver size and data rate. The length of serial (single-tone) modem transmissions is always a mathematical integer of interleaver intervals. When calculating the transmission time of a block of data of a given length, one must take into consideration that in addition to the total number of interleaver intervals required to transmit the user data presented to the modem, the modem will precede the data transmission with a preamble phase equal to one interleaver interval and will append 176 bits to the user data. Table XXX lists the total capacity of the interleaver buffer for each data rate, the minimum number of interleaver intervals required to transmit the 176 postamble bits, and the number of bits remaining for user data within the minimum number of interleaver intervals after the postamble is accounted for.

TABLE XXX. Serial (single-tone) interleaver buffer capacity

Interleaver size	Data rate (b/s)	Bits per interleaver	Minimum number of interleavers	Information bits available in the minimum number of interleavers
Short (0.6 s)	75	45	4	4
	150	90	2	4
	300	180	1	4
	600	360	1	184
	1200	720	1	544
	2400	1440	1	1264
Long (4.8 s)	75	360	1	184
	150	720	1	544
	300	1440	1	1264
	600	2880	1	2704
	1200	5760	1	5584
	2400	11520	1	11344

FS-1052: Appendix C

APPENDIX C
SIXTEEN-TONE DIFFERENTIAL PHASE-SHIFT KEYING (DPSK) MODE

10. GENERAL

10.1 Scope. This appendix describes the sixteen-tone differential phase-shift keying (DPSK) mode.

10.2 Applicability. This appendix is a nonmandatory part of FED-STD-1052, however, when the optional 16-tone DPSK mode is used, it shall be implemented in accordance with this appendix.

20. APPLICABLE DOCUMENTS. See section 2.

30. DEFINITIONS. See section 3.

40. GENERAL REQUIREMENTS.

40.1 Introduction. The modulator accepts serial binary data signals at the input and converts this information into DPSK data tones transmitted at the modulator output. The input data signaling rate determines the type of modulation and the degree of in-band diversity that is used. The modulation rate of the modulator output signal is constant for all input signaling rates accepted by the modulator. The modulator-demodulator (modem) provides a means for synchronization and, if required, a separate tone for doppler correction. The demodulator accepts the DPSK data tones at the input and reconverts this information into serial binary data signals at the demodulator output.

40.2 Input/output data signaling rates. The modulator input shall accept, and the demodulator output shall deliver, a serial binary bit stream with standard data signaling rates ranging from 75 to 2400 bits per second (b/s).

50. DETAILED REQUIREMENTS

50.1 Modulator output signal. The modulator output signal shall contain 16 DPSK data tones (table XXXI). The 16 data tones shall be simultaneously keyed to produce a signal element interval of 13-1/3 milliseconds (ms) for each data tone. The composite modulator output signal shall have a constant modulation rate of 75 baud for all input data signaling rates from 75 to 2400 b/s. The modulator shall provide a separate tone combination to initiate synchronization and, if required, a separate tone for doppler correction.

TABLE XXXI. Data-tone frequencies and bit locations

		Even and odd bit locations of serial binary bit stream, encoded and phase modulated on each data tone employing:					
		Quadrature-phase modulation		Biphase modulation			
Tone frequency (hz)	Function	2400 b/s	1200 b/s	600 b/s	300 b/s	150 b/s	75 b/s
605	Continuous doppler tone		In-band diversity (see par. 50.6)				
825*	Synchronization slot						
935	Data tone 1	1 2	1 2	1	1	1	1
1045	Data tone 2	3 4	3 4	2	2	2	1
1155	Data tone 3	5 6	5 6	3	3	1	1
1265	Data tone 4	7 8	7 8	4	4	2	1
1375	Data tone 5	9 10	9 10	5	1	1	1
1485	Data tone 6	11 12	11 12	6	2	2	1
1595	Data tone 7	13 14	13 14	7	3	1	1
1705	Data tone 8	15 16	15 16	8	4	2	1
1815	Data tone 9	17 18	1 2	1	1	1	1
1925	Data tone 10	19 20	3 4	2	2	2	1
2035	Data tone 11	21 22	5 6	3	3	1	1
2145	Data tone 12	23 24	7 8	4	4	2	1
2255	Data tone 13	25 26	9 10	5	1	1	1
2365	Data tone 14	27 28	11 12	6	2	2	1
2475	Data tone 15	29 30	13 14	7	3	1	1
2585	Data tone 16	31 32	15 16	8	4	2	1
* No tone is transmitted at this frequency (see par. 50.4).							

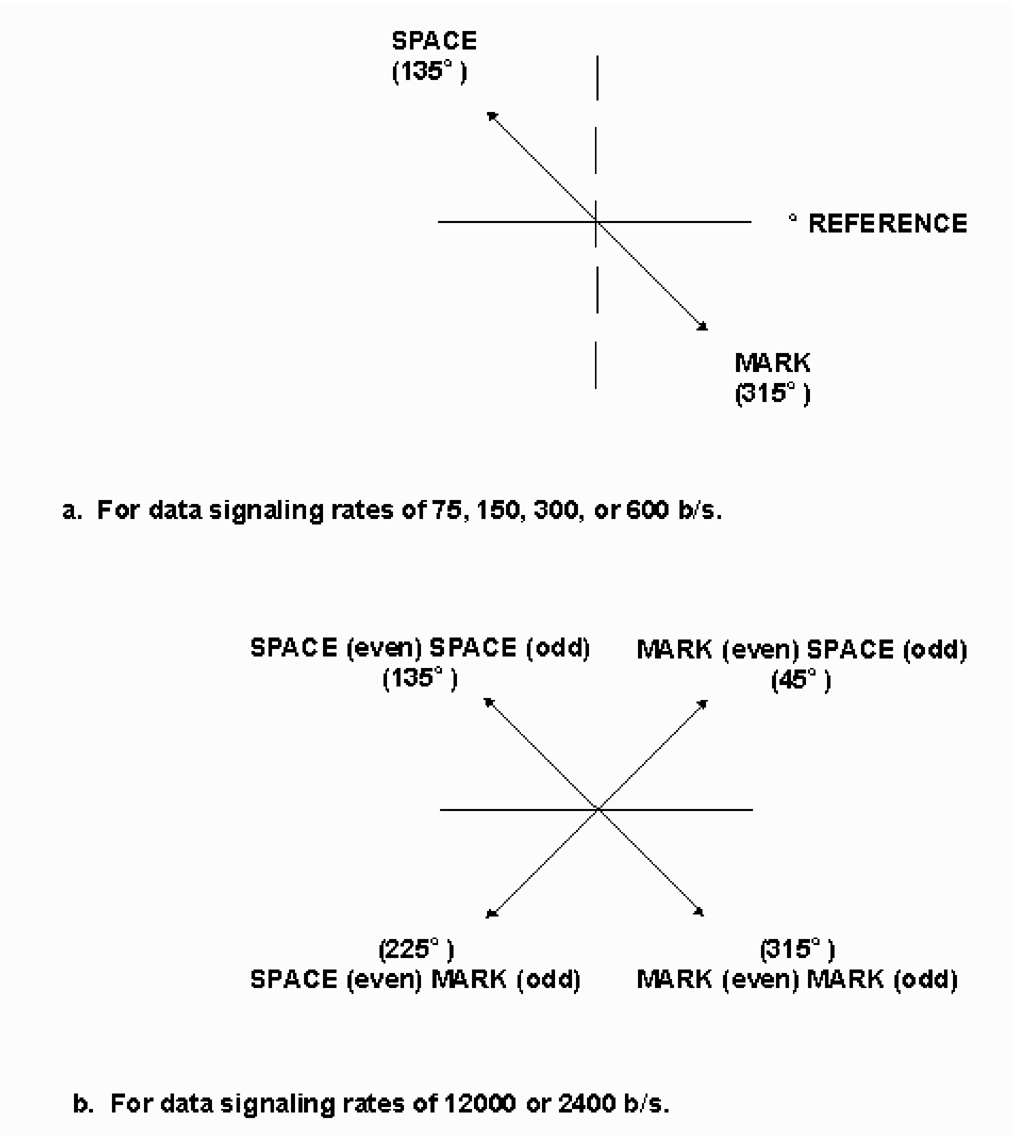
50.2 Data tone frequencies. The frequency of each data tone shall be as listed in Table XXXII. The tone frequencies shall maintain an accuracy of ±0.1 hertz (Hz).

TABLE XXXII. Modulation characteristics

<table>
<tr><th rowspan="2">Input data signaling rate (b/s)</th><th rowspan="2">Degree of in-band diversity combining</th><th rowspan="2">Type of modulation</th><th colspan="2">Logic sense of dibits or bits in serial binary bit stream depending on:</th><th rowspan="2">Phase (in degrees) of data tone signal element relative to phase of preceding signal element</th></tr>
<tr><th>Even bit locations</th><th>Odd bit locations</th></tr>
<tr><td rowspan="2">2400</td><td rowspan="2">N/A</td><td rowspan="4">Four-phase</td><td>MARK</td><td>SPACE</td><td>+45</td></tr>
<tr><td>SPACE</td><td>SPACE</td><td>+135</td></tr>
<tr><td rowspan="2">1200</td><td rowspan="2">2</td><td>SPACE</td><td>MARK</td><td>+225</td></tr>
<tr><td>MARK</td><td>MARK</td><td>+315</td></tr>
<tr><td>600</td><td>2</td><td rowspan="4">Two-phase</td><td colspan="2" rowspan="2">MARK*</td><td rowspan="2">+315</td></tr>
<tr><td>300</td><td>4</td></tr>
<tr><td>150</td><td>8</td><td colspan="2" rowspan="2">SPACE*</td><td rowspan="2">+135</td></tr>
<tr><td>75</td><td>16</td></tr>
<tr><td colspan="6">* Regardless of even or odd bit locations.</td></tr>
</table>

50.3 Phase modulation and encoding. For data signaling rates of 75, 150, 300, or 600 b/s at the modulator input, each data tone signal element shall be two-phase (biphase) modulated as shown on Figure 19a. Each bit of the serial binary input signal shall be encoded, depending on the MARK or SPACE logic sense of the bit, into a phase change of the data tone signal element as listed in table XXXII. For data signaling rates of 1200 or 2400 b/s at the modulator input, each data tone signal element shall be four-phase (quadrature-phase) modulated as shown on Figure 19b. Each dibit of the serial binary input signal shall be encoded, depending on the MARK or SPACE logic sense and the even or odd bit location of each bit, into a phase change of the data tone signal element as listed in Table XXXII. The phase changes of the data tone signal elements specified in Table XXXII shall be relative to the phase of the immediately preceding signal element.

Figure 19. Phase modulation vectors for 16-tone DPSK data modem



50.4 Synchronization. Upon receipt of a transmit command, the modem shall initiate a synchronization preamble. The preamble shall consist of two tones with frequencies of 605 Hz and 1705 Hz, for a minimum duration of 66-2/3 ms, corresponding to a duration of 5 to 32 data tone signal elements. The 605 Hz tone shall unmodulated and used for doppler correction, if required. The 1705 Hz tone shall be phase shifted 180 degrees for each data tone signal element and shall be used to obtain proper modem synchronization by the demodulator. During the preamble, the transmitted level of the 605 Hz tone shall be 7 decibels (dB) (±1 dB) higher than the level of the 1705 Hz tone. The composite transmitted signal level of the 605 Hz and 1705 Hz tones during the preamble shall have a root-mean-square (rms) value within ±1 dB of the rms value of the modulator output signal level during data transmission when all 16 data tones plus doppler correction tone are transmitted. At the completion of the preamble, all data tones shall be transmitted for the duration of one signal element (13-1/3 ms) prior to the transmission of data to establish a phase reference. During data transmission, synchronization shall be maintained by sampling the signal energy in the 825 Hz synchronization slot. No tone shall be transmitted in the synchronization slot of 825 Hz.

50.5 Doppler correction. For those applications where a doppler correction capability is required, a tone with a frequency of 605 Hz shall be used. The level of the 605 Hz tone shall be 7 dB (±1 dB) higher than the normal level of any one of the subcarriers.

50.6 In-band diversity combining. In-band diversity combining shall be accomplished at data signaling rates from 75 b/s to 1200 b/s. The data tones shall be combined in accordance with table XXXI. The degree of diversity combining shall be as listed in Table XXXII.

50.7 Demodulator signal alarm. Provisions shall be made in the demodulator to activate an alarm when the incoming signal from the HF radio link decreases below a preset level.

NOTE: The specific techniques and levels to be used for the demodulator signal alarm are not standardized and should be defined in applicable modem specifications.