DEFENSE INFORMATION SYSTEMS AGENCY

JOINT INTEROPERABILITY TEST COMMAND
FORT HUACHUCA, ARIZONA

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

MIL-STD-188-110B CONFORMANCE TEST PROCEDURES

JULY 2004

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MIL-STD-188-110B
CONFORMANCE
TEST PROCEDURES

JULY 2004

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INTRODUCTION

Military Standard (MIL-STD)-188-110B replaces MIL-STD-188-110A for establishing mandatory technical standards and design objectives that are necessary to ensure interoperability and to promote performance among data modulators-demodulators (modems) used in the voice frequency band of long-haul and tactical communications systems.

This document contains the test procedures that will establish the technical standards and design objectives for minimum interface and performance standards for voice frequency band modems that operate in both long-haul and tactical communications systems. This test plan is intended to be generic. It can be used to test any equipment that requires conformance to MIL-STD-188-110B.

If test item performance does not meet a requirement, the failure and its potential operational impact will be discussed in the follow-on test report and/or certification letter. Any requirement capabilities that are not implemented will also be discussed.

The Joint Interoperability Test Command will conduct testing at Fort Huachuca, Arizona.

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TEST PROCEDURES

SUBTEST 1. MODULATION RATES, DATA RATES, TIMING, AND SYNCHRONIZATION

1.1 Objective. To determine the extent of compliance to the requirements of Military Standard (MIL-STD)-188-110B, reference numbers 1-2, 7-10, 12-14, 18, and 27.

1.2 Criteria

a. Modulation and data signaling rates and tolerance. The modulation rates expressed in baud (Bd) and the data signaling rates expressed in bits per second (bps) at the standard interfaces shown on figure 1 of MIL-STD-188-110B shall be as listed below. These rates, with the exception of 50 Bd or bps, 75, 150, 300, and 600 bps, comply with the requirements of Federal Information Processing Standard Publication (FIPS PUB) 22-1: (1) 50 Bd or bps and (2) 75 X 2^m Bd or bps, up to and including 9600 Bd or bps, where m is a positive integer 0, 1, 2, … 7.

Except where specified otherwise, signaling rates shall not deviate from the nominal values by more than plus or minus (±) 0.01 percent.

Note: The data signaling rate is expressed in bps; the modulation rate is expressed in Bd. Data signaling rates in bps and modulation rates in Bd are the same only for binary signaling. Data signaling rates in bps relate to modulation rates in Bd through the following equation:

$$\text{Data signaling rates (bps)} = k \times \text{modulation rates (Bd)}$$

where $k = \log_2 M$ is the number of binary digits per modulation symbol, and M is the number of modulation symbols, MIL-STD-188-110B, paragraph 4.2.1.

b. 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 MIL-STD-188-110B, table 2, 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, MIL-STD-188-110B, paragraph 4.2.2.

c. Bit synchronous. In bit synchronous operation, clock timing shall be delivered at twice the data modulation rate. (For this purpose “data” includes information bits plus all bits added to the stream for whatever purpose they may serve in the system; i.e., error control, framing, etc.) The device shall release one bit within the duration of one clock cycle. It shall be assumed that, during periods of communication difficulty, a clock signal might be delivered to a send device occasionally or not at all for periods extending to hours. During periods when the sending equipment has no traffic to send, an idle pattern or all “ones” may be transmitted, MIL-STD-188-110B, paragraph 4.2.6.1.1.

d. Bit-by-bit asynchronous. In bit-by-bit asynchronous operation, it is assumed that rapid manual, semi-automatic, or automatic shifts in the data modulation rate will be accomplished by gating or slewing the clock modulation rate. It is possible that equipment may be operated at 50 bps one moment and the next moment at 1200 bps or 2400 bps, etc. It shall be assumed that, during periods of communication difficulty, a clock signal might be delivered to a send device occasionally or not at all for periods extending to hours. During periods when the sending equipment has no traffic to send, an idle pattern or all “ones” may be transmitted, MIL-STD-188-110B, paragraph 4.2.6.1.2.

e. Character interval synchronous. In character interval synchronized equipment, any character interval from 4 to 16 unit intervals per character interval shall be permitted. It is assumed that, having programmed a given facility for a particular character interval, no other character interval operation would be expected except by reprogramming. An example of such operation would be a 7.0 units per character interval tape reader being stepped at 8.0 units per character interval, MIL-STD-188-110B, paragraph 4.2.6.1.3.

f. Modulation rates. The standard clock modulation rates for compatibility with modulation or data signaling rates shall be two times the standard rates specified in MIL-STD-188-110B, subparagraph 4.2.1, MIL-STD-188-110B, paragraph 4.2.6.2.1.

g. Modulation rate stability. The stability of synchronized or crook timing, supplied in all synchronous digital transmission, switching, terminal, and security equipment, shall be sufficient to ensure that synchronization (sync) is maintained. Synchronization shall be within ±25 percent of the unit interval between transmitted and received signals for periods of not less than 100,000 consecutive seconds, MIL-STD-188-110B, paragraph 4.2.6.2.2.

h. Output signal. The output of the clock shall be an alternating symmetrically shaped wave at the required clock modulation rate. In the case of an unbalanced digital interface, the clock output signal shall comply with the voltage and wave-shaping requirement of MIL-STD-188-110B, subparagraphs 4.3.1.3.3.4 and 4.3.1.3.3.5, respectively. In the case of a balanced digital interface, the clock output signal shall comply with the voltage requirements of MIL-STD-188-110B, subparagraph 4.3.1.3.4.4, and shall contain no points of inflection prior to reaching the maximum amplitudes. When the clock is quiescent, the clock signal state shall be negative, MIL-STD-188-110B, paragraph 4.2.6.2.4.

i. Clock period. A clock period or cycle is defined as having one half-cycle of positive polarity (sense) and one half-cycle of negative polarity (sense). The duty cycle shall be 60 percent ±1.0 percent. Thus, in the binary sense, each clock period or cycle is composed of two clock unit intervals, and it follows that a clock rate of 50 hertz (Hz) is a clock modulation rate of 100 Bd, MIL-STD-188-110B, paragraph 4.2.6.2.5.

j. Clock/data phase relationship. Arrangements that may be used to supply clock pulses to sources and synchronizations are shown in MIL-STD-188-110B, subparagraph 4.3.1.6.3.1. Typical standard arrangements are shown from which one may be selected to meet a specific application. For those digital devices operated at direct current baseband which are interconnected by metallic wire (or other equipment that provides in effect the same function as a metallic wire), the following clock/data phase relationships apply only if, and only if, interface circuit lengths permit. Due to signal propagation delay time differences over different direct current wire circuits or direct current equivalent circuits at data modulation rates higher than 2400 Bd, there may be a significant relative clock/data phase-shift that must be adjusted in accordance with MIL-STD-188-110B, subparagraph 4.3.1.6.2.3. Practical operating experience indicates that typical multiple pair paper cable or polyvinyl chloride (PVC) insulated exchange grade telephone cable may be expected to function at modulation rates of 4800 Bd data/9600 Bd clock. The distance may be up to 3000 cable feet without any need for concern over relative pulse shift or noise if the standard low level digital interface is applied to both clock and data signals in accordance with MIL-STD-188-110B, subparagraph 4 3.1.3.

All data transition emitted by a source under direct control of an external clock shall occur on (be caused by) negative to positive transitions of that clock. The Design Objective (DO) is a minimum delay between the clock transition and the resulting data transition, but in no case shall this delay exceed 12.5 percent of the duration of the data unit interval. Once this delay is fixed in the equipment hardware, it shall be consistent within ±1 percent of itself for each clock transition. These delay limits shall apply directly at the driver interface.

Sampling of the data signal by the external clock at a synchronous interface shall occur on (be caused by) positive to negative clock transitions. When the clock is used for controlling intermittent data transmission, data may not change state except when requested by a negative to positive clock transition. The quiescent state of the clock shall be at negative voltage. The quiescent state of the data shall be that state resulting from the last negative to positive clock transition.

The phase relationship between external clock and data is not specified for devices in which the external clock is related only indirectly to the source data; for example, to maintain synchronism between a data source and data sync for a signal with a constant modulation rate. However, whatever the phase delay, it shall be consistent to within ±1 percent at the data unit interval at the applicable modulation rate. If the clock is also supplied as an output at twice the modulation rate at the same data, data transitions shall coincide within ±1 percent of the data unit interval with the negative to positive transitions of the output clock (see MIL-STD-188-110B, figure 4.3-9). Direct control means control of the data by a clock signal at twice the modulation rate of the data. Indirect control means use of a clock at some higher standard modulation rate; e.g., 4, 8, or 128 times the modulation rate, MIL-STD-188-110B, paragraph 4.2.6.3.

k. Frequency Shift Keying (FSK) data modems for Voice Frequency (VF) channel operation. Non-diversity FSK modems used primarily in point-to-point (switched or non-switched) connections over VF channels shall comply with the applicable requirements of MIL-STD-188-110B, paragraphs 4.2-4.3 and 5.2.1-5.2.2.2. The modems shall exhibit a Bit Error Rate (BER) of not more than 1 bit error in 10^5 (DO: 10^6) data bits 99 percent of the time when operating over a military C1 type circuit as defined in Defense Information Systems Agency Circular (DISAC) 300-175-9. As a DO, during 99 percent of the time that the network is in use, the user throughput should be equal to or greater than 50 percent, MIL-STD-188-110B, paragraph 5.2.

l. Remote control interface. A remote control interface is mandatory for all new procurements of High Frequency (HF) data modems, MIL-STD-188-110B, paragraph 5.3.1.5.

1.3 Test Procedures

a. Test Equipment Required

(1) Bit Error Rate Tester (BERT) (2 each [ea])

(2) Oscilloscope

(3) Modem

(4) Unit Under Test (UUT)

b. Test Configuration. Figures 1.1, 1.2, 1.3, and 1.4 show the equipment setup for this subtest.

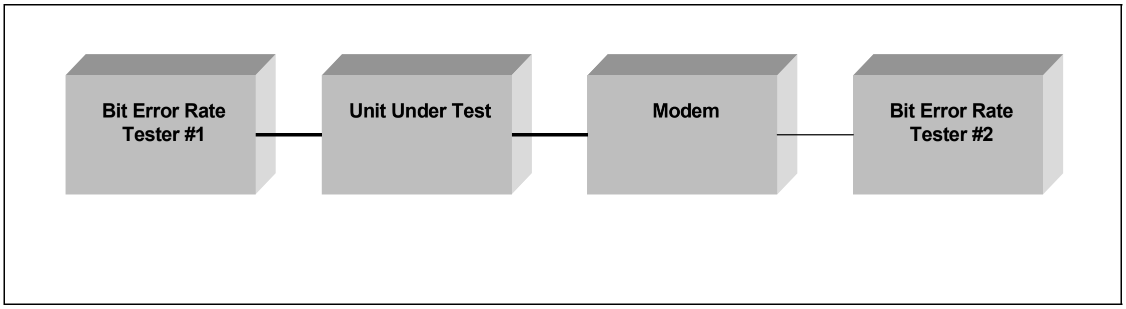

Figure 1.1. Equipment Configuration for Modulation Rate Test

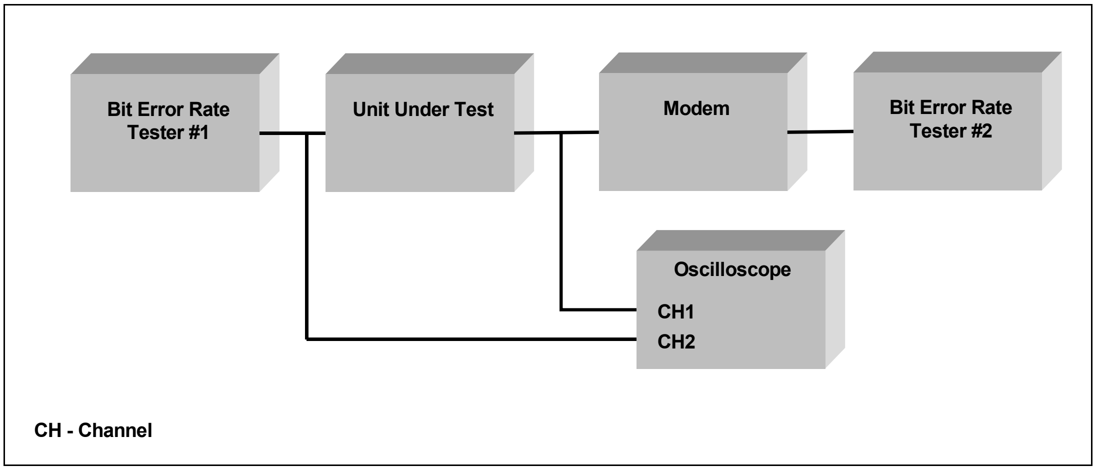

Figure 1.2. Equipment Configuration for Data Signaling Rate Test

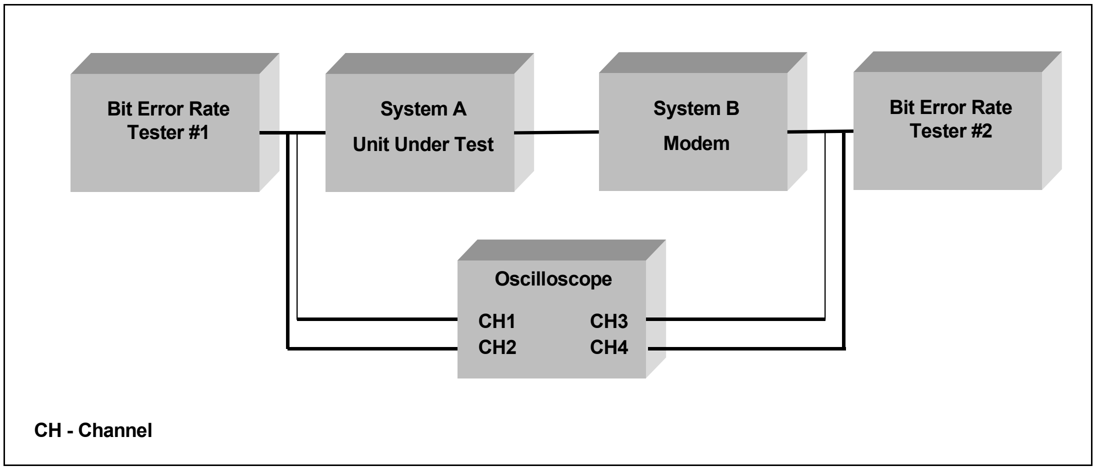

Figure 1.3. Equipment Configuration for Clock and Timing Test

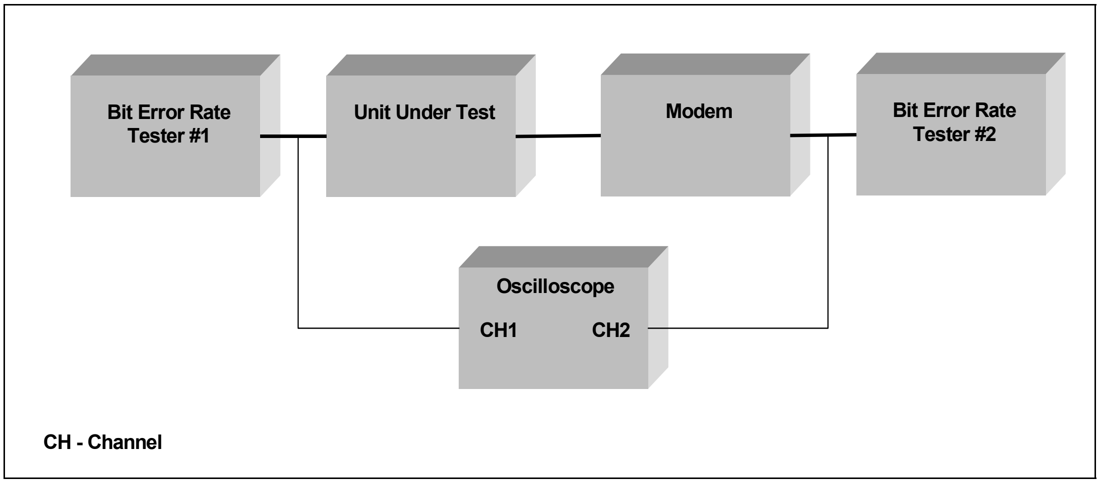

Figure 1.4. Equipment Configuration for Synchronization Test

c. Test Conduct. The procedures for this subtest are listed in tables 1.1 and 1.2.

Table 1.1. Procedures for Modulation Rate and Data Signaling Rate Test

Step	Action	Settings/Action	Result
The following procedure is for reference number 1.			
1	Set up equipment.	See figure 1.1.	
2	Connect modems and BERTs through DCE/DTE ports.		
3	Use BERT 1 to transmit a 2047 test pattern at 50 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
4	Use BERT 1 to transmit a 2047 test pattern at 75 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
5	Use BERT 1 to transmit a 2047 test pattern at 150 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
6	Use BERT 1 to transmit a 2047 test pattern at 300 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
7	Use BERT 1 to transmit a 2047 test pattern at 600 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
8	Use BERT 1 to transmit a 2047 test pattern at 1200 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
9	Use BERT 1 to transmit a 2047 test pattern at 2400 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
10	Use BERT 1 to transmit a 2047 test pattern at 4800 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
11	Use BERT 1 to transmit a 2047 test pattern at 9600 Bd for 1 minute.	Use BERT 2 to receive the 2047 test pattern. Record BER.	
The following procedure is for reference numbers 1 and 9.			
12	Set up equipment.	See figure 1.2.	
13	Connect channel 1 of oscilloscope to the modulator output of UUT. Connect channel 2 to the TX Clock line going into the UUT.		
14	Program UUT to transmit a 2047 test pattern at 50 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
15	Program UUT to transmit a 2047 test pattern at 75 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
16	Program UUT to transmit a 2047 test pattern at 150 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
17	Program UUT to transmit a 2047 test pattern at 300 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	

Table 1.1. Procedures for Modulation Rate and Data Signaling Rate Test (continued)

Step	Action	Settings/Action	Result
18	Program UUT to transmit a 2047 test pattern at 600 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
19	Program UUT to transmit a 2047 test pattern at 1200 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
20	Program UUT to transmit a 2047 test pattern at 2400 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
21	Program UUT to transmit a 2047 test pattern at 4800 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
22	Program UUT to transmit a 2047 test pattern at 9600 bps.	Use the oscilloscope to measure the clock frequency into the UUT and the frequency of the signal out of the UUT. Record results.	
The following procedure is for reference number 2.			
23	Connect oscilloscope channel 1 to the modulator output of the UUT. Connect channel 2 to the TX DATA port into the UUT.	See figure 1.2.	
24	Configure BERT 1 to transmit a MARK.		
25	Configure both modems for wireline FSK synchronous operation at 1200 bps with a transmit center frequency of 1700 Hz and shift of 800 Hz.		
26	Display a MARK frequency on the oscilloscope.	Verify when the TX DATA (CH 1) is negative (MARK), the modulator output frequency (CH 2) is 1300 Hz.	
27	Configure BERT 1 to transmit a SPACE.		
28	Display a SPACE frequency on the oscilloscope.	Verify when the TX DATA (CH 1) is negative (SPACE), the modulator output frequency is 2100 Hz.	
29	Configure BERT 1 to transmit a 2047 test pattern.	Verify that BERT 2 receives valid data. Record results.	

LEGEND:

BER – Bit Error Rate
BERT – Bit Error Rate Tester
Bd – baud
bps – bits per second
CH– Channel
DCE – Data Circuit-Terminating Equipment
DTE – Data Terminal Equipment
FSK – Frequency Shift Keying
Hz – hertz
Tx – Transmit
UUT – Unit Under Test

Table 1.2. Procedures for Clock, Timing, and Synchronization Test

Step	Action	Settings/Action	Result
The following procedure is for reference numbers 7, 12, and 13.			
1	Set up equipment as shown in figure 1.3.	Connect the 4 channel oscilloscope to monitor clock and data: CH 1: TX DATA of system A CH 2: TX CLOCK of system A CH 3: RX DATA of system B CH 4: RX CLOCK of system B	
2	Program BERT 1 to send a 1:1 data pattern.	Program modems to send data at 50 bps.	
3	Measure the frequency and duty cycle of both the TX and RX clock pulses.	A clock period or cycle is defined as having one half-cycle of positive polarity (sense) and one half-cycle of negative polarity (sense). It follows that a clock rate of 50 Hz is a clock modulation rate of 100 baud.	
4	Observe the relationship between the data and the clock pulses.	Expected: One data bit for every clock pulse. The output of the clock should be an alternating symmetrically shaped wave at the required modulation rate.	
5	Program modems to send data at 600 bps.		
6	Measure the frequency and duty cycle of both the TX and RX clock pulses.	A clock period or cycle is defined as having one half-cycle of positive polarity (sense) and one half-cycle of negative polarity (sense). It follows that a clock rate of 50 Hz is a clock modulation rate of 100 Bd.	
7	Observe the relationship between the data and the clock pulses.	Expected: One data bit for every clock pulse. The output of the clock should be an alternating symmetrically shaped wave at the required modulation rate.	
8	Program modems to send data at 2400 bps.		
9	Measure the frequency and duty cycle of both the TX and RX clock pulses.	A clock period or cycle is defined as having one half-cycle of positive polarity (sense) and one half-cycle of negative polarity (sense). It follows that a clock rate of 50 Hz is a clock modulation rate of 100 Bd.	
10	Observe the relationship between the data and the clock pulses.	Expected: One data bit for every clock pulse. The output of the clock should be an alternating symmetrically shaped wave at the required modulation rate.	

Table 1.2. Procedures for Clock, Timing, and Synchronization Test (continued)

Step	Action	Settings/Action	Result
The following procedure is for reference number 14.			
11	Record at what part of the clock transition the data transition occurs.		
12	Toggle the RUN/STOP button on the oscilloscope to freeze the display and measure the delay between the clock transition and the resulting data transition. (Modem should send data at 2400 bps.)	Repeat this measurement 50 times.	1:
The following procedure is for reference number 8.			
13	If UUT is character interval synchronized equipment, verify by programming that any character interval from 4 to 16 unit intervals per character interval is permitted.		
The following procedure is for reference number 18.			
14	Step 15 is applicable only if the UUT is a non-diversity FSK modem used primarily in point-to-point connections over VF channels.		
15	Send FSK data from UUT to BERT 2 at the highest data rate available for 15 minutes.	Record the BER measured by BERT at the end of the 15-minute period.	
The following procedure is for reference number 10.			
16	Set up equipment.	See figure 1.4.	
17	Set up BERT 1 to send a 2047 test pattern.		
18	Set up BERT 2.	Program to measure PATL SEC. This gives the number of seconds during which the receiver is not in continuous pattern synchronization.	
19	Set up UUT.	Program to send synchronous data.	
20	Send synchronous data from UUT to BERT for a period of 28 hours.		
21	Record the number of seconds measured by the BERT during which the receiver was not in continuous pattern synchronization.	If the result is zero, skip step 22.	
22	Set up oscilloscope to monitor data on channels 1 and 2.	Use oscilloscope markers to verify that the time difference between the transmitted and received data is within ±25% of the unit interval.	

Table 1.2. Procedures for Clock, Timing, and Synchronization Test (continued)

Step	Action	Settings/Action	Result
The following procedure is for reference number 27.			
23	Verify that the UUT is capable of remote control operation.		

LEGEND:

Bd – baud
CH – Channel
PATL SEC – Pattern Sync Loss Seconds
TX – Transmit
BER – Bit Error Rate
FSK – Frequency Shift Keying
RX – Receive
UUT – Unit Under Test
BERT – Bit Error Rate Tester
Hz – hertz
Sync – Synchronization
VF – Voice Frequency
bps – bits per second

1.4 Presentation of Results. The results will be shown in table 1.3 indicating the requirement and measured value or indications of capability.

Table 1.3. Modulation Rate, Data Rate, Clock, and Timing Results

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
1	4.2.1	Modulation and data signaling rates and tolerance. The modulation rates expressed in baud (Bd) and the data signaling rates expressed in bits per second (bps) at the standard interfaces shown on figure 1 shall be as listed below. These rates, with the exception of 50 Bd or bps, 75, 150, 300, and 600 bps, comply with the requirements of FIPS-PUB-22-1: 1. 50 Bd or bps b. 75 X 2^m Bd or bps, up to and including 9600 Bd or bps, where m is a positive integer 0, 1, 2, … 7. Except where specified otherwise, signaling rates shall not deviate from the nominal values by more than ±0.01%.	75 X 2^m Bd ±0.01%			

Table 1.3. Modulation Rate, Data Rate, Clock, and Timing Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
2	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 2 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.	MARK-neg SPACE-pos Interface with MARK-pos SPACE-neg			
7	4.2.6.1.1	Bit synchronous. In bit synchronous operation, clock timing shall be delivered at twice the data modulation rate. (For this purpose “data” includes information bits plus all bits added to the stream for whatever purpose they may serve in the system; i.e., error control, framing, etc.). The device shall release one bit within the duration of one clock cycle. It shall be assumed that, during periods of communication difficulty, a clock signal might be delivered to a send device occasionally or not at all for periods extending to hours. During periods when the sending equipment has no traffic to send, an idle pattern or all “ones” may be transmitted.	Clock rate = data rate X 2			

Table 1.3. Modulation Rate, Data Rate, Clock, and Timing Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
8	4.2.6.1.3	Character interval synchronous. In character interval synchronized equipment, any character interval from 4 to 16 unit intervals per character interval shall be permitted. It is assumed that, having programmed a given facility for a particular character interval, no other character interval operation would be expected except by reprogramming. An example of such operation would be 7.0 units per character interval tape reader being stepped at 8.0 units per character interval.	Character interval from 4 to 16 unit intervals per character interval.			
9	4.2.6.2.1	Modulation rates. The standard clock modulation rates for compatibility with modulation or data signaling rates shall be two times the standard rates specified in subparagraph 4.2.1.	Two times standard rates.			
10	4.2.6.2.2	Modulation rate stability. The stability of synchronized or crook timing supplied in all synchronous digital transmission, switching, terminal, and security equipment shall be sufficient to ensure that synchronization is maintained within ±25 percent of the unit interval between transmitted and received signals for periods of not less than 100,000 consecutive seconds.	±25%			

Table 1.3. Modulation Rate, Data Rate, Clock, and Timing Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
12	4.2.6.2.4	Output signal. The output of the clock shall be an alternating symmetrically-shaped wave at the required clock modulation rate. In the case of an unbalanced digital interface, the clock output signal shall comply with the voltage and wave-shaping requirement of subparagraphs 4.3.1.3.3.4 and 4.3.1.3.3.5, respectively. In the case of a balanced digital interface, the clock output signal shall comply with the voltage requirements of subparagraph 4.3.1.3.4.4 and shall contain no points of inflection prior to reaching the maximum amplitudes. When the clock is quiescent, the clock signal state shall be negative. When the clock is quiescent, the clock signal state is negative.	Alternating symmetrical wave at required clock modulation rate.			
13	4.2.6.2.5	Clock period. A clock period or cycle is defined as having one half-cycle of positive polarity (sense) and one half-cycle of negative polarity (sense). The duty cycle shall be 60 percent ±1.0 percent. Thus, in the binary sense, each clock period or cycle is composed of two clock unit intervals, and it follows that a clock rate of 50 Hz is a clock modulation rate of 100 Bd.	60% ±1.0%			

Table 1.3. Modulation Rate, Data Rate, Clock, and Timing Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
18	5.2	FSK data modems for voice frequency (VF) channel operation. Non-diversity FSK modems used primarily in point-to-point (switched or non-switched) connections over VF channels shall comply with the applicable requirements of 4.2, 4.3, and 5.2.1 through 5.2.2.2. The modems shall exhibit a Bit Error Rate (BER) of not more than 1 bit error in 10^5 (design objective (DO): 10^6) data bits 99 percent of the time when operating over a military C1 type circuit as defined in Defense Information Systems Agency Circular (DISAC) 300-175-9. As a DO, during 99 percent of the time that the network is in use the user throughput should be equal to or greater than 50 percent.	BER of not more than 1 bit error in 10^5 data bits 99% of the time.			
27	5.3.1.5	Remote control interface. A remote control interface is mandatory for all new procurements of HF data modems.	Provide remote control interface.			

LEGEND:

Bd – baud	DO – Design Objective	Hz – hertz
BER – Bit Error Rate	FIPS PUB – Federal Information Processing Standard Publication	neg – negative
bps – bits per second	FSK – Frequency Shift Keying	pos – positive
DISAC – Defense Information Systems Agency Circular	HF – High Frequency	STANAG – Standardization Agreement
		VF – Voice Frequency

SUBTEST 2. MODEM IMPEDANCE

2.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B, reference numbers 4, 5, and 6.

2.2 Criteria

a. Modems used in multi-channel subsystems. For modems used in long-haul systems and in tactical subsystem types I, II, and III (see table 3), the terminal impedance at the modulator output and the demodulator input shall be 600 ohms, balanced to ground, with a minimum return loss of 26 decibels (dB) against a 600-ohm resistance over the frequency band of interest. The electrical symmetry shall be sufficient to suppress longitudinal currents to a level that is at least 40 dB below reference level (-40 decibels referenced to 1 milliwatt [dBm] measured at zero transmission level point [dBm0]), MIL-STD-188-110B, paragraph 4.2.4.1.

b. Modems used in single channel radio subsystems. For modems used with radio equipment of single channel radio subsystems, the terminal impedance at the modulator output shall be 150 ohms, unbalanced to ground, with a minimum return loss of 20 dB against a 150-ohm resistance over the frequency band of interest. The terminal impedance at the demodulator input shall be 600 ohms, balanced to ground, with a minimum return loss of 26 dB against a 600-ohm resistance over the frequency band of interest. The electrical symmetry shall be sufficient to suppress longitudinal currents to a level that is at least 40 dB below reference level (-40 dBm0), MIL-STD-188-110B, paragraph 4.2.4.2.

c. Modems used in multi-channel subsystems. For modems used in long-haul systems and in tactical subsystem types I, II, and III (see table 3), the quasi-analog signal level at the modulator output shall be adjustable from at least -18 dBm to +3 dBm. The difference in the output levels between the MARK and SPACE binary signals shall be less than 1 dB. The demodulator shall be capable of operating, without degradation of performance, with a received quasi-analog signal level ranging from at least -35 dBm to +3 dBm.

(1) For long-haul systems and tactical subsystem types I and III, the transmitted quasi-analog signal level of telegraph and data equipment (modem, multiplexer, etc.) shall be adjustable from at least -18 dBm to +3 dBm to provide -13 dBm0 (e.g., -13 dBm at a zero transmission level point) at the input terminals of a data trunk or switch. For multitone data signals, the level of each data tone with reference to -13 dBm shall be equal to -13 - (10 log t), measured in dBm, where t is the number of tones.

(2) For tactical subsystem type II, the transmitted quasi-analog signal level of telegraph and data equipment (modem, multiplexer, etc.) shall be adjustable from at least -18 dBm to +3 dBm to provide -6 dBm0 (e.g., –10 dBm at a - 4 transmission level point (TLP)) at the input terminals of a data trunk or switch. For

multitone data signals, the level of each data tone with reference to -10 dBm shall be equal to -10 - (10 log t), measured in dBm, where t is the number of tones, MIL-STD-188-110B, paragraph 4.2.5.1.

2.3 Test Procedures

a. Test Equipment Required

(1) Audio Voltmeter (2 ea)

(2) Transformer

(3) Audio Generator

(4) Resistor

(5) Multimeter

(6) UUT

(7) Audio Analyzer

(8) BERT

(9) Modem

(10) Spectrum Analyzer

b. Test Configuration. Figures 2.1, 2.2, 2.3, and 2.4 show the equipment setup for this subtest.

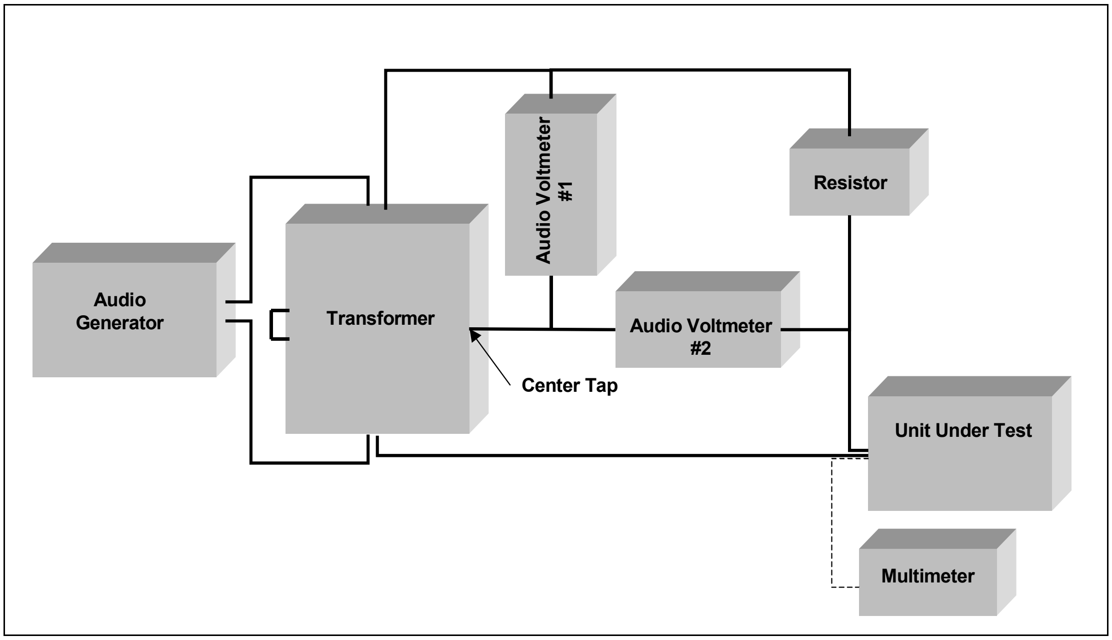

Figure 2.1. Equipment Configuration for Demodulator Input Impedance and Return Loss

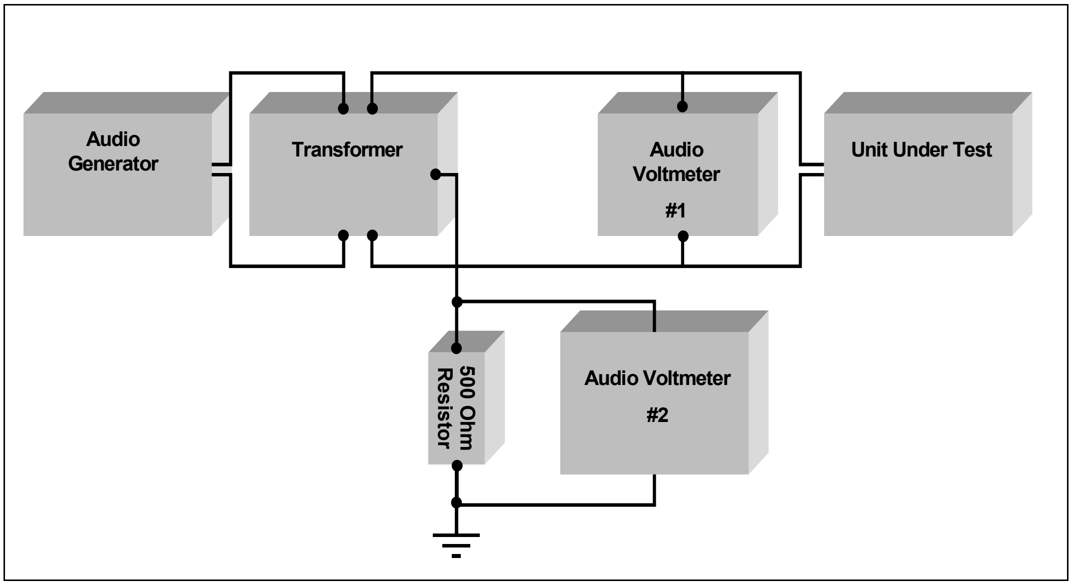

Figure 2.2. Equipment Configuration for Measuring Longitudinal Current Suppression

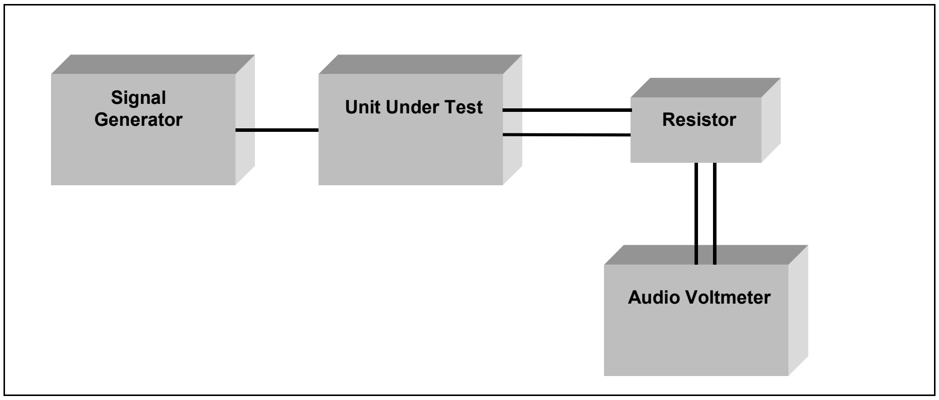

Figure 2.3. Equipment Configuration for Measuring Modulator Output Impedance

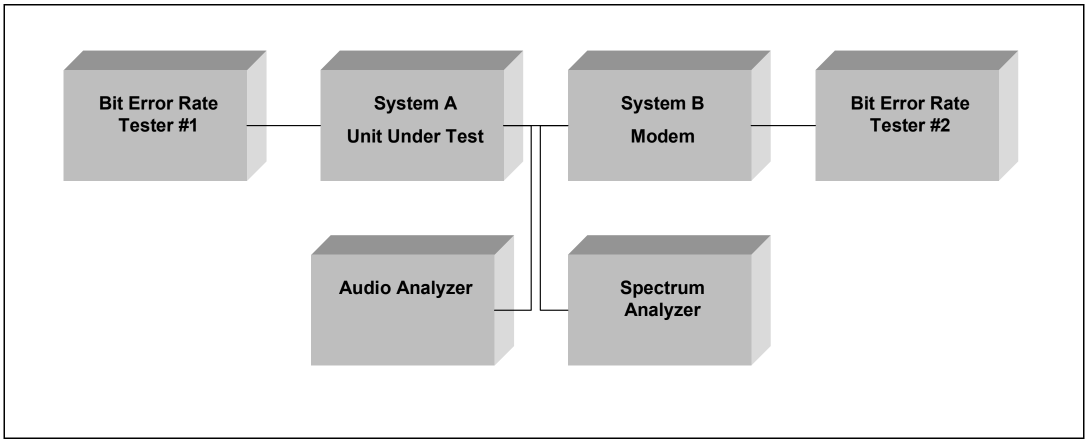

Figure 2.4. Equipment Configuration for Measuring Output Signal Level of Unit Under Test

c. Test Conduct. The test procedures for this subtest are listed in tables 2.1 through 2.4.

Table 2.1. Procedures for Measuring Modulator Output Impedance

Step	Action	Settings/Action	Result
The following procedures are for reference numbers 4 and 5.			
1	Set up equipment.	See figure 2.3.	
2	Set up audio voltmeter.	Input: High Impedance	
3	Program UUT to begin sending data.		
4	Connect the audio voltmeter across the audio output terminals of the UUT. Do not use the load resistor for this measurement.	Record the output voltage (V).	
5	Connect a 1000-ohm resistor across the audio output.	Again, measure the output voltage (Vo).	
6	Calculate the output impedance (Zo) of the UUT using the given equation.	Zo = 1000(V-Vo)/Vo	
LEGEND: UUT – Unit Under Test; V – volts			

Table 2.2. Procedures for Measuring Demodulator Input Impedance and Return Loss

Step	Action	Settings/Action	Result
The following procedures are for reference number 5.			
1	Set up test equipment as shown in figure 2.1.	Use a 150-ohm resistor if the UUT is used in long-haul systems or in tactical subsystem types I, II, and III. Use a 600-ohm resistor if the UUT is used with radio equipment of single channel radio subsystems.	
2	Use multimeter to determine if the audio input interface is unbalanced or balanced with respect to ground.		
3	Set the audio generator to 300 Hz. Adjust audio level such that V_1 = 1 Volt.	Read V_2. Calculate return loss by: Return Loss = $20\log_{10}(V_1/V_2)$ dB	300 Hz:
4	Repeat step 3 at 1000 Hz, 2000 Hz, and 3000 Hz.		1000 Hz:
			2000 Hz:
			3000 Hz:
LEGEND: dB – decibels; Hz – hertz; UUT – Unit Under Test; V– volts			

Table 2.3. Procedures for Measuring Longitudinal Current Suppression

Step	Action	Settings/Action	Result
The following procedure is for reference numbers 4 and 5.			
1	Set up equipment.	See figure 2.2.	
2	Set up audio generator.	Frequency: 300 Hz	
3	Turn receiver off.	Disconnect power source.	
4	Adjust the audio generator to a –16-dBm signal at 300 Hz.		
5	The difference, in dB, between the voltage reading observed on audio voltmeter #1 and the reading on audio voltmeter #2 is taken as the longitudinal balance indication.	Record frequency and level of audio generator and audio voltmeter readings.	
6	Repeat steps 4 and 5 in 300-Hz steps across the audio range (i.e., 600, 900, 1200 Hz, etc.).		
LEGEND: dB – decibels; dBm – decibels referenced to 1 milliwatt; Hz – hertz			

Table 2.4. Procedures for Modem Output Signal Level

Step	Action	Settings/Action	Result
The following procedure is for reference number 6.			
1	Set up equipment.	See figure 2.4.	
2	Connect an audio analyzer across the modulator output of the UUT.	Key modem and record the measured audio level.	
3	Decrease the transmit audio level of the UUT to its minimum output level.	Key modem and record the measured audio level.	
4	Increase the transmit audio level of the UUT to its maximum output level.	Key modem and record the measured audio level.	
5	Return the transmit audio level of the UUT to the level recorded in step 2.		
6	Set up BERT 2 and modem to transmit a 2047 test pattern.		
7	Adjust the audio level from modem to provide a –35-dBm signal into the UUT.	It may be necessary to place an adjustable attenuator between the modem and UUT.	
8	Transmit the 2047 test pattern for 1 minute.	Record the received BER from BERT 1.	
9	Adjust the audio level out of the modem to provide a –32-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
10	Adjust the audio level out of the modem to provide a –29-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
11	Adjust the audio level out of the modem to provide a –26-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
12	Adjust the audio level out of the modem to provide a –23-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	

Table 2.4. Procedures for Modem Output Signal Level (continued)

Step	Action	Settings/Action	Result
12	Adjust the audio level out of the modem to provide a –23-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
13	Adjust the audio level out of the modem to provide a –20-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
14	Adjust the audio level out of the modem to provide a –17-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
15	Adjust the audio level out of the modem to provide a –14-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
16	Adjust the audio level out of the modem to provide a –11-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
17	Adjust the audio level out of the modem to provide a –8-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
18	Adjust the audio level out of the modem to provide a –5-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
19	Adjust the audio level out of the modem to provide a –2-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
20	Adjust the audio level out of the modem to provide a +1-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
21	Adjust the audio level out of the modem to provide a +3-dBm signal into the UUT.	Transmit the 2047 test pattern for 1 minute. Record the received BER from BERT 1.	
22	Set up spectrum analyzer.	Center Frequency: 1800 Hz Span: 3600 Hz	
23	Bridge the modulator output of the modem across the high impedance input of the spectrum analyzer.		
24	Configure the UUT to transmit a MARK by setting BERT 1 to transmit MARK.	Key UUT and obtain a plot of the MARK signal from the spectrum analyzer.	
25	Configure the modem to transmit a SPACE by setting BERT 2 to transmit MARK and jumpering CTS to TX DATA.	Key UUT and obtain a plot of the SPACE signal from the spectrum analyzer.	
26	Record the difference (in dB) between the level of the MARK and the level of the SPACE.		

LEGEND:

BER – Bit Error Rate	dB – decibels	TX – Transmit
BERT – Bit Error Rate Tester	dBm – decibels referenced to 1 milliwatt	UUT – Unit Under Test
CTS – Clear-to-Send	Hz – hertz	

2.4 Presentation of Results. The results will be shown in table 2.5 indicating the requirement and measured value or indications of capability.

Table 2.5. Modem Impedance Results

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
4	4.2.4.1	Modems used in multi-channel subsystems. For modems used in long-haul systems and in tactical subsystem types I, II, and III (see table 3), the terminal impedance at the modulator output and the demodulator input shall be 600 ohms, balanced to ground,	600 ohms, balanced to ground.			
		with a minimum return loss of 26 decibels (dB) against a 600-ohm resistance over the frequency band of interest.	26 dB			
		The electrical symmetry shall be sufficient to suppress longitudinal currents to a level, which is at least 40 dB below reference level (-40 dBm0).	-40 dBm0			
5	4.2.4.2	Modems used in single channel radio subsystems. For modems used with radio equipment of single channel radio subsystems, the terminal impedance at the modulator output shall be 150 ohms, unbalanced to ground, with a minimum return loss of 20 dB against a 150-ohm resistance over the frequency band of interest.	150 ohms, unbalanced to ground. 20 dB return loss.			
		The terminal impedance at the demodulator input shall be 600 ohms, balanced to ground, with a minimum return loss of 26 dB against a 600-ohm resistance over the frequency band of interest.	600 ohms, balanced to ground. 26 dB return loss.			
		The electrical symmetry shall be sufficient to suppress longitudinal currents to a level that is at least 40 dB below reference level (-40 dBm0).	-40 dBm0			

Table 2.5. Modem Impedance Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
6	4.2.5.1	Modems used in multi-channel subsystems. For modems used in long-haul systems and in tactical subsystem types I, II, and III (see table 3), the quasi-analog signal level at the modulator output shall be adjustable from at least -18 dB referred to one milliwatt (dBm) to +3 dBm. The difference in the output levels between the MARK and SPACE binary signals shall be less than 1 dB. The demodulator shall be capable of operating, without degradation of performance, with a received quasi-analog signal level ranging from at least -35 dBm to +3 dBm.	-18 dBm to +3 dBm -35 dBm to +3 dBm			

LEGEND:

dB – decibels	dBm0 – dBm referenced to or measured at zero transmission level point
dBm – decibels referenced to 1 milliwatt	STANAG – Standardization Agreement

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SUBTEST 3. ELECTRICAL CHARACTERISTICS OF DIGITAL INTERFACES

3.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B, reference number 5.

3.2 Criteria. The electrical characteristics of the digital interface at the modulator input and the demodulator output shall be in accordance with the applicable requirements of MIL-STD-188-114.

Note: MIL-STD-188-114, Electrical Characteristics of Digital Interface Circuits, paragraphs 5.1 through 5.3, specifies the electrical characteristics of digital interface circuits in terms of direct electrical measurements of the interface circuits' unbalanced or balanced generator component. Therefore, the following criteria have been developed in terms of an unbalanced or balanced generator.

a. Unbalanced Generator Criteria for an Unbalanced Voltage Digital Interface Circuit:

(1) Open Circuit Measurement. The magnitude of the voltage (V_o) measured between the output terminal and ground shall not be less than 4 volts (V) nor more than 6 V for any interface circuit in either binary state ($4V \le |V_o| \le 6V$). See figure 3.1.

(2) Test Termination Measurement. The magnitude of the voltage (V_t), measured between the output terminal and ground, shall not be less than 90 percent of the magnitude of V_o with a test load (R_t) of 450 ohm ±1 percent connected between the generator output terminal and generator circuit ground, or ($|V_t| \ge 0.9|V_o|$, when R_t = 450 ohm, ±1 percent). See figure 3.1.

(3) Short Circuit Measurement. The magnitude of the current (I_s) flowing through the generator output terminal shall not exceed 150 milliamperes (mA) when the generator output terminal is short circuited to generator circuit ground, ($|I_s| \le 150$ mA). See figure 3.1.

(4) Power-Off Measurement. The magnitude of the generator output leakage current (I_x) shall not exceed 100 microamps (μA) under power-off conditions, with a voltage V_x ranging between +6 V and –6 V applied between the generator output terminal and generator circuit ground, or ($|I_x| \le 100$ μA, when $-6\text{ V} \le V_x \le +6\text{ V}$). See figure 3.1.

b. Balanced Generator Criteria for a Balanced Voltage Digital Interface Circuit:

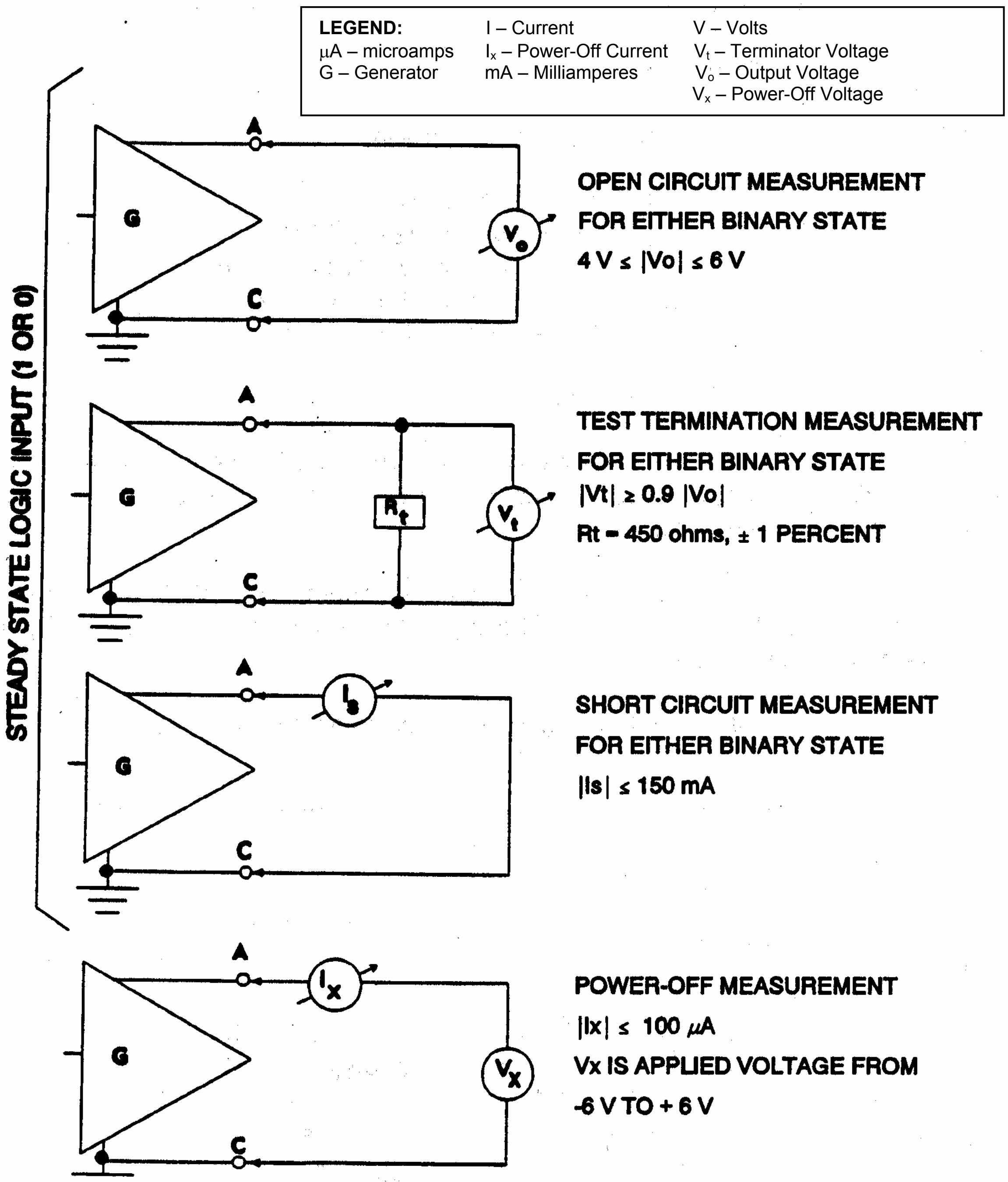
Note: MIL-STD-188-114, Electrical Characteristics of Digital Interface Circuits, paragraph 4.4.1, describes the three types of balanced generators. The type I balanced generator is best suited to meet the requirements of the data modem. The following criteria have been developed in terms of a balanced generator.

(1) Open Circuit Measurement. The magnitude of the differential voltage (V_o) between two generator output terminals shall not be less than 4 V nor more than 6 V ($4V \leq |V_o| \leq 6V$). The magnitude of the open circuit voltage V_{oa} and V_{ob} between the generator output terminals and the generator circuit ground shall not be less than 2 V nor more than 3 V, or ($2V \leq |V_{oa}| \leq 3V$ and $2V \leq |V_{ob}| \leq 3V$). See figure 3.2.

(2) Test Termination Measurement. With a test load (R_t) of two resistors, 50 ohms (Ω) ±1 percent each, connected in series between the generator output terminals, the magnitude of the differential voltage V_t, between the generator output terminals shall not be less than one-half of the absolute value of V_o, or ($|V_t| \geq 0.5|V_o|$). For the opposite binary state, the polarity of V_t shall be reversed($_t$). The magnitude of the difference of the absolute values of V_t and $\mathbf{V_t}$ shall not be more than 0.4 V, or $|V_t| - |\mathbf{V_t}| \leq 0.4$ V. The magnitude of the difference of V_{os} and $\mathbf{V_{os}}$ for the opposite binary state shall not be more than 0.4 V, or $|V_{os} - \mathbf{V_{os}}| \leq 0.4$ V. The magnitude of the generator offset voltage V_{os} between the center point of the test load and generator circuit ground shall not be more than 0.4 V for either binary state, or $|V_{os}| \leq 0.4$ V. See figure 3.2.

(3) Short Circuit Measurement. With the generator output terminals short-circuited to generator circuit ground, the magnitudes of the currents (I_{sa} and I_{sb}) flowing through each generator output terminal shall not exceed 150 mA for either binary state, ($|I_{sa}| \leq 150$ mA and $|I_{sb}| \leq 150$ mA). See figure 3.2.

(4) Power-Off Measurement. Under power-off conditions, the magnitude of the generator output leakage current I_{xa} and I_{xb} shall not exceed 100 microamps with voltage V_x ranging between +6 V and –6 V applied between each generator output terminal and generator circuit ground, or ($|I_{xa}| \leq 100\ \mu A$ and $|I_{xb}| \leq 100\ \mu A$, when $-6V \leq V_x \leq +6V$). See figure 3.2.

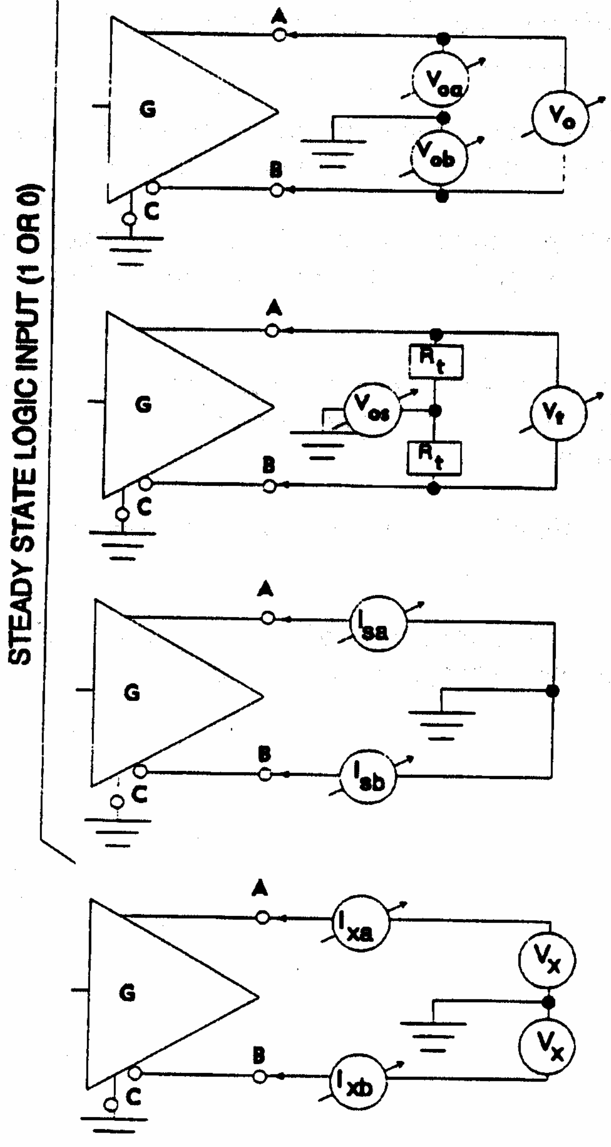


SIGNAL SENSE FOR UNBALANCED GENERATORS

VOLTAGE POLARITY	DATA	TIMING	CONTROL and ALARM
Point A negative with respect to Point C	1 or MARK	OFF (QUIESCENT)	OFF
Point A negative with respect to Point C	0 or SPACE	ON (ACTIVE)	ON

Figure 3.1. Measurement Diagram for Unbalanced Circuit

LEGEND:
µA – microamps
G – Generator
I_{sb} – Current through node B
I_{xa} – Current through node A
I_{xb} – Current through node B
mA – milliamperes
V – Volts
V_o – Output Voltage
V_{oa} – Voltage between point A and the output
V_{ob} – Voltage between the output and point B
V_{os} – Voltage between O and S
V_x – applied Voltage
V_t – Differential Voltage



OPEN CIRCUIT MEASUREMENT FOR EITHER BINARY STATE

$4\text{ V} \le |Vo| \le 6\text{ V}$

$2\text{ V} \le |Voa| \le 3$

$2\text{ V} \le |Vob| \le 3$

TEST TERMINATION MEASUREMENT FOR EITHER BINARY STATE

$|Vt| \ge 0.5\ |Vo|$

$||Vt| - |\bar{Vt}|| \le 0.4\text{ V}$

$|Vos - \bar{Vos}| \le 0.4\text{ V}$

$|Vos| \le 0.4\text{ V}$

SHORT CIRCUIT MEASUREMENT FOR EITHER BINARY STATE

$|Isa| \le 150\text{ mA}$

$|Isb| \le 150\text{ mA}$

POWER-OFF MEASUREMENT

$|Ixa| \le 100\ \mu A$

$|Ixb| \le 100\ \mu A$

Vx IS APPLIED VOLTAGE

Vx FROM -6 V TO +6 V

SIGNAL SENSE FOR BALANCED GENERATORS

VOLTAGE POLARITY	DATA	TIMING	CONTROL and ALARM
Point A negative with respect to Point B	1 or MARK	OFF (QUIESCENT)	OFF
Point A negative with respect to Point B	0 or SPACE	ON (ACTIVE)	ON

Figure 3.2. Measurement Diagram for Balanced Circuit

3.3 Test Procedures

a. Test Equipment Required

(1) Digital Volt Meter

(2) Oscilloscope

(3) Power Supply

(4) UUT

b. Test Configuration. Configure the equipment as shown in figure 3.3.

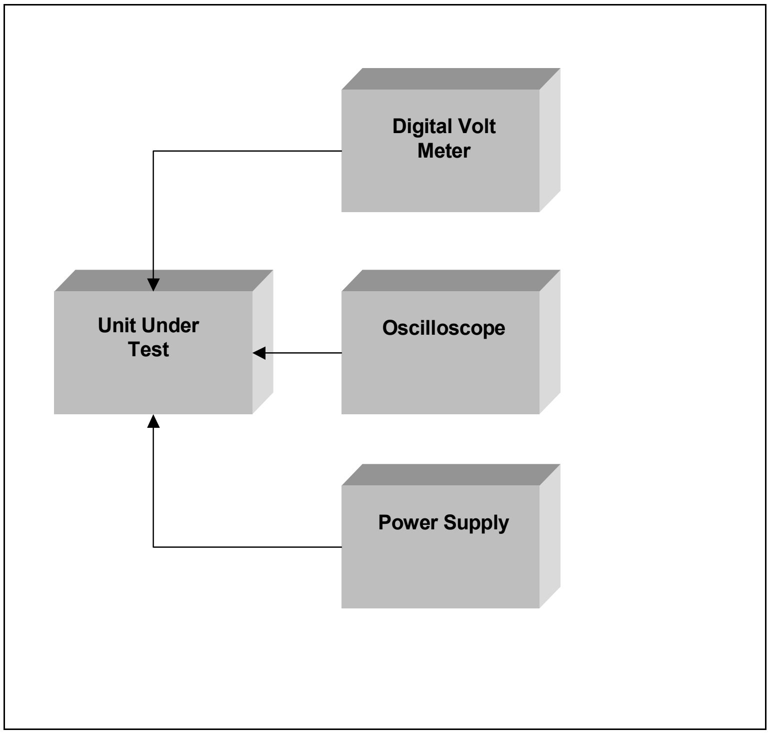


Figure 3.3. Electrical Characteristics of Digital Interfaces Test Equipment Configuration

c. Test Conduct. The procedures for this subtest are listed in table 3.1.

Table 3.1. Electrical Characteristics of Digital Interfaces Procedures

Step	Action	Settings/Action	Result
The following procedure is for reference number 5.			
1	Set up equipment.	See figure 3.3.	
2	Determine the type of interface that has been implemented (balanced or unbalanced).		
3	Conduct open circuit, test termination, and short circuit measurements for both binary states.	See figures 3.1 and 3.2.	
4	Power down system, apply external voltage from power supply to appropriate test points, and measure leakage current.		
5	Voltage and current readings will be taken from the respective measuring points as shown in figures 3.1 or 3.2, depending on which interface is implemented.		Record results on data collection form.

3.4 Presentation of Results. The results will be shown in table 3.2 indicating the requirement and measured value or indications of capability.

Table 3.2. Electrical Characteristics of Digital Interfaces Results

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
5	4.3.1	As a minimum, any incorporated interfaces for serial binary data shall be in accordance with the provisions of MIL-STD-188-114, and any other interfaces specified by the contracting agencies.	Provisions of MIL-STD-188-114.			
5	4.3.1	Such interfaces shall include provisions for request-to-send (RTS) and clear-to-send (CTS) signaling. The capability to accept additional standard interfaces is not precluded.	RTS and CTS			
LEGEND: CTS – Clear-to-Send; MIL-STD – Military Standard; RTS – Request-to-Send						

SUBTEST 4. FREQUENCY SHIFT KEYING (FSK) MODULATION

4.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B, reference numbers 15-17 and 20-25.

4.2 Criteria

a. Narrow-shift FSK modem. For single-radio operation with binary narrow-shift FSK modulation, a shift of 170 Hz shall be used with the characteristic frequencies given in MIL-STD-188-10B, table 4.1. The tolerance of each characteristic frequency shall be ±4 Hz, MIL-STD-188-110B, paragraph 5.1.1.

Table 4.1. Characteristic Frequencies of FSK Data Modems for Single-Channel Radio Equipment

Channel	Mark Frequency (Hz)	Center Frequency (Hz)	Space Frequency (Hz)
LF Radio	915	1000	1085
MF Radio	1615	1700	1785
HF Radio	1575	2000	2425
UHF Radio	500	600	700

LEGEND:
FSK – Frequency Shift Keying
LF – Low Frequency
HF – High Frequency
MF – Medium Frequency
Hz – hertz
UHF – Ultra High Frequency

b. Wide-shift FSK modem. For single channel telegraph operation over HF radio links operating under 150 Bd, the use of FSK with an 850-Hz shift is not consistent with the requirement that the United States (U.S.) operate its HF communication services in accordance with International Telecommunications Union (ITU) recommendations. However, where 850-Hz wide-shift FSK is used, the characteristic frequencies given in MIL-STD-188-110B, table 4.1, shall apply. The tolerance of each characteristic frequency shall be ±4 Hz, MIL-STD-188-110B, paragraph 5.1.2.

c. Speech-plus-telegraph operation. For speech-plus-telegraph operation, the modem shall use binary FSK modulation with a shift of 85 Hz at the characteristic frequencies shown in table 4.2. The tolerance of each characteristic frequency shall be ±1 Hz, MIL-STD-188-110B, paragraph 5.1.3.

Table 4.2. Characteristic Frequencies of FSK Data Modems for Single-Channel Speech-Plus-Telegraph Operation

Parameters	Characteristic Frequencies (Hz)
MARK Frequency	2762.5
CENTER Frequency	2805.0
SPACE Frequency	2847.5
LEGEND: FSK – Frequency Shift Keying; Hz – hertz	

d. FSK data modems for 150 bps or less. Non-diversity FSK modems used primarily for single channel telegraph with data signaling rates of 150 bps or less shall comply with MIL-STD-188-110B, paragraphs 5.2.1.1 - 5.2.1.4, MIL-STD-188-110B, paragraph 5.2.1.

e. Operational characteristics. The modem shall be capable of 2-wire half-duplex and 4-wire full-duplex operation. When the modem is connected for 2-wire half-duplex operation, the modem shall be capable of generating a break-in signal (see MIL-STD-188-110B, paragraph 5.2.1.4) that stops the transmission from the remote modem and allows the direction of data flow to be reversed, MIL-STD-188-110B, paragraph 5.2.1.1.

f. Modulation characteristics. The modem shall use binary FSK modulation with a shift of 85 Hz at the characteristic frequencies shown in table 4.3. The tolerance of each characteristic frequency shall be ±4 Hz. The modem shall have a ready means of reversing the signaling sense of MARK and SPACE conditions to facilitate interoperation with older modems, MIL-STD-188-110B, paragraph 5.2.1.2.

Table 4.3. Characteristic Frequencies of FSK Data Modems for 150 bps or Less

Parameters	Characteristic Frequencies (Hz)
MARK Frequency	1232.5
CENTER Frequency	1275.0
SPACE Frequency	1317.5
LEGEND: bps – bits per second; FSK – Frequency Shift Keying; Hz – hertz	

g. Carrier suppression. During periods of no transmission, the modulator output shall be removed automatically. The carrier suppression time delay shall be such that the modulator output persists for 2.5 seconds (s), ±0.5 s, MIL-STD-188-110B, paragraph 5.2.1.3.

h. Break-in signal characteristics. The frequency of the break-in signal shall be 1180 Hz, ±3 Hz. The nominal level of the break-in signal shall be the same as the nominal level of the quasi-analog data signal at the modulator output. The break-in frequency detector of the demodulator shall operate with signal levels ranging at least from -35 dBm to -5 dBm, MIL-STD-188-110B, paragraph 5.2.1.4.

i. Modulation characteristics. The modem shall use phase-continuous FSK with a shift of 400 Hz for data signaling rates of 600 bps or less, and a shift of 800 Hz for a data signaling rate of 1200 bps. The characteristic frequencies shall comply with those listed in table 4.4 and shall have a tolerance of ±5 Hz, MIL-STD-188-110B, paragraph 5.2.2.1.

Table 4.4. Characteristic Frequencies of FSK Data Modems for 1200 bps or Less

Parameters	Characteristic Frequencies (Hz)	
	600 bps or Less* (400-Hz Shift)	1200 bps Only (800-Hz Shift)
MARK Frequency	1300	1300
CENTER Frequency	1500	1700
SPACE Frequency	1700	2100

LEGEND:
bps – bits per second; FSK – Frequency Shift Keying; Hz – hertz; MIL-STD – Military Standard

* Standard modulation and data signaling rates are given in MIL-STD-188-110B, paragraph 4.2.1.

j. Modulator output spectrum. The transmitted spectrum energy of the quasi-analog signal, measured at the modulator output, shall be suppressed for all frequencies above 3400 Hz to a level that is at least 40 dB below the level of the maximum spectrum energy. This requirement shall apply to all modulation rates for which the modem was designed, MIL-STD-188-110B, paragraph 5.2.2.2.

4.3 Test Procedures

a. Test Equipment Required

(1) Spectrum Analyzer

(2) Modem

(3) BERT (2 ea)

(4) Oscilloscope

(5) UUT

b. Test Configuration. Figure 4.1 shows the equipment setup for this subtest.

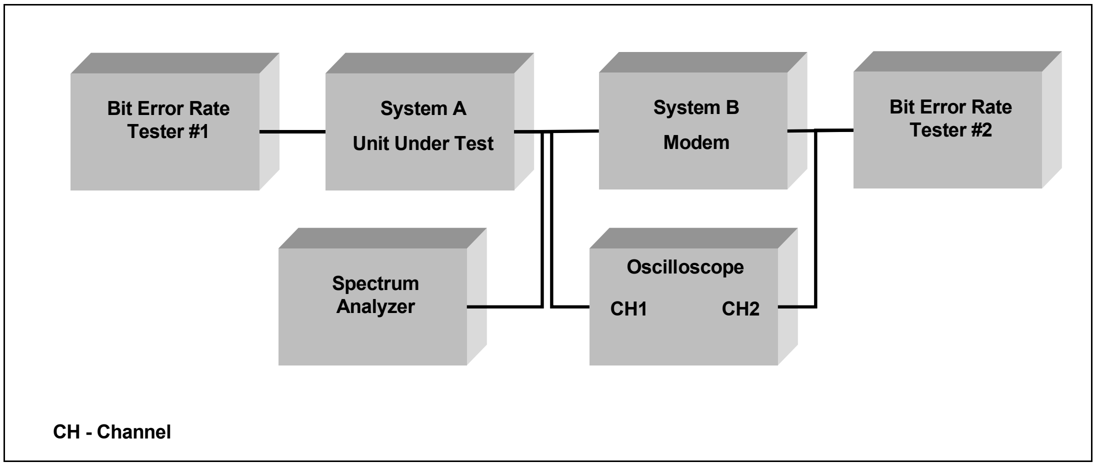


Figure 4.1. Equipment Configuration for Modulation Subtest

c. Test Conduct. The procedures for this subtest are listed in table 4.5.

Table 4.5. Procedures for FSK Modulation Subtest

Step	Action	Settings/Action	Result
The following procedure is for reference number 15.			
1	Set up equipment.	See figure 4.1.	
2	Set up spectrum analyzer.	Center Frequency: 2 kHz Span: 2.5 kHz RBW: 10 Hz VBW: 10 Hz Max hold: On	
3	Set up UUT.	Program modem for narrow-shift FSK operation for a single channel LF radio (see table 4.1).	
4	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
5	Set up UUT.	Program modem for narrow-shift FSK operation for a single channel MF radio (see table 4.1).	

Table 4.5. Procedures for FSK Modulation Subtest (continued)

Step	Action	Settings/Action	Result
6	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
7	Set up UUT.	Program modem for narrow-shift FSK operation for a single channel HF radio (see table 4.1).	
8	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
9	Set up UUT.	Program modem for narrow-shift FSK operation for a single channel UHF radio (see table 4.1).	
10	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
The following procedure is for reference number 16.			
11	If the UUT is capable of 850-Hz wide-shift FSK operation, repeat steps 3 through 10 with the modem programmed for wide-shift FSK operation.		
The following procedure is for reference number 17.			
12	Set up spectrum analyzer.	Center Frequency: 2805 Hz Span: 2.5 kHz RBW: 10 Hz VBW: 10 Hz Max hold: On	
13	Set up UUT.	Program modem for single channel FSK speech-plus-telegraph operation.	

Table 4.5. Procedures for FSK Modulation Subtest (continued)

Step	Action	Settings/Action	Result
14	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
The following procedure is for reference number 21.			
15	The procedures given in steps 16 through 24 apply to non-diversity FSK modems used primarily for single channel telegraph with data signaling rates of 150 bps or less.		
16	Set up spectrum analyzer.	Center Frequency: 1275 Hz Span: 2 kHz RBW: 10 Hz VBW: 10 Hz Max hold: On	
17	Set up UUT.	Program modem for 150 bps (or less) FSK operation.	
18	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
19	Repeat step 18 for all programmable data signaling rates at or below 150 bps.		
20	Verify and record that the modem has a ready means of reversing the signaling sense of MARK and SPACE conditions.		
The following procedure is for reference numbers 20 and 23.			
21	Configure both modems for 4-wire full-duplex operation.		
22	Configure BERTs for synchronous operation and INTF timing with a 2047 test pattern.		
23	Send data simultaneously with both modems.		
24	Confirm and record that both BERTs indicate full-duplex operation.		
25	Configure the modems for 2-wire half duplex operation.		
26	Configure the BERTs for synchronous operation with a synthesized frequency of 150 Hz.	Send a 2047 test pattern from system A. Record BER for BERT 2.	

Table 4.5. Procedures for FSK Modulation Subtest (continued)

Step	Action	Settings/Action	Result
27	Use spectrum analyzer to measure the level of the quasi-analog data at the modulator output of the transmitting modem.		
28	Send a break-in signal from system B to stop data transmission from the UUT. The UUT should stop transmitting data.	View the break-in signal on the spectrum analyzer. Measure and record the frequency and the level of the break-in signal.	
29	Send data with system B and confirm that system A is receiving.		
30	Use spectrum analyzer to measure the level of the quasi-analog data at the modulator output of the transmitting modem.		
31	Send a break-in signal from system A to stop data transmission from system B. System B should stop transmitting data.	View the break-in signal on the spectrum analyzer. Measure and record the frequency and the level of the break-in signal.	
32	Place a variable attenuator at the modulator output of the modem that is initiating the break-in tone.		
33	Repeat step 31 while varying the attenuation level, in 3-dB steps, to simulate a receive level of –5 dBm to –35 dBm into the modem that is transmitting data.	Record all break in signals that the UUT is capable of detecting, ranging from –35 dBm to –5 dBm.	
The following procedure is for reference number 22.			
34	Set up oscilloscope.	CH 1: System A TX AUDIO CH 2: System B RX DATA	
35	Configure modems for full-duplex FSK operation, synchronous at 150 bps.		
36	Configure BERTs for synchronous, synthesized frequency of 150 Hz with 2047 test pattern.		
37	Disable the carrier suppression function on system A. Key the modem, and ensure that system B is receiving data.		
38	Program BERT 1 to send a constant MARK.	The carrier should remain present until BERT 1 stops sending data. Record observations.	
39	Use the oscilloscope to measure the time duration of the carrier, after BERT 1 stops sending data.		
40	Enable the carrier suppression mode on the modem. Key system A. Program BERT 1 to send a constant MARK.	Record observations.	
The following procedure is for reference number 24.			

Table 4.5. Procedures for FSK Modulation Subtest (continued)

Step	Action	Settings/Action	Result
41	Set up spectrum analyzer.	Center Frequency: 3 kHz Span: 6 kHz RBW: 30 Hz VBW: 30 Hz Max hold: On	
42	Set up UUT.	Program modem for phase-continuous FSK operation at 600 bps.	
43	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
44	Repeat step 43 for all programmable data signaling rates below 600 bps.		
45	Set up spectrum analyzer.	Center Frequency: 3 kHz Span: 6 kHz RBW: 30 Hz VBW: 30 Hz Max hold: On	
46	Set up UUT.	Program modem for phase-continuous FSK operation at 1200 bps.	
47	Send data with modem. View modem output on spectrum analyzer.	Measure and record the MARK and SPACE frequencies sent by the UUT. Note: The modem UUT can be configured to transmit a MARK by setting BERT 1 to transmit MARK. The modem UUT can be configured to transmit a SPACE by setting BERT 1 to transmit MARK and inverting the data.	Mark: Space:
The following procedure is for reference number 25.			
48	Set up spectrum analyzer.	Center Frequency: 5 kHz Frequency Span: 10 kHz Noise Level: Off	
49	Send data with modem. View modem output on spectrum analyzer.	Measure and record the level of all peaks on the spectrum analyzer above 3400 Hz that are less than 40 dB below the level of the maximum spectrum energy.	
50	Set up spectrum analyzer.	Center Frequency: 50 kHz Frequency Span: 100 kHz Noise Level: Off	

Table 4.5. Procedures for FSK Modulation Subtest (continued)

Step	Action	Settings/Action	Result
51	Send data with modem. View modem output on spectrum analyzer.	Measure and record the level of all peaks on the spectrum analyzer above 3400 Hz that are less than 40 dB below the level of the maximum spectrum energy.	
52	Repeat steps 48 through 51 for all modulation rates that the UUT is capable of.		

LEGEND:

BER – Bit Error Rate	FSK – Frequency Shift	MF – Medium Frequency
BERT – Bit Error Rate Tester	HF – High Frequency	RX – Receive
bps – bits per second	Hz – hertz	TX – Transmit
CH – Channel	INFT – Interface Medium Frequency	UHF – Ultra High Frequency
dB – decibels	kHz – kilohertz	UUT – Unit Under Test
dBm – decibels referenced to 1 milliwatt	LF – Low Frequency	

4.4 Presentation of Results. The results will be shown in table 4.6 indicating the requirement and measured value or indications of capability.

Table 4.6. FSK Modulation Results

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
15	5.1.1	Narrow-shift FSK modem. For single-radio operation with binary narrow-shift FSK modulation, a shift of 170 hertz (Hz) shall be used with the characteristic frequencies given in table 4. The tolerance of each characteristic frequency shall be ±4 Hz.	See MIL-STD-188-110B table 4. Tolerance: ±4 Hz 170 Hz shift			

Table 4.6. FSK Modulation Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
16	5.1.2	Wide-shift FSK modem. For single channel telegraph operation over high frequency (HF) radio links operating under 150 baud (Bd), the use of FSK with an 850-Hz shift is not consistent with the requirement that the U.S. operate its HF communication services in accordance with International Telecommunications Union (ITU) recommendations. However, where 850-Hz wide-shift FSK is used, the characteristic frequencies given in table 4 shall apply. The tolerance of each characteristic frequency shall be ±4 Hz.	See MIL-STD-188-110B table 4. Tolerance: ±4 Hz			
17	5.1.3	Speech-plus-telegraph operation. For speech-plus-telegraph operation, the modem shall use binary FSK modulation with a shift of 85 Hz at the characteristic frequencies shown in table 5. The tolerance of each characteristic frequency shall be ±1 Hz.	Mark frequency: 2762.5 Hz Center frequency: 2805.0 Hz Space frequency: 2847.5 Hz Tolerance: ±1 Hz			
20	5.2.1.1	Operational characteristics. The modem shall be capable of 2-wire half-duplex and 4-wire full-duplex operation. When the modem is connected for 2-wire half-duplex operation, the modem shall be capable of generating a break-in signal (see 5.2.1.4) that stops the transmission from the remote modem and allows the direction of data flow to be reversed.	Half-duplex Full-duplex 1180 Hz break-in signal.			

Table 4.6. FSK Modulation Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
21	5.2.1.2	Modulation characteristics. The modem shall use binary FSK modulation with a shift of 85 Hz at the characteristic frequencies shown in table 6. The tolerance of each characteristic frequency shall be ±4 Hz. The modem shall have a ready means of reversing the signaling sense of MARK and SPACE conditions to facilitate interoperation with older modems	Mark frequency: 1232.5 Hz Center frequency: 1275.0 Hz Space frequency: 1317.5 Hz Tolerance: ±4 Hz UUT capable of reverse signaling sense.			
22	5.2.1.3	Carrier suppression. During periods of no transmission, the modulator output shall be removed automatically. The carrier suppression time delay shall be such that the modulator output persists for 2.5 seconds (s), ±0.5 s.	Modulator output removed automatically. 2.5 seconds, ±0.5 s.			
23	5.2.1.4	Break-in signal characteristics. The frequency of the break-in signal shall be 1180 Hz, ±3 Hz. The nominal level of the break-in signal shall be the same as the nominal level of the quasi-analog data signal at the modulator output. The break-in frequency detector of the demodulator shall operate with signal levels ranging at least from -35 dBm to -5 dBm.	Freq.-1180 Hz, ±3 Hz Break-in signal level between -5 dBm and -35 dBm.			

Table 4.6. FSK Modulation Results (continued)

Reference Number	STANAG 4203 Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
24	5.2.2.1	Modulation characteristics. The modem shall use phase-continuous FSK with a shift of 400 Hz for data signaling rates of 600 bps or less, and a shift of 800 Hz for a data signaling rate of 1200 bps. The characteristic frequencies shall comply with those listed in table 7 and shall have a tolerance of ±5 Hz.	Frequency shift = 400 Hz for 600 bps or less; shift = 800 Hz for 1200 bps. See MIL-STD-188-110B table 7. Tolerance: ±5 Hz.			
25	5.2.2.2	Modulator output spectrum. The transmitted spectrum energy of the quasi-analog signal, measured at the modulator output, shall be suppressed for all frequencies above 3400 Hz to a level that is at least 40 dB below the level of the maximum spectrum energy. This requirement shall apply to all modulation rates for which the modem was designed.	Level of spectrum (above 3400 Hz) > 40 dB below maximum spectrum energy.			

LEGEND:

Bd – baud	FSK – Frequency Shift Keying	MIL-STD – Military Standard
bps – bits per second	HF – High Frequency	s – seconds
dB – decibels	Hz – hertz	STANAG – Standardization Agreement
dBm – decibels referenced to 1 milliwatt	ITU – International Telecommunications Union	UUT – Unit Under Test

SUBTEST 5. SERIAL (SINGLE-TONE) MODE

5.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B, reference numbers 26, 28-47, and 50.

5.2 Criteria

a. Serial (single-tone) mode. This mode shall employ M-ary Phase-Shift Keying (PSK) on a single carrier frequency as the modulation technique for data transmission. 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 MIL-STD-188-110B, paragraph 5.3.1.1. Selectable interleaver settings shall be provided, MIL-STD-188-141B, paragraph 5.3.2.1. This waveform (signal structure) has four functionally distinct, sequential transmission phases. These time phases are:

(1) Synchronization preamble phase

(2) Data phase

(3) End-of-message (EOM) phase

(4) Coder and interleaver flush phase

b. 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 MIL-STD-188-110B, figure 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 data terminal equipment (DTE). Switches S2 and S3 shall be in the SYNC position. The transmitting modem shall send the required sync preamble sequence (see MIL-STD-188-110B, paragraph 5.3.2.3.7.2) to achieve time and frequency sync with the receiving modem. The length of the sync preamble sequence pattern shall be 0.6 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. For radio frequency hopping operation, S4 and the data fetch controller shall provide the required traffic dead time at the beginning of each hop by disabling the modem output. The dead time shall be equal to the duration of 96 symbols. Switch S4 shall be placed in the through position during fixed-frequency operation.

Referring to MIL-STD-188-110B, figure 3, the sequence of events for synchronous and asynchronous operation is as follows:

(1) For fixed-frequency, full-duplex data operation, upon receipt of the

message Request-to-Send (RTS) signal from the DTE, the modem shall simultaneously perform the following:

(a) Return to the DTE a Clear-to-Send (CTS) signal.

(b) Begin loading the interleaver with data traffic.

(c) Commence sending the special sync preamble pattern described in MIL-STD-188-110B, paragraphs 5.3.2.3.7.2 and 5.3.2.3.8.2.

(2) For fixed-frequency 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 fixed-frequency full-duplex operation.

(3) Fixed-frequency 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, MIL-STD-188-110B, paragraph 5.3.2.2.1:

(a) Key the radio.

(b) Return a CTS signal to the DTE.

(c) Begin loading the interleaver with the data traffic and commence sending the special sync pattern described in MIL-STD-188-110B, paragraphs 5.3.2.3.7.2 and 5.3.2.3.8.2.

c. 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 (figure 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 MIL-STD-188-110B, paragraph 5.3.2.3.7.1.2). The period of dwell in each switch position shall be as follows:

(1) For frequency-hopping operation, the dwell is a function of bit rate and time duration of the hop. MIL-STD-188-148 gives the required timing of switches S2 and S4 during each hop time as a function of data rate and dead time.

(2) For fixed-frequency operation, the period of dwell shall be a function of bit rate only. At 2400 and 4800 bps, 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 bps, the two durations shall be 20 symbols in each position. At 75 bps, 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, MIL-STD-188-110B, paragraph 5.3.2.2.2.

Note: In all cases, switch S2 is placed in the unknown data position first, following the end of the sync preamble phase.

d. 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 (MIL-STD-188-110B, figure 2) shall be switched to the EOM position. This shall cause a fixed 32-bit pattern (see MIL-STD-188-110B, paragraph 5.3.2.3.1) to be sent to the FEC encoder. Function switches S2 and S3 (and also S4 in frequency-hopping operation) shall continue to operate as established for the data phase, MIL-STD-188-110B, paragraph 5.3.2.2.3.

e. FEC coder and interleaver flush phase. Immediately upon completion of the EOM phase, S1 (figure 2 shall be switched to the FLUSH position causing input of flush bits (see MIL-STD-188-110B, paragraph 5.3.2.3.2) to the FEC encoder), MIL-STD-188-110B, paragraph 5.3.2.2.4.

f. EOM sequence. The eight-digit hexadecimal number 4B65A5B2 shall represent the EOM sequence. The bits shall be transmitted with the most significant digit first. Thus the first eight bits are, left to right, 0100 1011, MIL-STD-188-110B, paragraph 5.3.2.3.1.

g. 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 interleaved matrix data block (see MIL-STD-188-110B paragraph 5.3.2.3.4 for data block size) containing the last coder flush bit. Flush bits shall be set to "0." If the interleaver is in a bypass (0.0 s) state, only the coder flush bits are transmitted, MIL-STD-188-110B, paragraph 5.3.2.3.2.

h. FEC encoder. The FEC encoder shall be used for data rates up to and including 2400 bps. The FEC encoder block diagram for frequency-hopping and fixed-frequency operation is shown on figure 4. For frequency-hopping operation, the FEC encoder function shall be accomplished by a constraint length 7 convolutional coder with repeat coding used at the 75, 150, and 300 bps rates. 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 $T_l(x)$ being taken first. For the 2400 bps rate, every fourth bit the second value of $T_2(x)$ shall be omitted at the interleaver output to form a punctured rate 2/3 convolutional rate. At all other rates, the convolutional coder shall be rate 1/2. Coded bit streams of 3600, 2400, and 1200 bps shall be generated for the input data rates of 2400, 1200, and 600 bps, respectively. For the 300, 150, and 75 bps input data rates, a 1200 bps 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, $T_l(x)$, followed by repetitions of the second $T_2(x)$. Error-correction coding for frequency-hopping operation shall be in accordance with MIL-STD-188-110B, table 8.

(1) For fixed-frequency operation, the FEC encoder function shall be accomplished by a single rate 1/2 constraint length 7 convolutional coder with repeat coding used at 150 and 300 bps. The two summing nodes shall operate as given for frequency-hopping operation; that is, for each bit input to the encoder, two bits shall be taken as output from the encoder. Coded bit streams of 4800, 2400, and 1200 bps shall be generated for input data rates of 2400, 1200, and 600 bps, respectively. For 300 bps and 150 bps input data rates, repeating the pairs of output bits the appropriate number of times shall generate a 1200 bps coded bit stream. 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 bps, a different transmit format (see MIL-STD-188-110B, paragraph 5.3.2.3.7.1.1) is used and the effective code rate of 1/2 shall be employed to produce a 150 bps coded stream. Error-correction coding for fixed-frequency operation shall be in accordance with MIL-STD-188-110B, table 9.

(2) For 4800-bps fixed-frequency operation, the FEC encoder shall be bypassed, MIL-STD-88-110B, paragraph 5.3.2.3.3.

i. Interleaver. The interleaver, when used, shall be a matrix block type that 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 interleaves is contained in the transmitted sync pattern (MIL-STD-188-110B, paragraph 5.3.2.3.7.2). The short interleaves shall be switch selectable to be either 0.0 s or 0.6 s (see MIL-STD-188-110B, paragraph 5.3.2.3.7.2.1).

To maintain the interleave delay at a constant value, the block size shall be scaled by bit rate. MIL-STD-188-110B, table 10, lists the interleaver matrix dimensions (rows and columns) that shall be allocated for each required bit rate and interleave delay.

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 bps fixed-frequency operation.

For fixed-frequency operation at 75 bps only, the following changes to the above description shall apply:

(1) When the interleaver setting is on long, the procedure is the same, but the row number shall be advanced by 7 modulo 20.

(2) When the interleaver 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.

Note: For frequency-hopping operation at rates of 300, 150, and 75 bps, the number of bits required for a constant time delay is the same as that for 600 bps due to repeat coding. For fixed-frequency operation, repeat coding is used with only the 300 bps and 150 bps rates, MIL-STD-188-110B, paragraph 5.3.2.3.4.

j. Interleave 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 bps with a long interleave 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. The interleaver fetch process shall be the same for frequency-hopping and fixed-frequency operation except as follows:

(1) For frequency-hopping operation (MIL-STD-188-110B, paragraph 5.3.2.3.3), the puncture process at 2400 bps shall occur during the fetch routine by omitting every fourth bit from the interleaver output.

(2) For fixed-frequency operation at the 75-bps 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 1, 2, or 3 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 11, MIL-STD-188-110B, paragraph 5.3.2.3.5.

k. Modified-Gray Decoder (MGD). At 4800 and 2400 bps, the channel bits are effectively transmitted with 8-ary channel symbols. At 1200 bps and 75 bps (fixed frequency), the channel bits are effectively transmitted with 4-ary channel symbols.

MGD of the 2400-bps, 4800-bps (tribit), 75-bps (fixed frequency), 1200-bps (dibit) channel symbols shall be in accordance with MIL-STD-188-110B, tables 12 and 13, respectively. When one-bit channel symbols are used (600–150 bps and 75 bps [frequency-hopping operation]) the MGD does not modify the unknown data bit stream, MIL-STD-188-110B, paragraph 5.3.2.3.6.

l. 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 frequency-hopping and fixed-frequency operation data rates, the output of the symbol formation shall be scrambled with pseudo-random 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 MIL-STD-188-110B, paragraph 5.3.2.3.9, MIL-STD-188-110B, paragraph 5.3.2.3.7.1.

m. Unknown data. At all frequency-hopping operation rates and rates above 75 bps for fixed-frequency operation, each 1-, 2-, or 3-bit channel symbol shall map directly into one of the 8-ary tribit numbers as shown on the state constellation diagram, figure 5. When one-bit channel symbols are used (600-150 bps and 75 bps [frequency-hopping]), the symbol formation output shall be tribit numbers 0 and 4. At the 1200 bps rate, the dibit channel symbol formation shall use tribit numbers 0, 2, 4, and 6. At the 4800 bps and 2400 bps rates, all the tribit numbers (0-7) shall be used for symbol formation. At 75 bps fixed-frequency operation, 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 MIL-STD-188-110B, table 14. The mapping in table 14a 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 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 14b. In any case, the resultant output is one of four orthogonal waveforms produced for each of the possible dibits of information. As before, these values will be scrambled later to take on all 8-phase states.

Note: Each set consists of 32-tribit numbers. The receive modem shall use the modification of the known data at interleaver boundaries to synchronize without a preamble and determine the correct date rate and mode of operation, MIL-STD-188-110B, paragraph 5.3.2.3.7.1.1.

n. 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 interleaved block. The block length shall be 1440-tribit channel symbols for short interleave setting and 11520-tribit channels 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 15 of MIL-STD-188-110B, paragraph 5.3.2.3.7.2.1 and table 17 of MIL-STD-188-110B, paragraph 5.3.2.3.7.2.2. The two known symbol patterns are repeated twice rather than four times as they are in table 17 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), MIL-STD-188-110B, paragraph 5.3.2.3.7.1.2.

o. Synchronization preamble sequence - General. The waveform for synchronization is essentially the same for all data rates. The sync pattern shall consist of either three or twenty-four 200-millisecond (msec) segments (depending on whether either zero, short, or long interleave periods are used). Each 200-msec segment shall consist of a transmission of 15 three-bit channel symbols as described in MIL-STD-188-110B, paragraph 5.3.2.3.7.2.2. The sequence of channel symbols shall be: 0, 1, 3, 0, 1, 3, 1, 2, 0, D1, D2, C1, C2, C3, 0. The encoding sequences for each of the eight possible channel symbols (0 through 7) are discussed in table 5.1.

The three-bit values of D1 and D2 shall designate the bit rate and interleave setting of the transmitting modem. MIL-STD-188-110B, table 15, gives the assignment of these values, which is tabulated in table 5.2.

If a demodulator receives any D1, D2 combination that it does not implement, it shall not synchronize but shall continue to search for synchronization.

Note: The short interleave can be selected to either 0.0 (bypassed) or 0.6 s. 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, MIL-STD-188-110B, paragraph 5.3.2.3.7.2.1.

The three-count symbols C1, C2, and C3 shall represent a count of the 200-msec 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. Adding a “1” before the two-bit value does this so that this “1” becomes the most significant bit. This conversion shall be as shown in MIL-STD-188-110B, table 16, and summarized in table 5.3.

Table 5.1. Synchronization Preamble

The preamble sequence is: 0, 1, 3, 0, 1, 3, 1, 2, 0, D1, D2, C1, C2, C3, 0.
The preamble sequence should be repeated three or twenty-four times.
(See table 5.2 for values of D1 and D2 at bit rates of 2400, 1200, 600, 300, 150, and 75 bps. See MIL-STD-188-110B paragraph 5.3.2.3.7.2.1 and table 5.3 for values of C1, C2, and C3.)

Each digit in the preamble sequence corresponds to transmission of 32 symbols. For example, the first digit of the preamble sequence is 0. A 0 corresponds to the transmission of the following 32 symbols: 74305150221157435026216200505266. So, the preamble will always begin 74305….

The following list provides the 32 digit numbers represented by symbols 0 through 7.

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

Table 5.2. Values for D1 and D2

Bit Rate	Interleaver	D1	D2
4800	long	–	–
	short	7	6
2400	long	4	4
	short	6	4
1200	long	4	5
	short	6	5
600	long	4	6
	short	6	6
300	long	6	7
	short	4	7
150	long	5	4
	short	7	4
75	long	5	5
	short	7	5

Table 5.3. Values for C1, C2, and C3

Preamble Sync Setting	Count	C1	C2	C3
Short	2	4	4	6
	1	4	4	5
	0	4	4	4
Long	23	5	5	7
	22	5	5	6
	21	5	5	5
	20	5	5	4
	19	5	4	7
	18	5	4	6
	17	5	4	5
	16	5	4	4
	15	5	7	7
	14	4	7	6
	13	4	7	5
	12	4	7	4
	11	4	6	7
	10	4	6	6
	9	4	6	5
	8	4	6	4
	7	4	5	7
	6	4	5	6
	5	4	5	5
	4	4	5	4
	3	4	4	7
	2	4	4	6
	1	4	4	5
	0	4	4	4

p. Preamble pattern generation. The sync preamble pattern shall be a sequence of channel symbols containing three bits each (see MIL-STD-188-110B, paragraph 5.3.2.3.7.2.1). These channel symbols shall be mapped into 32-tribit numbers as given in MIL-STD-188-110B, table 17.

Note: When the two known symbol patterns preceding the transmission of each new interleaves block are transmitted, the patterns in table 17 are repeated twice rather than four times to produce an 8 pattern of 16-tribit numbers, MIL-STD-188-110B, paragraph 5.3.2.3.7.2.2.

q. 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, MIL-STD-188-110B, paragraph 5.3.2.3.8.

r. Data sequence randomizing generator. The data sequence randomizing generator shall be a 12-bit shift register with the functional configuration shown on MIL-STD-188-110B, figure 6. At the start of the data phase, the shift register shall be loaded with the initial pattern shown in figure 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, MIL-STD-188-110B, paragraph 5.3.2.3.8.1.

s. 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 MIL-STD-188-110B, paragraph 5.3.2.3.8.1 and this paragraph, shall be modulo 8 added to the output of the symbol formation function.

t. PSK modulation

(1) The eight-phase modulation process shall be achieved by assigning the tribit numbers from the scrambler to 45-degree increments of an 1800-Hz sine wave. Thus, 0 (000) corresponds to 0 degrees, 1 (001) corresponds to 45 degrees, 2 (010) corresponds to 90 degrees, etc. MIL-STD-188-110B, figure 5, shows the assignment and pattern of output waveform generation.

(2) Clock accuracy for generation of the 1800-Hz carrier shall be within ±1 Hz, MIL-STD-188-110B, paragraph 5.3.2.3.9.

u. Robust serial tone mode for severely degraded HF links (optional). The optional robust serial tone mode shall employ the waveform specified above for 75-bps operation and shall meet the performance requirements of Standardization Agreement (STANAG) 4415, MIL-STD-188-110B, paragraph, 5.3.4.

v. Output power level. The total power transmitted by the modem to the line shall be adjustable in no greater than 1-dB steps from at least –12 dBm to –3 dBm, MIL-STD-188-110B, paragraph 5.4.1.2.

5.3 Test Procedures

a. Test Equipment Required

(1) Personal Computer with LabVIEW V6.1 software

(2) Vector Signal Analyzer (Agilent 89400 Series)

(3) BERT (2)

(4) UUT (2)

(5) ALE Radio (2)

(6) Attenuator

(7) Oscilloscope

b. Test Configuration. Configure the equipment as shown in figure 5-1 for steps 1-91, 103, and 104. Configure the equipment as shown in figure 5-2 for steps 92-102.

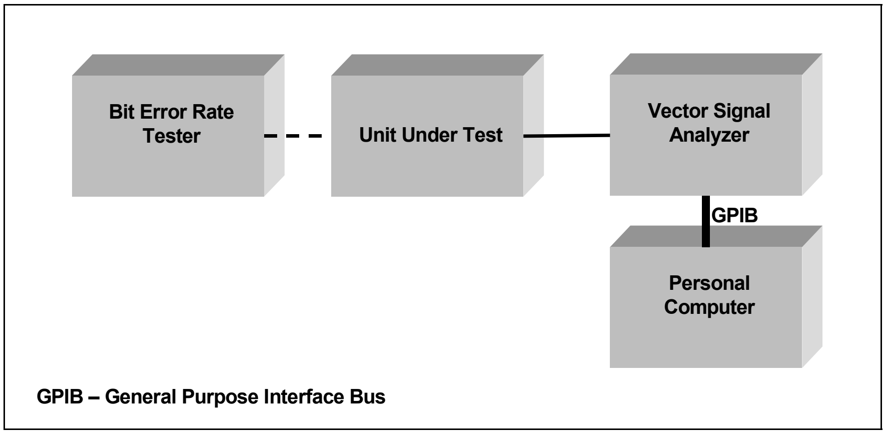


Figure 5.1. Serial (Single-Tone) Mode Test Equipment Configuration

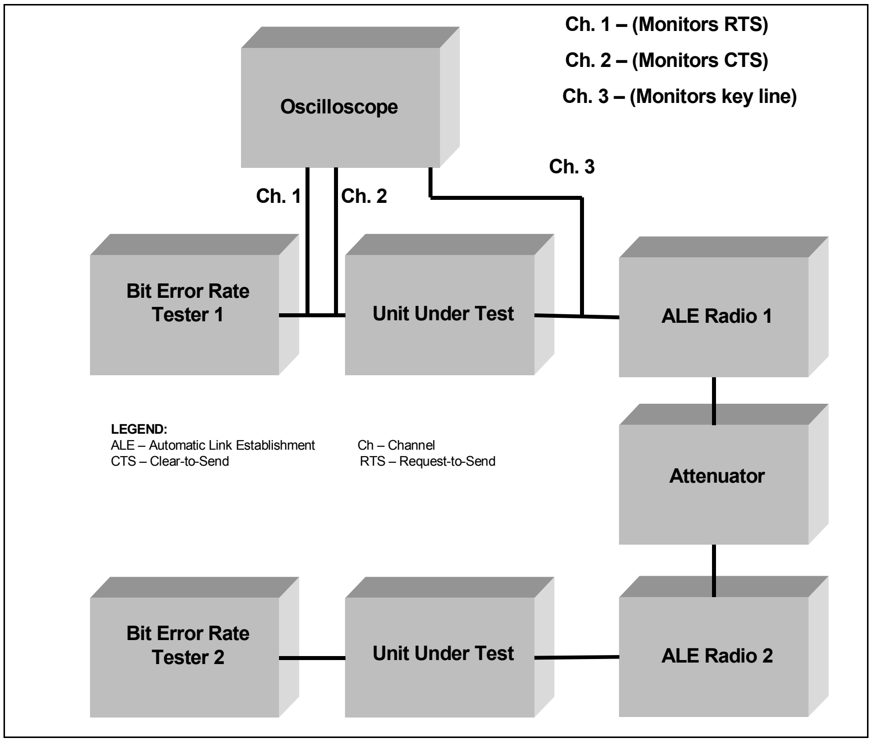


Figure 5.2. RTS/CTS Signaling Test Equipment Configuration

c. Test Conduct. The procedures for this subtest are listed in table 5.4.

Table 5.4. Serial (Single-Tone) Mode Test Procedures

Step	Action	Settings/Action	Result
1	Set up equipment.	See figure 5.1.	
2	Set up vector signal analyzer.	Frequency Center: 1.8 kHz Span: 3.6 kHz Time Result Length: 2000 symbols Search Length: 850 msec Sync Setup Pattern: 111100011000101 Offset: 0 symbols Instrument Mode Digital Demodulation Demodulation Setup Demodulation Format: 8 PSK Symbol Rate: 2.4 kHz Result Length: 1800 symbols Reference Filter: Gaussian Sweep: Single Trigger Trigger Type: IF CH1 Configure state constellation diagram as given in MIL-STD-188-110B, figure 5.	
The following procedure is for reference numbers 26, 28, 29, 42, 43, 46.			
3	Set up UUT.	Program UUT to send data using the serial tone waveform at 4800 bps (if available).	
4	Begin sending serial data from the UUT to the vector signal analyzer.		
5	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the first 9 preamble digit sent by the UUT correspond to the appropriate 32 symbol sequences, shown in table 5.1. Expected values: D1 = 7, D2 = 6. D1 and D2 represent the 10th and 11th preamble digits. Note that the vector signal analyzer displays the preamble in three-bit binary. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
6	Set up UUT to send serial data at 2400 bps using the long interleaver.		
7	Begin sending serial data from the UUT to the vector signal analyzer.		

Table 5.4. Serial (Single-Tone) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
8	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the preamble digit sent by the UUT correspond to the appropriate 32 symbol sequences, shown in table 5.1. Expected values: D1 = 4, D2 = 4. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
9	Repeat previous three steps using the short interleaver.	Expected values: D1 = 6, D2 = 4. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
10	Set up UUT to send serial data at 1200 bps using the long interleaver.		
11	Begin sending serial data from the UUT to the vector signal analyzer.		
12	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the preamble digit sent by the UUT correspond to the appropriate 32 symbol sequences, shown in table 5.1. Expected values: D1 = 4, D2 = 5. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
13	Repeat previous three steps using the short interleaver.	Expected values: D1 = 6, D2 = 5. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
14	Set up UUT to send serial data at 600 bps using the long interleaver.		
15	Begin sending serial data from the UUT to the vector signal analyzer.		
16	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the preamble digit sent by the UUT correspond to the appropriate 32 symbol sequences, shown in table 5.1. Expected values: D1 = 4, D2 = 6. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
17	Repeat previous three steps using the short interleaver.	Expected values: D1 = 6, D2 = 6. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
18	Set up UUT to send serial data at 300 bps using the long interleaver.		

Table 5.4. Serial (Single-Tone) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
19	Begin sending serial data from the UUT to the vector signal analyzer.		
20	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the preamble digit sent by the UUT correspond to the appropriate 32 symbol sequences, shown in table 5.1. Expected values: D1 = 4, D2 = 7. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
21	Repeat previous three steps using the short interleaver.	Expected values: D1 = 6, D2 = 7. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
22	Set up UUT to send serial data at 150 bps using the long interleaver.		
23	Begin sending serial data from the UUT to the vector signal analyzer.		
24	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the preamble digit sent by the UUT correspond to the appropriate 32 symbol sequences, shown in table 5.1. Expected values: D1 = 5, D2 = 4. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
25	Repeat previous three steps using the short interleaver.	Expected values: D1 = 7, D2 = 4. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
26	Set up UUT to send serial data at 75 bps using the long interleaver (fixed frequency operation).		
27	Begin sending serial data from the UUT to the vector signal analyzer.		
28	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the preamble digit sent by the UUT correspond to the appropriate 32 symbol sequences, shown in table 5.1. Expected values: D1 = 5, D2 = 5. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=
29	Repeat previous three steps using the short interleaver.	Expected values: D1 = 7, D2 = 5. The preamble values for C1, C2, and C3 should correspond with values given in table 5.3.	Preamble D1= D2=

Table 5.4. Serial (Single-Tone) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
The following procedure is for reference numbers 29-30, 35-41, 44-45, and 47.			
30	The following procedures use automated software to decode Serial (Single-Tone) data from the UUT. The test operator must program UUT to transmit a 2047 test pattern. The automated software is available for download from the JITC website: http://jitc.fhu.disa.mil/it/hf.htm	Successful decode of the serial (Single-Tone) data validates that the following requirements have been met: FEC encoder, interleaver, interleaver fetch, Modified-Gray coding, symbol formation, probes, scrambler, preamble length, and the data sequence randomizing generator.	
31	Copy and paste MIL_STD_188_110B.vi file onto hard disk of personal computer containing LabVIEW software.	Copy and paste INTVvstate file onto a 3.5-inch floppy disk. Insert floppy disk into drive a: of vector signal analyzer.	
32	Connect the UUT to channel 1 of the vector signal analyzer.	Connect the vector signal analyzer to personal computer via the GPIB interface.	
33	Load LabVIEW software.	Open MIL_STD_188_110B.vi.	
34	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
35	Program UUT to send (serial tone) data at 4800 bps (if available).		
36	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem and begin sending data.	
37	Automated software will run for several minutes.	Record results of software decode. (Note that the operator may choose to view the raw data captured on the vector signal analyzer.) Save encoded data to file.	
38	Program UUT to send (serial tone) data at 2400 bps using the long interleaver.	Ensure that the UUT is in the idle state (not sending data).	
39	Use the automated software’s Test Information box to select data rate and interleaver type.		
40	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem and begin sending data.	
41	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
42	Program UUT to send (serial tone) data at 2400 bps using the short interleaver.	Ensure that the UUT is in the idle state (not sending data).	
43	Use the automated software’s Test Information box to select data rate and interleaver type.		
44	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem and begin sending data.	

Table 5.4. Serial (Single-Tone) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
45	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
46	Program UUT to send (serial tone) data at 1200 bps using the long interleaver.	Ensure that the UUT is in the idle state (not sending data).	
47	Use the automated software's Test Information box to select data rate and interleaver type.		
48	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
49	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
50	Program UUT to send (serial tone) data at 1200 bps using the short interleaver.	Ensure that the UUT is in the idle state (not sending data).	
51	Use the automated software's Test Information box to select data rate and interleaver type.		
52	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
53	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
54	Program UUT to send (serial tone) data at 600 bps using the long interleaver.	Ensure that the UUT is in the idle state (not sending data).	
55	Use the automated software's Test Information box to select data rate and interleaver type.		
56	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
57	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
58	Program UUT to send (serial tone) data at 600 bps using the short interleaver.	Ensure that the UUT is in the idle state (not sending data).	
59	Use the automated software's Test Information box to select data rate and interleaver type.		
60	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
61	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
62	Program UUT to send (serial tone) data at 300 bps using the long interleaver.	Ensure that the UUT is in the idle state (not sending data).	
63	Use the automated software's Test Information box to select data rate and interleaver type.		

Table 5.4. Serial (Single-Tone) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
64	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
65	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
66	Program UUT to send (serial tone) data at 300 bps using the short interleaver.	Ensure that the UUT is in the idle state (not sending data).	
67	Use the automated software's Test Information box to select data rate and interleaver type.		
68	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
69	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
70	Program UUT to send (serial tone) data at 150 bps using the long interleaver.	Ensure that the UUT is in the idle state (not sending data).	
71	Use the automated software's Test Information box to select data rate and interleaver type.		
72	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
73	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
74	Program UUT to send (serial tone) data at 150 bps using the short interleaver.	Ensure that the UUT is in the idle state (not sending data).	
75	Use the automated software's Test Information box to select data rate and interleaver type.		
76	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
77	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
78	Program UUT to send (serial tone) data at 75 bps using the long interleaver.	Ensure that the UUT is in the idle state (not sending data).	
79	Use the automated software's Test Information box to select data rate and interleaver type.		
80	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
81	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
82	Program UUT to send (serial tone) data at 75 bps using the short interleaver.	Ensure that the UUT is in the idle state (not sending data).	

Table 5.4. Serial (Single-Tone) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
83	Use the automated software's Test Information box to select data rate and interleaver type.		
84	Run MIL_STD_188_110B.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
85	Automated software will run for several minutes.	Record results of software decode. Save encoded data to file.	
The following procedure is for reference numbers 32 and 34.			
86	Program UUT to send 'the quick brown fox' at 4800 bps.		
87	Use automated software to capture raw data and decode both the message and the EOM sequence sent by the UUT.	Record the EOM data sequence.	
The following procedure is for reference numbers 33 and 35.			
88	Record the decoded UUT output after the EOM sequence.	Expected results: 144 "0" flush bits	
The following procedure is for reference number 50.			
89	Set up vector signal analyzer as shown in figure 5.1, but without the PC.	Frequency Center: 1.8 kHz Span: 3.6 kHz	
90	Program BER Test Set to begin continuously sending data.	Use vector signal analyzer to measure total power out of the UUT.	
91	Use the vector signal analyzer to measure the power level of the audio signal sent by the UUT.	Program UUT to send data at level of –12 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –11 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –10 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –9 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –8 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –7 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –6 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –5 dBm. Record total power level in dBm.	
		Program UUT to send data at level of –4 dBm. Record total power level in dBm.	

Table 5.4. Serial (Single-Tone) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
		Program UUT to send data at level of –3 dBm. Record total power level in dBm.	
The following procedure is for reference number 29.			
92	Set up equipment.	See figure 5.2.	
93	Set up ALE Radios in ALE mode.	ALE Radio Setup Low Power Freq 8.00 MHz	
94	Program BERT 1 to send data.	Monitor RTS signal. Observe oscilloscope for toggle on RTS pin. Record observations.	
95	Link radios.	Wait to establish link between radios.	
96	Monitor CTS signal.	Observe oscilloscope for toggle on CTS pin. Record observations.	
97	Verify that BERT 2 is correctly receiving data.	Record BER.	
98	Take both radios out of ALE mode.		
99	Program BERT 1 to send data.	Monitor RTS signal. Observe oscilloscope for toggle on RTS pin. Record observations.	
100	Observe oscilloscope for toggle on key line pin.	record observations	
101	Monitor CTS signal.	Observe oscilloscope for toggle on CTS pin. Record observations.	
102	Verify that BERT 2 is correctly receiving data.	Record BER.	
The following procedure is for reference number 47.			
103	Set up BERT 1.	Analysis Results Signal: Received Frequency	
104	Measure clock frequency.	The clock frequency will be displayed under “Received Frequency.” Record results.	

LEGEND:
ALE – Automatic Link Establishment
BER – Bit Error Rate
BERT – Bit Error Rate Tester
bps – bits per second
CH – Channel
CTS – Clear-to-Send
dBm – decibels referenced to 1 milliwatt
EOM – End-of-Message
FEC – Forward Error Correction
GPIB – General Purpose Information Bus
JITC – Joint Interoperability Test Command
kHz – kilohertz
MHz – megahertz
MIL-STD – Military Standard
msec – millisecond
PC –Personal Computer
PSK – Phase-Shift Keying
RTS – Request-to-Send
Sync – synchronization
UUT – Unit Under Test

5.4 Presentation of Results. The results will be shown in table 5.5 indicating the requirements and measured value or indications of capability.

Table 5.5. Serial (Single-Tone) Mode Test Results

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
26	5.3.1.1	Capability. The HF modems shall be capable of modulating and demodulating serial binary data into/from a serial (single-tone) waveform. This waveform is transmitted and received over HF radio operating in either fixed-frequency or frequency-hopping modes of operation. The minimum acceptable performance and joint service interoperability shall be at 75, 150, 300, 600, 1200, and 2400 bps using the fixed-frequency Phase-Shift Keying (PSK) serial waveform specified herein. Uncoded serial tone modem operation at 4800 bps is a design objective (DO). Note that this is a less robust mode of operation at 4800 bps than that capability specified in appendix C.	75, 150, 300, 600, 1200, and 2400 bps using 8-ary serial waveform. (4800 bps is optional)			
28	5.3.2.1	This mode shall employ M-ary Phase-Shift Keying (PSK) on a single carrier frequency as the modulation technique for data transmission. The modulation of this output carrier shall be a constant 2400 symbols-per-second waveform regardless of the actual throughput rate. Selectable interleaver settings shall be provided. This 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.	Symbol rate: 2400 bps. Selectable interleaver settings: short, long			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
29	5.3.2.2.1	Synchronization (sync) preamble phase. During this phase, switch S1 (see figure 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 data terminal equipment (DTE). Switches S2 and S3 shall be in the SYNC position. The transmitting modem shall send the required sync preamble sequence (see 5.3.2.3.7.2) to achieve time and frequency sync with the receiving modem. Referring to figure 3, the sequence of events for synchronous and asynchronous operation is as follows: a. For fixed-frequency, full-duplex data operation, upon receipt of the message request-to-send (RTS) signal from the DTE, the modem shall: (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 5.3.2.3.7.2 and 5.3.2.3.8.2. b. For fixed-frequency 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 fixed-frequency full-duplex operation.	Preamble as identified in tables 5.1, 5.2, and 5.3.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
29	5.3.2.2.1	c. Fixed-frequency half-duplex data operation using ALE radio equipment shall delay the data CTS signal until radio link confirmation. Upon receipt of the RTS signal from the user data terminal, the controller initiates and confirms linking with the called station. After confirmation, the controller sends the RTS signal to the modem. Upon receipt of the RTS signal from the controller, the modem shall simultaneously perform the following: 1) Key the radio, 2) Return a CTS signal to DTE, and 3) Load the interleaver with data traffic and send the special sync pattern described in 5.3.2.3.7.2 and 5.3.2.3.8.2.	Preamble as identified in tables 5.1, 5.2, and 5.3.			
30	5.3.2.2.2	Data phase. During the data phase, the transmit waveform shall contain both message information (UNKNOWN DATA) and channel probes (KNOWN DATA). The probe shall consist of zeros, D1, and D2 (D1 and D2 are defined in 5.3.2.3.7.1.2). For fixed-frequency operation, the period of dwell shall be a function of bit rate only. At 2400 and 4800 bps, 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 bps, the two durations shall be 20 symbols in each position. At 75 bps, 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.	Raw data recorded by JITC decode software in steps 36-86 at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
31	5.3.2.2.3	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 (figure 2) shall be switched to the EOM position. This shall cause a fixed 32-bit pattern (see 5.3.2.3.1) to be sent to the FEC encoder. Function switches S2 and S3 (and also S4 in frequency-hopping operation) shall continue to operate as established for the data phase.	01001011 01100101 10100101 10110010			
32	5.3.2.2.4	FEC coder and interleaver flush phase. Immediately upon completion of the EOM phase, S1 (figure 2 shall be switched to the FLUSH position causing input of flush bits (see 5.3.2.3.2) to the FEC encoder).	Send “0” FLUSH bits after EOM.			
33	5.3.2.3.1	EOM sequence. The eight-digit hexadecimal number, 4B65A5B2 shall represent the EOM sequence. The bits shall be transmitted with the most significant digit first. Thus the first eight bits are, left to right, 0100 1011.	01001011 01100101 10100101 10110010			
34	5.3.2.3.2	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 interleaved matrix data block (see 5.3.2.3.4 for data block size) containing the last coder flush bit. Flush bits shall be set to “0”. If the interleaver is in a bypass (0.0 s) state, only the coder flush bits are transmitted.	Send 144 “0” FLUSH bits.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
35	5.3.2.3.3	FEC encoder. The FEC encoder shall be used for data rates up to and including 2400 bps. The FEC encoder block diagram for frequency-hopping and fixed-frequency operation is shown on figure 4. For frequency-hopping operation, the FEC encoder function shall be accomplished by a constraint length 7 convolutional coder with repeat coding used at the 75, 150, and 300 bps rates. 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_l (x) being taken first. For the 2400 bps rate, every fourth bit (the second value of T_2 (x) shall be omitted at the interleaver output to form a punctured rate 2/3 convolutional rate. At all other rates, the convolutional coder shall be rate 1/2. Coded bit streams of 3600, 2400, and 1200 bps shall be generated for the input data rates of 2400, 1200, and 600 bps, respectively. For the 300, 150, and 75 bps input data rates, a 1200 bps 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_l (x), followed by repetitions of the second T_2 (x). Error-correction coding for frequency-hopping operation shall be in accordance with table 8.	Test procedures for frequency-hopping operation are to be determined.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
35	5.3.2.3.3 continued	b. For fixed-frequency operation, the FEC encoder function shall be accomplished by a single rate 1/2 constraint length 7 convolutional coder with repeat coding used at 150 and 300 bps. The two summing nodes shall operate as given for frequency-hopping operation; that is, for each bit input to the encoder, two bits shall be taken as output from the encoder. Coded bit streams of 4800, 2400, and 1200 bps shall be generated for input data rates of 2400, 1200, and 600 bps, respectively. For 300 bps and 150 bps input data rates, repeating the pairs of output bits the appropriate number of times shall generate a 1200 bps coded bit stream. 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 bps, a different transmit format (see 5.3.2.3.7.1.1) is used and the effective code rate of 1/2 shall be employed to produce a 150 bps coded stream. Error-correction coding for fixed-frequency operation shall be in accordance with table 9. c. For 4800 bps fixed-frequency operation, the FEC encoder shall be bypassed.	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
36	5.3.2.3.4	The interleaver shall be a matrix block type that 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. 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. For fixed-frequency operation at 75 bps only, the following changes to the above description shall apply: a. When the interleaver setting is on long, the procedure is the same, but the row number shall be advanced by 7 modulo 20. b. When the interleaver 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.	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
37	5.3.2.3.5	Interleave 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 bps with a long interleave 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. 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 11.	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
38	5.3.2.3.6	Modified-Gray Decoder. At 4800 and 2400 bps, the channel bits are effectively transmitted with 8-ary channel symbols. At 1200 bps and 75 bps (fixed frequency), the channel bits are effectively transmitted with 4-ary channel symbols. Modified-Gray decoding of the 2400 bps, 4800 bps (tribit), and 75 bps (fixed frequency) 1200 bps (dibit) channel symbols shall be in accordance with tables 12 and 13, respectively. When one-bit channel symbols are used (600-150 bps, and 75 bps (frequency-hopping operation)) the MGD does not modify the unknown data bit stream.	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			
39	5.3.2.3.7.1	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 frequency-hopping and fixed-frequency operation data rates, the output of the symbol formation shall be scrambled with pseudo-random 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 5.3.2.3.9.	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
40	5.3.2.3.7.1.1	Unknown data. At all frequency-hopping operation rates and rates above 75 bps for fixed-frequency operation, 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, figure 5. At the 4800 bps and 2400 bps rates, all the tribit numbers (0-7) shall be used for symbol formation. 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 in table 14a 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 sync pattern) if long interleave is selected. Note: Each set consists of 32-tribit numbers. The receive modem shall use the modification of the known data at interleaver boundaries to synchronize without a preamble and determine the correct date rate and mode of operation.	Test procedures for frequency-hopping operation are to be determined.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
41	5.3.2.3.7.1.2	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 interleaved block. The block length shall be 1440-tribit channel symbols for short interleave setting and 11520-tribit channels 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 15 of 5.3.2.3.7.2.1 and table 17 of 5.3.2.3.7.2.2. The two known symbol patterns are repeated twice rather than four times as they are in table 17 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).	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
42	5.3.2.3.7.2.1	General. The synchronization pattern shall consist of either three or twenty-four 200 millisecond (msec) segments (depending on whether either zero, short, or long interleave periods are used). Each 200-msec segment shall consist of a transmission of 15 three-bit channel symbols as described in 5.3.2.3.7.2.2. The sequence of channel symbols shall be 0, 1, 3, 0, 1, 3, 1, 2, 0. D1, D2, C1, C2, C3, 0. Table 15 gives the three bit values of D1 and D2 shall designate the bit rate and interleave setting of the transmitting modem. If a demodulator receives any D1, D2 combination that it does not implement, it shall not synchronize but shall continue to search for synchronization. The three count symbols C1, C2, and C3 shall represent a count of the 200 msec 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. Adding a “1” before the two-bit value does this so that this “1” becomes the most significant bit. This conversion shall be as shown in table 16.	See Preamble sequences that are specified in reference 30.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
43	5.3.2.3.7.2.2	Preamble pattern generation. The sync preamble pattern shall be a sequence of channel symbols containing three bits each (see 5.3.2.3.7.2.1). These channel symbols shall be mapped into thirty two-tribit numbers as given in table 17. Note: When the two known symbol patterns preceding the transmission of each new interleaves block are transmitted, the patterns in table 17 are repeated twice rather than four times to produce 8 pattern of 16-tribit numbers.	See Preamble sequences that are specified in reference 30.			
44	5.3.2.3.8	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.	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
45	5.3.2.3.8.1	Data sequence randomizing generator. The data sequence randomizing generator shall be a 12-bit shift register with the functional configuration shown on figure 6. The shift register shall be loaded with the initial pattern shown in figure 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.	Properly decode 2047 bit pattern UUT (using JITC developed MIL-STD-188-110B decode software) at data rates of 4800, 2400, 1200, 600, 300, 150, and 75 bps.			
46	5.3.2.3.8.2	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 5.3.2.3.8.1 and this paragraph shall be modulo 8 added to the output of the symbol formation function.	Preamble sequences in table 5.1, 5.2, and 5.3, correspond to decoded preamble sequences specified in reference 30.			

Table 5.5. Serial (Single-Tone) Mode Test Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
47	5.3.2.3.9	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 sine wave. 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. b. Clock accuracy for generation of the 1800-Hz carrier shall be within ±1 Hz.	1800 Hz sine wave ∠ tribit 0° 000 45° 001 90° 010 135° 011 180° 100 225° 101 270° 110 315° 111 clock frequency: 1800 Hz ±1 Hz			
50	5.4.1.2	Output power level. The total power transmitted by the modem to the line shall be adjustable in no greater than 1 dB steps from at least –12 dBm to –3 dBm.	-12 dBm to -3 dBm in 1 dB steps.			

LEGEND:

ALE – Automatic Link Establishment
bps – bits per second
CTS – Clear-to-Send
dB – decibels
dBm – decibels referenced to 1 milliwatt
DO – Design Objective
DTE – Data Terminal Equipment
EOM – End-of-Message
FEC – Forward Error Correction
HF – High Frequency
Hz – hertz
JITC – Joint Interoperability Test Command
MGD – Modified-Gray Decoder
MIL-STD – Military Standard
msec – millisecond
PSK – Phase-Shift Keying
RTS – Request-to-Send
s – seconds
sync – synchronization
UUT – Unit Under Test
∠ – Angle

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SUBTEST 6. 16-TONE DIFFERENTIAL PHASE-SHIFT KEYING (DPSK) MODE

6.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B, reference numbers 51-58.

6.2 Criteria

a. 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 bps, MIL-STD-188-110B, paragraph A.4.2.

b. Modulator output signal. The modulator output signal shall contain 16 Differential Phase-Shift Keying (DPSK) data tones (MIL-STD-188-110B, table A-1). The 16 data tones shall be simultaneously keyed to produce a signal element interval of 13 1/3 msec for each data tone. The composite modulator output signal shall have a constant modulation rate of 75 Bd for all input data signaling rates from 75 to 2400 bps. The modulator shall provide a separate tone combination to initiate synchronization and, if required, a separate tone for Doppler correction, MIL-STD-188-110B, paragraph A.5.1.

c. Data tone frequencies. The frequency of each data tone shall be as listed in MIL-STD-188-110B, table A-2. The tone frequencies shall maintain an accuracy of ±0.1 Hz, MIL-STD-188-110B, paragraph A.5.2.

d. Phase modulation and encoding. For data signaling rates of 75, 150, 300, or 600 bps at the modulator input, each data tone signal element shall be two-phase (biphase) modulated (see MIL-STD-188-110B, figure A-1a). 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 MIL-STD-188-110B, table A-2. For data signaling rates of 1200 or 2400 bps at the modulator input, each data-tone signal element shall be four-phase (quadrature-phase) modulated (see MIL-STD-188-110B, figure A-1b). 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 MIL-STD-188-110B, table A-2. The phase changes of the data tone signal elements specified in MIL-STD-188-110B, table A-2, shall be relative to the phase of the immediately preceding signal element, MIL-STD-188-110B, paragraph A.5.3.

e. 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 msec, corresponding to a duration of five to 32 data tone signal elements. The 605-Hz tone shall be 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 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 msec) 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, MIL-STD-188-110B, paragraph A.5.4.

f. 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, MIL-STD-188-110B, paragraph A.5.5.

g. In-band diversity combining. In-band diversity combining shall be accomplished at data signaling rates from 75 bps to 1200 bps. The data tones shall be combined in accordance with MIL-STD-188-110B, table A-1. The degree of diversity combining shall be as listed in MIL-STD-188-110B, table A-2, MIL-STD-188-110B, paragraph A.5.6.

h. Demodulator signal alarm. Provisions shall be made in the demodulator to activate an alarm when the incoming signals from the HF radio link decreases below a preset level, MIL-STD-188-110B, paragraph A.5.7.

6.3 Test Procedures

a. Test Equipment Required

(1) BERT (2 ea)

(2) Personal Computer with Soundcard and Matlab Software

(3) Modem (certified to appendix A of MIL-STD-188-110B)

(4) Channel Simulator

(5) UUT (modem with 16-tone waveform)

b. Test Configuration. Configure the equipment as shown in figures 6.1 and 6.2.

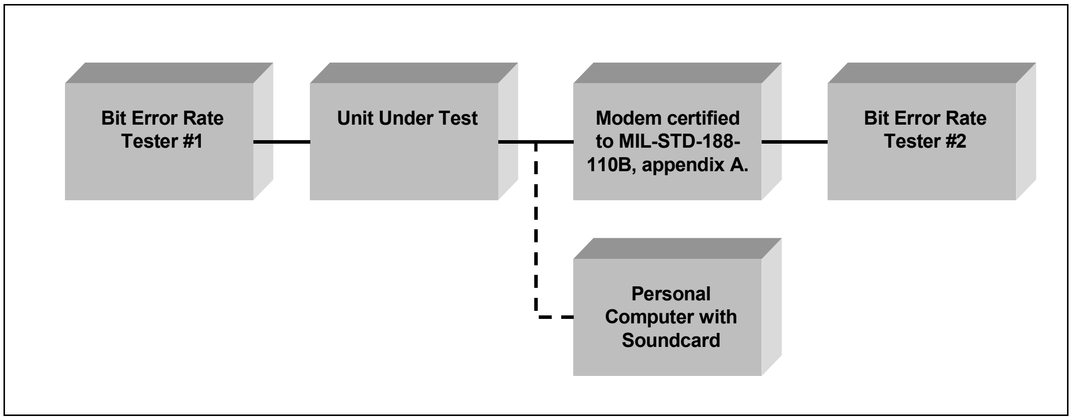

Figure 6.1. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Test Equipment Configuration

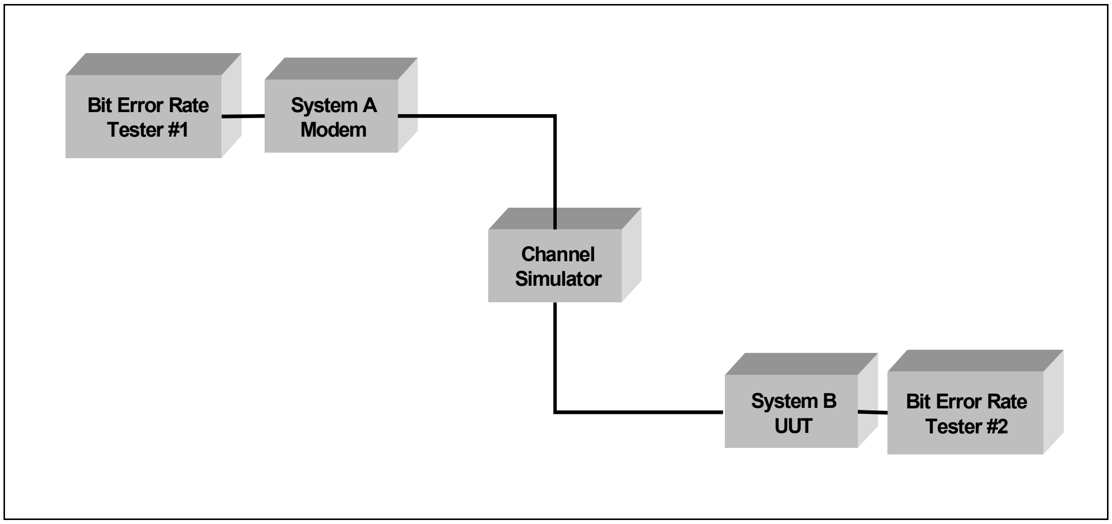

Figure 6.2. Demodulator Signal Alarm Equipment Configuration

c. Test Conduct. The procedures for this subtest are listed in table 6.1.

Table 6.1. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Test Procedures

Step	Action	Settings/Action	Result
1	Set up equipment.	See figure 6.1.	
The following procedure is for reference numbers 51, 54, and 57.			
2	Configure UUT and modem to operate using the 16-tone waveform.		
3	Send data from UUT to modem at 75 bps for 1 minute.	Record BER received by BERT 2 after 1 minute of operation.	

Table 6.1. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
4	Send data from UUT to modem at 150 bps for 1 minute.	Record BER received by BERT 2 after 1 minute of operation.	
5	Send data from UUT to modem at 300 bps for 1 minute.	Record BER received by BERT 2 after 1 minute of operation.	
6	Send data from UUT to modem at 600 bps for 1 minute.	Record BER received by BERT 2 after 1 minute of operation.	
7	Send data from UUT to modem at 1200 bps for 1 minute.	Record BER received by BERT 2 after 1 minute of operation.	
8	Send data from UUT to modem at 2400 bps for 1 minute.	Record BER received by BERT 2 after 1 minute of operation.	
The following procedure is for reference numbers 52 and 55.			
9	Set up UUT to operate using the 16-tone waveform with no Doppler correction.	Set data rate to 2400 bps.	
10	Configure PC to capture a WAV file (use wave-editor software).	Capture at least 2.5 seconds of data at 8 kHz, 16 bits, mono. File name: 16-tone.wav	
11	Send data with UUT.	Capture data in WAV format.	
12	Run Matlab software.		
13	Load file: “16-tone preamble.m” (see appendix D).		
14	Cut and paste “16-tone preamble.m” file into Matlab’s Command Window.	The result is a plot of the preamble shown in the frequency domain. Record the center frequency of each tone displayed. Print results.	
The following procedure is for reference numbers 52, 55, and 56.			
15	Set up UUT to operate using the 16-tone waveform with the Doppler correction tone.		
16	Configure PC to capture a WAV file (use wave-editor software).	Capture at least 2.5 seconds of data at 8 kHz, 16 bits, mono. File name: 16-tone2.wav	
17	Load file: “16-tone preamble.m” (see appendix D).		
18	Cut and paste “16-tone preamble.m” file into Matlab’s Command Window.	The result is a plot of the preamble shown in the frequency domain. Record the center frequency of each tone displayed. Record the level of the 605-Hz tone referenced to the level of the subcarriers. Print results.	
The following procedure is for reference number 54.			
19	Set up UUT to operate at 1200 bps.		
20	Configure PC to capture a WAV file (use wave-editor software).	Capture at least 2.5 seconds of data at 8 kHz, 16 bits, mono. File name: 1200bps.wav	
The following procedure is for reference number 58.			
21	Set up equipment.	See figure 6.2.	

Table 6.1. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Test Procedures (continued)

Step	Action	Settings/Action	Result
22	Program modem to begin sending 16-tone data to the UUT through the HF simulator.		
23	Slowly decrease the SNR through the simulator.	Does the UUT activate an alarm when the incoming signal decreases below a preset level?	

LEGEND:
BER – Bit Error Rate
BERT – Bit Error Rate Tester
bps – bits per second
Hz – hertz
HF – High Frequency
kHz – kilohertz
PC – Personal Computer
SNR – Signal-to-Noise Ratio
UUT – Unit Under Test
WAV – Wave

6.4 Presentation of Results. The results will be shown in table 6.2 indicating the requirement and measured value or indications of capability.

Table 6.2. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Results

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
51	A.4.2	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 (bps).	75, 150, 300, 600 1200, and 2400 bps.			

Table 6.2. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
52	A.5.1	Modulator output signal. The modulator output signal shall contain 16 DPSK data tones (table A-1). The 16 data tones shall be simultaneously keyed to produce a signal element interval of 13 1/3 milliseconds (msec) 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 bps. The modulator shall provide a separate tone combination to initiate synchronization and, if required, a separate tone for Doppler correction.	16 DPSK data tones. Signal element = 13 1/3 msec Provide separate tone combination for synchronization, and tone for Doppler correction			
53	A.5.2	Data tone frequencies. The frequency of each data tone shall be as listed in table A-2.	MIL-STD-188-110B, table A-2			
		The tone frequencies shall maintain an accuracy of ±0.1 hertz (Hz).	Not measured, not testable at this time.			

Table 6.2. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
54	A.5.3	Phase modulation and encoding. For data signaling rates of 75, 150, 300, or 600 bps at the modulator input, each data tone signal element shall be two-phase (biphase) modulated (see figure A-1a). 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 A-2. For data signaling rates of 1200 or 2400 bps at the modulator input, each data-tone signal element shall be four-phase (quadrature-phase) modulated (see figure A-1b). 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 A-2. The phase changes of the data tone signal elements specified in table A-2 shall be relative to the phase of the immediately preceding signal element.	Not directly measured. Validated operation at each data rate via interoperability test with JITC certified modem.			

Table 6.2. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
55	A.5.4	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 msec, corresponding to a duration of five to 32 data tone signal elements. The 605-Hz tone shall be 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 msec) 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.	Preamble: 605-Hz tone (unmodulated) 7 dB ±1 dB higher than 1705-Hz tone (180 degree phase-shifted). Minimum duration: 66 2/3 msec			

Table 6.2. 16-Tone Differential Phase-Shift Keying (DPSK) Mode Results (continued)

Reference Number	MIL-STD-188-141B, paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
56	A.5.5	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.	605-Hz tone 7 dB ±1 dB higher than the level of the subcarriers.			
57	A.5.6	In-band diversity combining. In-band diversity combining shall be accomplished at data signaling rates from 75 bps to 1200 bps. The data tones shall be combined in accordance with table A-1. The degree of diversity combining shall be as listed in table A-2.	Not directly measured. Validated operation at each data rate via interoperability test with JITC certified modem.			
58	A.5.7	Provisions shall be made in the demodulator to activate an alarm when the incoming signals from the HF radio link decreases below a preset level.	Provide signal alarm.			

LEGEND:

bps – bits per second	HF – High Frequency	MIL-STD – Military Standard
dB – decibels	Hz – hertz	msec – millisecond
DPSK –Differential Phase-Shift Keying	JITC – Joint Interoperability Test Command	

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SUBTEST 7. 39-TONE PARALLEL MODE

7.1 Objective. To determine the extent of compliance to the requirements of 39-Tone Parallel Mode, MIL-STD-188-110B, reference numbers 60-80.

7.2 Criteria

a. 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 MIL-STD-188-110B, figure B-1) (1) accepts unknown serial binary data at its line side data input port, (2) performs FEC encoding and interleaving, and (3) converts the resulting 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 bps. 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 (1) accepts QDPSK data tones at its input, (2) converts them into the transmitted serial bit stream, (3) performs deinterleaving and FEC decoding, and (4) makes the resulting data stream available at its line-side output port, MIL-STD-188-110B, paragraph B.4.

b. 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:

$$g(x) = x^4 + a^{l3} x^3 + a^6x^2 + a^3x + a^{10};$$

where "*a*" is a non-zero element of the Galois Field (GF)(2^4) formed as the field of polynomials over GF(2) module $x^4 + x + 1$.

For input signaling rates of 2400 bps, the code shall be shortened to (14,10). Otherwise, the code shall be shortened to (7,3) MIL-STD-188-110B, paragraph B.5.2.

c. 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 are shown in MIL-STD-188-110B, table B-1, shall be provided. For a data-signaling rate of 2400 bps, the selection shall consist of eight degrees. At data signaling rates below 2400 bps, four degrees for each bit rate shall be provided as shown in MIL-STD-188-110B, table B-1. The input data stream shall be loaded into the interleaver buffer as described by MIL-STD-188-110B, figures B-2 and B-3, MIL-STD-188-110B, paragraph B.5.3.

d. 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 msec. The transmit sequence of events is shown on MIL-STD-188-110B, figure B-4, MIL-STD-188-110B, paragraph B.5.4.

e. 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 Hz. Part two shall last for eight 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 rms value within ±1 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 MIL-STD-188-110B table B-2, MIL-STD-188-110B, paragraph B.5.4.1.

f. Extended preamble. To improve the probability of synchronization and signal presence detection in low Signal-to-Noise-Ratio (SNR) 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 non-extended 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, MIL-STD-188-110B, paragraph B.5.4.2.

g. 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 pseudo-random 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 MIL-STD-188-110B, figure B-5, MIL-STD-188-110B, paragraph B.5.4.3.

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 MIL-STD-188-110B, table B-3, 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 MIL-STD-188-110B, table B-3. However, the final bit of the framing sequence shall always be the first space bit that 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), MIL-STD-188-110B, paragraph B.5.4.3.

h. Modulator output signal. The modulator output shall contain 39 QDPSK data tones (see MIL-STD-188-110B, table B-4). The 39 data tones shall be simultaneously keyed to produce a signal element interval of 22.5 msec for each data tone. The composite modulator output shall have a constant modulation rate of 44.44 Bd for all standard input data signaling rates from 75 to 2400 bps. At input signaling rates less than 2400 bps, 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 MIL-STD-188-110B, table B-5, MIL-STD-188-110B, paragraph B.5.5.

i. In-band diversity. Two selectable methods of in-band diversity for data rates of 75-600 bps 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), MIL-STD-188-110B, paragraph B.5.6.

j. 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 -msec 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 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 MIL-STD-188-110B, table B-6), MIL-STD-188-110B, paragraph B.5.6.1.

k. Frequency diversity. In-band diversity shall be characterized by transmitting a data word and its (d-1) copies in one signal element (e.g., 22.5-msec time interval). This characterization is according to the tone/bit assignments shown in MIL-STD-188-110B, table B-7, MIL-STD-188-110B, paragraph B.5.6.2.

l. 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, and convert it to bit synchronous data prior to FEC encoding. Conversely, after FEC decoding, the demodulator shall convert bit synchronous data back into asynchronous format. Also, before FEC encoding, SPACE bits shall replace the start, stop, and parity bits. After FEC decoding, the start, stop, and parity bits shall be regenerated before placing the characters in the output data stream. Otherwise, the mode operates as specified in B.5.1 - B.5.6.2 above, MIL-STD-188-110B, paragraph B.5.7.

m. Character length. A means shall be provided whereby the modulator will accept, and the demodulator will generate, any of the data characters shown in MIL-STD-188-110B, table B-8, MIL-STD-188-110B, paragraph B.5.7.1.

n. 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, MIL-STD-188-110B, paragraph B.5.7.2.

o. 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, MIL-STD-188-110B, paragraph B.5.7.3.

p. 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, MIL-STD-188-110B, paragraph B.5.7.3.1.

q. Input data source rate less 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, MIL-STD-188-110B, paragraph B.5.7.3.2.

r. 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, MIL-STD-188-110B, paragraph B.5.7.4.

s. 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 MIL-STD-188-110B, tables B-9, B-10, and B-11). 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, MIL-STD-188-110B, paragraph B.5.7.6.

Table 7.1. Listing of the 39-Tone Waveform Frequencies and Their Initial Phases

Data Tone	Frequency (Hz)	Initial Phase (deg)	Data Tone	Frequency (Hz)	Initial Phase (deg)	Data Tone	Frequency (Hz)	Initial Phase (deg)
Doppler	393.75	0.0	14	1406.25	59.1	28	2193.75	123.8
1	675.00	0.0	15	1462.50	185.6	29	2250.00	19.7
2	731.25	5.6	16	1518.75	317.8	30	2306.25	281.3
3	787.50	19.7	17	1575.00	101.3	31	2362.50	194.1
4	843.75	42.2	18	1631.25	253.1	32	2418.75	115.3
5	900.00	73.1	19	1687.50	56.3	33	2475.00	45.0
6	956.25	115.3	20	1743.75	225.0	34	2531.25	345.9
7	1012.50	165.9	21	1800.00	45.0	35	2587.50	295.3
8	1068.75	225.0	22	1856.25	236.3	36	2643.75	253.1
9	1125.00	295.3	23	1912.50	73.1	37	2700.00	222.2
10	1181.25	14.1	24	1968.75	281.3	38	2756.25	199.7
11	1237.50	101.3	25	2025.00	137.8	39	2812.50	185.6
12	1293.75	199.7	26	2081.25	5.6			
13	1350.00	303.8	27	2137.50	239.1			
LEGEND: deg – degree; Hz – hertz								

7.3 Test Procedures

a. Test Equipment Required

(1) BERT (2 ea)

(2) Personal Computer with Soundcard and Matlab Software

(3) UUT (modem with 39-tone waveform)

(4) Modem (certified to appendix B of MIL-STD-188-110B)

(5) Oscilloscope

b. Test Configuration. Figures 7.1, 7.2, and 7.3 show the equipment setup for this subtest.

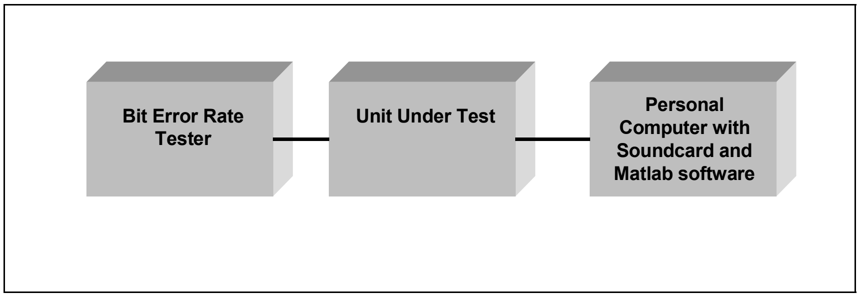

Figure 7.1. 39-Tone Waveform Measurement Configuration

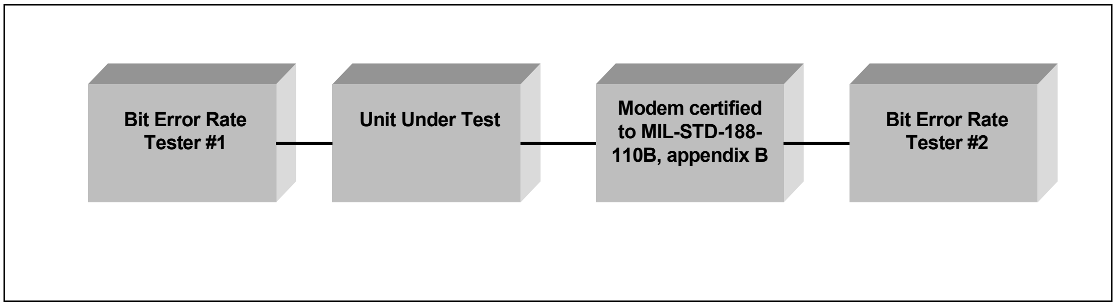

Figure 7.2. Asynchronous Mode Measurement Configuration

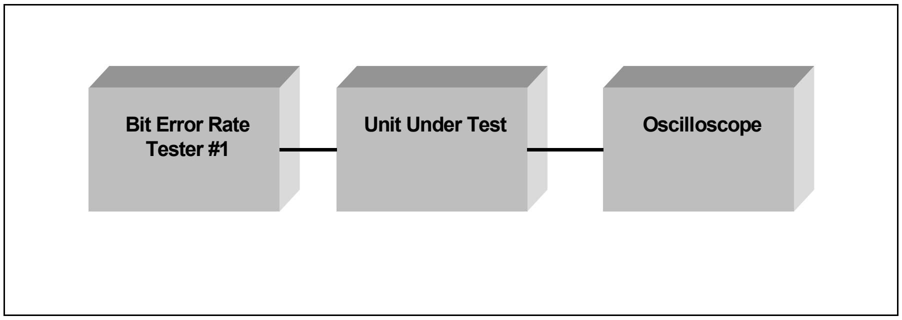

Figure 7.3. Composite Signal Measurement Configuration

c. Test Conduct. The procedures for this subtest are listed in table 7.2.

Table 7.2. 39-Tone Waveform Test Procedures

Step	Action	Settings/Action	Result
1	Set up equipment.	See figure 7.1.	
2	Set up UUT to operate using the 39-tone waveform (standard preamble).		
3	Configure PC to capture a WAV file (use wave-editor software).	Capture at least 2.5 seconds of data at 8 kHz, 16 bits, mono. File name: wave.wav	
4	Send data with UUT at 75 bps.	Capture data in WAV format.	
The following procedure is for reference number 63.			
5	Run Matlab software.		
6	Load file: "39-tone preambles 1 and 2.m" (see appendix D).	Modify Matlab code to view the first part of the preamble (set i = 1:14). This Matlab algorithm plots the magnitude of the input .wav file in the frequency domain. The input .wav file must be sampled at 8 kHz.	
7	Cut and paste "39-tone preambles 1 and 2.m" file into Matlab's Command Window.	The result is a plot of the first part of the preamble shown in the frequency domain. Record the center frequency of each tone displayed. Print results.	
8	Open file: "39-tone preambles 1 and 2.m."	Modify Matlab code to view the second part of the preamble (set i = 15:22).	
9	Cut and paste "39-tone preambles 1 and 2.m" file into Matlab's Command Window.	The result is a plot of the second part of the preamble shown in the frequency domain. Record the center frequency of each tone displayed. Print results.	
The following procedure is for reference number 66.			
10	Open file: "39-tone phase-shift decode.m" (see appendix D).	Modify Matlab code to view the phase-shift between symbols 25 and 26 (set symbol_number = 25). This Matlab algorithm calculates and displays amplitude and phase-shift of all 40 tones over each 22.5 msec interval. The input .wav file must be sampled at 8 kHz. The algorithm down samples the .wav file to 7200 Hz.	
11	Cut and paste "39-tone phase-shift decode.m" file into Matlab's Command Window.	The result is a list of the individual phase-shifts for each of the 39-tones, and the amplitude of each of the 39-tones. Print results.	
12	Set up UUT to operate using the 39-tone waveform with the extended preamble.		
13	Configure PC to capture a WAV file (use wave-editor software).	Capture at least 2.5 seconds of data at 8 kHz, 16 bits, mono. File name: wave.wav	
The following procedure is for reference number 64.			
14	Send data with UUT.	Capture data in WAV format.	
15	Load Matlab software.		

Table 7.2. 39-Tone Waveform Test Procedures (continued)

Step	Action	Settings/Action	Result
16	Open file: “39-tone preambles 1 and 2.m.”	Modify Matlab code to view the first part of the extended preamble (set i = 1:58).	
17	Cut and paste “39-tone preambles 1 and 2.m” file into Matlab’s Command Window.	The result is a plot of the first part of the preamble shown in the frequency domain. Record the center frequency of each tone displayed. Print results.	
18	Open file: “39-tone preambles 1 and 2.m” (see appendix D).	Modify Matlab code to view the second part of the extended preamble (set i = 59:85).	
19	Cut and paste “39-tone preambles 1 and 2.m” file into Matlab’s Command Window.	The result is a plot of the second part of the preamble shown in the frequency domain. Record the center frequency of each tone displayed. Print results.	
20	Open file: “39-tone phase-shift decode.m.”	Modify Matlab code to view the phase-shift between signal element periods 86 and 87 (set symbol_number = 86). Note that these symbols are in the third part of the preamble.	
21	Cut and paste “39-tone phase-shift decode.m” file into Matlab’s Command Window.	The result is a list of the individual phase-shifts for each of the 39 tones during the third part of the preamble. Print results.	
The following procedure is for reference number 66.			
22	Open file: “39-tone phase-shift decode.m.”	Modify Matlab code to view the phase-shift between signal element periods 96 and 97 (set symbol_number = 96). Note that these symbols are in the third part of the preamble.	
23	Cut and paste “39-tone phase-shift decode.m” file into Matlab’s Command Window.	The result is a list of the individual phase-shifts for each of the 39 tones during the third part of the preamble. Successful decode validates that the output of the UUT is 39 QDPSK data tones, with signal elements equal to 22.5 msec. Print results.	
24	Open file: “39-tone phase-shift decode.m.”	Modify Matlab code to view the phase-shift between signal element periods 100 and 101 (set symbol_number = 100).	
25	Cut and paste “39-tone phase-shift decode.m” file into Matlab’s Command Window.	The result is a list of the individual phase-shifts for each of the 39 tones. Print results. Record the level of the Doppler correction tone and the level of any data tone.	
26	Repeat steps 1–25 for the following data rates: 150, 300, 600, 1200, and 2400 bps.		
The following procedure is for reference number 68.			

Table 7.2. 39-Tone Waveform Test Procedures (continued)

<table>
<tr><th>Step</th><th>Action</th><th>Settings/Action</th><th>Result</th></tr>
<tr><td>27</td><td>Research documentation to determine what methods of in-band diversity the UUT is capable of.</td><td>Expected: (for data rates of 75-600 bps)
Time/frequency diversity
Frequency diversity</td><td></td></tr>
<tr><td colspan="4">The following procedure is for reference numbers 60, 61, 62, 65, 69, and 70-75.</td></tr>
<tr><td>28</td><td>Set up equipment.</td><td>See figure 7.2.</td><td></td></tr>
<tr><td>29</td><td>Configure BERTs and modems to operate in asynchronous mode.</td><td>Verify that the UUT modulator can accept, and the UUT demodulator will generate, any of the data characters shown in table B-8 of MIL-STD-188-110B.</td><td></td></tr>
<tr><td>30</td><td>Send a 2047 test pattern from BERT 1 for 10 minutes, at 4800 Hz. Program UUT to operate at 75 bps.</td><td>Observe CTS light on BERT 1. Use a stop watch to measure the time from when the CTS light first appears (at the beginning of data transmission) to the time when the CTS light goes off.
Record BER from BERT 2 after 10 minutes of operation.</td><td></td></tr>
<tr><td>31</td><td>Send a 2047 test pattern from BERT 1 for 10 minutes, at 4800 Hz. Program UUT to operate at 150 bps.</td><td>Record BER from BERT 2.</td><td></td></tr>
<tr><td>32</td><td>Send a 2047 test pattern from BERT 1 for 10 minutes, at 4800 Hz. Program UUT to operate at 300 bps.</td><td>Record BER from BERT 2.</td><td></td></tr>
<tr><td>33</td><td>Send a 2047 test pattern from BERT 1 for 10 minutes at 4800 Hz. Program UUT to operate at 600 bps.</td><td>Observe CTS light on BERT 1. Use a stop watch to measure the time from when the CTS light first appears (at the beginning of data transmission) to the time when the CTS light goes off. Compare to time measurement taken in step 30. (Expected result: CTS light remains on longer when UUT is operating at higher data rates.)
Record BER from BERT 2 after 10 minutes of operation.</td><td></td></tr>
<tr><td>34</td><td>Send a 2047 test pattern from BERT 1 for 10 minutes at 4800 Hz. Program UUT to operate at 1200 bps.</td><td>Record BER from BERT 2.</td><td></td></tr>
<tr><td>35</td><td>Send a 2047 test pattern from BERT 1 for 10 minutes at 4800 Hz. Program UUT to operate at 2400 bps.</td><td>Record BER from BERT 2.</td><td></td></tr>
<tr><td colspan="4">The following procedure is for reference number 76.</td></tr>
<tr><td>36</td><td>Send a 2047 test pattern from BERT 1 for 10 minutes at 1200 Hz. Program UUT to operate at 2400 bps.</td><td>Record BER from BERT 2.</td><td></td></tr>
<tr><td colspan="4">The following procedure is for reference number 63.</td></tr>
<tr><td>37</td><td>Configure equipment as shown in figure 7.3.</td><td></td><td></td></tr>
</table>

Table 7.2. 39-Tone Waveform Test Procedures (continued)

Step	Action	Settings/Action	Result
38	Set up oscilloscope.	Configure oscilloscope to trigger on the start of preamble transmission out of the UUT.	
39	Use oscilloscope to measure the rms level of the composite signal (in dB) for all parts of the preamble, and the rms level (in dB) of the modulator output (39-tone) occurring during subsequent data transmission.	Record composite signal levels of each part of the preamble, and levels of subsequent data transmission at least 100 msec after preamble.	

LEGEND:

BER – Bit Error Rate
BERT – Bit Error Rate Tester
bps – bits per second
CTS – Clear-to-Send
dB – decibels
Hz – hertz
kHz – kilohertz
MIL-STD – Military Standard
msec – millisecond
PC – Personal Computer
QDPSK – Quadrature Differential Phase-Shift Keying
rms – root mean squared
UUT – Unit Under Test
WAV - Wave

7.4 Presentation of Results. The results will be shown in table 7.3 indicating the requirement and measured value or indications of capability.

Table 7.3. 39-Tone Waveform Results

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
60	B.5.2	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: $g(x) = x^4 + a^{l3} x^3 + a^6x^2 + a^3x + a^{10}$; where "*a*" is a non-zero element of the Galois field (GF)(2^4) formed as the field of polynomials over GF(2) module $x^4 + x + 1$. For input signaling rates of 2400 bps, the code shall be shortened to (14,10). Otherwise, the code shall be shortened to (7,3).	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
61	B.5.3	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 are shown in table B-1 shall be provided. For a data signaling rate of 2400 bps, the selection shall consist of eight degrees. At data signaling rates below 2400 bps, four degrees for each bit rate shall be provided as shown in table B-1. The input data stream shall be loaded into the interleaver buffer as described by figures B-2 and B-3.	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			
62	B.5.4	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 (msec). The transmit sequence of events is shown on figure B-4.	Not directly measured. Validated operation at each data rate via interoperability test with Q9600 and RF-5710A modems.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
60	B.5.2	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: $g(x) = x^4 + a^{l3} x^3 + a^6x^2 + a^3x + a^{10}$; where “*a*” is a non-zero element of the Galois field (GF)(2^4) formed as the field of polynomials over GF(2) module $x^4 + x + 1$. For input signaling rates of 2400 bps, the code shall be shortened to (14,10). Otherwise, the code shall be shortened to (7,3).	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			
61	B.5.3	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 are shown in table B-1 shall be provided. For a data signaling rate of 2400 bps, the selection shall consist of eight degrees. At data signaling rates below 2400 bps, four degrees for each bit rate shall be provided as shown in table B-1. The input data stream shall be loaded into the interleaver buffer as described by figures B-2 and B-3.	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			
62	B.5.4	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 (msec). The transmit sequence of events is shown on figure B-4.	Not directly measured. Validated operation at each data rate via interoperability test with Q9600 and RF-5710A modems.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
63	B.5.4.1	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 B-2.	Part one: Center Frequency of Preamble tones (i = 1 to 14): 787.5, 1462.5, 2137.5, and 2812.5 Hz. Part two: Center Frequency of Preamble tones (i = 15 to 22): 1125.0, 1800.0, and 2475.0 Hz with 180 degree phase advance at start of each signal element. Part three: All data tones listed in table 7.1. Phase in accordance with MIL-STD-188-110B, table B-2.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
64	B.5.4.2	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 non-extended 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.	Part one: Center Frequency of Preamble tones (i = 1 to 58): 787.5, 1462.5, 2137.5, and 2812.5 Hz. Part two: Center Frequency of Preamble tones (i = 59 to 85): 1125.0, 1800.0, and 2475.0 Hz. Part three: All data tones and phases listed in table 7.1.			
64	B.5.4.2	Frame synchronization shall be acquired within 2.5 seconds (s). Note: See subtest 10 for the minimum Doppler correction of ±20 Hz requirement.	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
65	B.5.4.3	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 pseudo-random 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 B-5.	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			
65	B.5.4.3	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 B-3 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 B-3. However, the final bit of the framing sequence shall always be the first space bit that 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).	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
67	B.5.5	Modulator output signal. The modulator output shall contain 39 QDPSK data tones (see table B-4). The 39 data tones shall be simultaneously keyed to produce a signal element interval of 22.5 milliseconds (msec) 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 bps. At input signaling rates less than 2400 bps, 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.	Successful decode of phase-shifts of all 39 data tones plus Doppler correction tone using MatLab code developed by JITC. Special preamble tone combination: see reference number 63.			
67	B.5.5	During data transmission, the unmodulated Doppler correction tone shall be 6 dB ±1 dB higher than the normal level of any data tone. 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 B-5.	6 dB ±1 dB higher than data tones. Successful decode of phase shifts using MatLab code developed by JITC.			
67	B.5.5	All tone frequencies shall maintain an accuracy of ±0.05 Hz.	Not measured, not testable at this time.			
68	B.5.6	In-band diversity. Two selectable methods of in-band diversity for data rates of 75 - 600 bps 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).	Selectable in UUT: Time and frequency diversity or frequency diversity.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
69	B.5.6.1	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 msec 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 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 B-6).	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			
70	B.5.6.2	Frequency diversity. In-band diversity shall be characterized by transmitting a data word and its (d-1) copies in one signal element (e.g., 22.5 msec time interval). This characterization is according to the tone/bit assignments shown in table B-7.	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
71	B.5.7	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, and convert it to bit synchronous data prior to FEC encoding. Conversely, after FEC decoding, the demodulator shall convert bit synchronous data back into asynchronous format. Also, before FEC encoding, SPACE bits shall replace the start, stop, and parity bits. After FEC decoding, the start, stop, and parity bits shall be regenerated before placing the characters in the output data stream. Otherwise, the mode operates as specified in B.5.1 through B.5.6.2 above.	Support asynchronous mode operation at data rates of 75, 150, 300, 600, 1200, and 2400 bps.			
72	B.5.7.1	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 B-8.	Accept and generate characters from MIL-STD-188-110B table B-8.			
73	B.5.7.2	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.	Zero BER during asynchronous mode operation at all baud rates. CTS light remains on longer when UUT is operating at higher data rates			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
74	B.5.7.3	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.	Zero BER during asynchronous mode operation at all baud rates. CTS light remains on longer when UUT is operating at higher data rates			
75	B.5.7.3.1	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.	Zero BER during asynchronous mode operation at all baud rates. CTS light remains on longer when UUT is operating at higher data rates			
76	B.5.7.3.2	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.	UUT capable of operating at a higher rate than the input data source.			

Table 7.3. 39-Tone Waveform Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
77	B.5.7.4	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.	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			
78	B.5.7.6	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 B-9, B-10, and B-11). 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.	Not directly measured. Validated operation at each data rate via interoperability test of all synchronous and asynchronous modes with Q9600 and 5710A modems.			

LEGEND:

Bd – baud	FEC – Forward Error Correction	rms – root mean square
BER – Bit Error Rate	Hz – hertz	s – seconds
bps – bits per second	JITC – Joint Interoperability Test Command	Sync – Synchronization
CTS – Clear-to-Send	MIL-STD – Military Standard	UUT – Unit Under Test
dB – decibels	msec – millisecond	
EOM – End-of-Message	QDPSK – Quadrature Differential Phase-Shift Keying	

SUBTEST 8. HF DATA MODEM WAVEFORMS FOR DATA RATES ABOVE 2400 BPS

8.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B reference numbers 82-112.

8.2 Criteria

a. Modulation. The symbol rate for all symbols shall be 2400-symbols-per-second, which shall be accurate to a minimum of ±0.24 (10 parts per million [ppm]) symbols-per-second when the transmit data clock is generated by the modem and not provided by the DTE. PSK and Quadrature Amplitude Modulation (QAM) modulation techniques shall be used. The sub-carrier (or pair of Quadrature sub-carriers in the case of QAM) shall be centered at 1800 Hz accurate to a minimum of 0.018 Hz (10 ppm). The phase of the Quadrature sub-carrier relative to the In-phase carrier shall be 90 degrees. The correct relationship can be achieved by making the In-phase sub-carrier cos (1800 Hz) and the Quadrature sub-carrier sin (1800 Hz).

The power spectral density of the modulator output signal should be constrained to be at least 20-dB below the signal level measured at 1800 Hz, when tested outside of the band from 200 Hz to 3400 Hz. The filter employed shall result in a ripple of no more than ±2 dB in the range from 800 Hz to 2800 Hz, MIL-STD-188-110B, paragraph C.5.1.

b. Known symbols. For all known symbols, the modulation used shall be PSK, with the symbol mapping shown in MIL-STD-188-110B, table C-1 and figure C-1. No scrambling shall be applied to the known symbols, MIL-STD-188-110B, paragraph C.5.1.1.

c. Data symbols. For data symbols, the modulation used shall depend upon the data rate. MIL-STD-188-110B, table C-2, specifies the modulation that shall be used with each data rate.

The 3200-bps QPSK constellation is scrambled to appear, on-air, as an 8-PSK constellation. Both the 16-QAM and 32-QAM constellations use multiple PSK rings to maintain good peak-to-average ratios, and the 64-QAM constellation is a variation of the standard square QAM constellation, which has been modified to improve the peak-to-average ratio, MIL-STD-188-110B, paragraph C.5.1.2.

d. PSK data symbols. For the PSK constellations, a distinction is made between the data bits and the symbol number for the purposes of scrambling the QPSK modulation to appear as 8-PSK, on-air. Scrambling is applied as a modulo 8 addition of a scrambling sequence to the 8-PSK symbol number. Trans-coding is an operation which links a symbol to be transmitted to a group of data bits, MIL-STD-188-110B, paragraph C.5.1.2.1.

e. QPSK symbol mapping. For the 3200-bps user data rate, trans-coding shall be achieved by linking one of the symbols specified in MIL-STD-188-110B, table C-1, to a set of two consecutive data bits (dibit) as shown in MIL-STD-188-110B, table C-3. In this table, the leftmost bit of the dibit shall be the older bit; i.e., fetched from the interleaver before the rightmost bit, MIL-STD-188-110B, paragraph C.5.1.2.1.1.

f. 8-PSK symbol mapping. For the 4800-bps user data rate, trans-coding shall be achieved by linking one symbol to a set of three consecutive data bits (tribit) as shown in MIL-STD-188-110B, table C-4. In this table, the leftmost bit of the tribit shall be the oldest bit; i.e., fetched from the interleaver before the other two, and the rightmost bit is the most recent bit, MIL-STD-188-110B, paragraph C.5.1.2.1.2.

g. QAM data symbols. For the QAM constellations, no distinction is made between the number formed directly from the data bits and the symbol number. Each set of 4 bits (16-QAM), 5 bits (32-QAM), or 6 bits (64-QAM) is mapped directly to a QAM symbol. For example, the four-bit grouping 0111 would map to symbol seven in the 16-QAM constellation, while the 6 bits 100011 would map to symbol 35 in the 64-QAM constellation. Again, in each case the leftmost bit shall be the oldest bit, i.e. fetched from the interleaver before the other bits, and the rightmost bit is the most recent bit. The mapping of bits to symbols for the QAM constellations has been selected to minimize the number of bit errors incurred when errors involve adjacent signaling points in the constellation, MIL-STD-188-110B, paragraph C.5.1.2.2.

h. The 16-QAM constellation. The constellation points that shall be used for 16-QAM are shown in MIL-STD-188-110B, figure C-2, and specified in terms of their In-phase and Quadrature components in MIL-STD-188-110B, table C-5. As can be seen in the figure, the 16-QAM constellation is comprised of two PSK rings: 4-PSK inner and 12-PSK outer, MIL-STD-188-110B, paragraph C.5.1.2.2.1.

i. The 32-QAM constellation. The constellation points that shall be used for 32-QAM are shown in MIL-STD-188-110B, figure C-3, and specified in terms of their In-phase and Quadrature components in MIL-STD-188-110B, table C-6. This constellation contains an outer ring of 16 symbols and an inner square of 16 symbols, MIL-STD-188-110B, paragraph C.5.1.2.2.2.

j. The 64-QAM constellation. The constellation points that shall be used for the 64-QAM modulation are shown in MIL-STD-188-110B, figure C-4, and specified in terms of their In-phase and Quadrature components in MIL-STD-188-110B, table C-7. This constellation is a variation on the standard 8 x 8 square constellation, which achieves better peak-to-average without sacrificing the very good pseudo-Gray code properties of the square constellation, MIL-STD-188-110B, paragraph C.5.1.2.2.3.

k. Data scrambling. Data symbols for the 8-PSK symbol constellation (3200 bps, 4800 bps) shall be scrambled by modulo 8 addition with a scrambling sequence. The data symbols for the 16-QAM, 32-QAM, and 64-QAM constellations shall be scrambled by using an Exclusive OR (XOR) operation. Sequentially, the data bits forming each symbol (4 for 16-QAM, 5 for 32-QAM, and 6 for 64-QAM) shall be XOR'd with an equal number of bits from the scrambling sequence. In all cases, the scrambling sequence generator polynomial shall be $x^9 + x^4 + 1$ and the generator shall be initialized to 1 at the start of each data frame. A block diagram of the scrambling sequence generator is shown in MIL-STD-188-110B, figure C-5.

For 8-PSK symbols (3200 bps and 4800 bps), the scrambling shall be carried out taking the modulo 8 sum of the numerical value of the binary triplet consisting of the last (rightmost) three bits in the shift register and the symbol number (trans-coded value). For example, if the last three bits in the scrambling sequence shift register were 010, which has a numerical value equal 2 and the symbol number before scrambling was 6, symbol 0 would be transmitted since (6+2) Modulo 8 = 0. For 16-QAM symbols, scrambling shall be carried out by XORing the 4-bit number consisting of the last (rightmost) four bits in the shift register with the symbol number. For example, if the last 4 bits in the scrambling sequence shift register were 0101 and the 16-QAM symbol number before scrambling was 3 (i.e., 0011), symbol 6 (0110) would be transmitted. For 32-QAM symbols, scrambling shall be carried out by XORing the 5-bit number formed by the last (rightmost) five bits in the shift register with the symbol number. For 64-QAM symbols, scrambling shall be carried out by XORing the 6-bit number formed by the last (rightmost) six bits in the shift register with the symbol number.

After each data symbol is scrambled, the generator shall be iterated (shifted) the required number of times to produce all new bits for use in scrambling the next symbol (i.e., three iterations for 8-PSK, four iterations for 16-QAM, five iterations for 32-QAM, and six iterations for 64-QAM). Since the generator is iterated after the bits are used, the first data symbol of every data frame shall, therefore, be scrambled by the appropriate number of bits from the initialization value of 00000001.

The length of the scrambling sequence is 511 bits. For a 256-symbol data block with 6 bits per symbol, this means that the scrambling sequence will be repeated just slightly more than three times, although in terms of symbols, there will be no repetition, MIL-STD-188-110B, paragraph C.5.1.3.

l. Frame structure. The frame structure that shall be used for the waveforms specified in this subtest is shown in MIL-STD-188-110B, figure C-6. An initial 287-symbol preamble is followed by 72 frames of alternating data and known symbols. Each data frame shall consist of a data block consisting of 256 data symbols, followed by a mini-probe consisting of 31 symbols of known data. After 72 data frames, a 72-symbol subset of the initial preamble is reinserted to facilitate late acquisition, Doppler shift removal, and sync adjustment. It should be noted that the total length of known data in this segment is actually 103 symbols: the 72 reinserted preamble symbols plus the preceding 31 symbol mini-probe segment which follows the last 256-symbol data block, MIL-STD-188-110B, paragraph C.5.2.

m. Synchronization preamble. The synchronization preamble shall consist of two parts. The first part shall consist of at least N blocks of 184 8-PSK symbols to be used exclusively for radio and modem Automatic Gain Control (AGC). The value of N shall be configurable to range from values of 0 to 7 (for N=0, this first section is not sent at all). These 184 symbols shall be formed by taking the complex conjugate of the first 184 symbols of the sequence specified below for the second section.

The second section shall consist of 287 symbols. The first 184 symbols are intended exclusively for synchronization and Doppler offset removal purposes while the final 103 symbols, which are common with the reinserted preamble, also carry information regarding the data rate and interleaver settings.

Expressed as a sequence of 8-PSK symbols, using the symbol numbers given in MIL-STD-188-110B, table C-1, the synchronization preamble shall be as shown in MIL-STD-188-110B, table C-8, where the data symbols D0, D1, and D2 take one of 30 sets of values chosen from MIL-STD-188-110B, table C-9, to indicate the data rate and interleaver settings. Values for D are given in table 8.1. The Modulo operations are meant to signify that each of the D values are used to shift the phase of a length 13-bit Barker code (0101001100000) by performing modulo 8 addition of the D value with each of the Barker code 13-phase values (0 or 4). This operation can encode six bits of information using QPSK modulation of the 13-bit (chip) Barker codes. Since the three Barker code sequences only occupy 39 symbols, the 31 symbol mini-probes are lengthened to 32 symbols each to provide the additional two symbols required to pad the three 13-symbol Barker codes up to a total of 41 symbols.

Table 8.1. Values for D

D Values (D0, D1, or D2) within Preamble	Preamble Symbol Pattern Corresponding to D Values
0	0404004400000
2	2626226622222
4	4040440044444
6	6262662266666

The mapping chosen to create MIL-STD-188-110B, table C-9, uses three bits each to specify the data rate and interleaver length. The three data rate bits are the three most significant bits (MSB) of three dibit symbols and the interleaver length bits are the least significant bits (LSB). The phase of the Barker code is determined from the three resulting dibit words using MIL-STD-188-110B, table C-3, the dibit trans-coding table. The three-bit data rate and interleaver length mappings are shown in MIL-STD-188-110B, table C-10. Note that the trans-coding has the effect of placing the 3 interleaver length bits in quadrature with the three data rate bits.

Because the Barker code is unbalanced in terms of the number of 0s and 1s, the 000 or 111 patterns exhibit a net imbalance in each quadrature component of the 39 symbols that is 12 to 27. These two patterns are reserved for future standardization of high data rate modes that employ constellations more dense than those specified in MIL-STD-188-110B, paragraph C.5.1. The other three-bit patterns are more balanced (17 to 22) and are used for the more robust constellations, MIL-STD-188-110B, paragraph C.5.2.1.1.

n. Reinserted preamble. The reinserted preamble shall be identical to the final 72 symbols of the synchronization preamble. In fact, the final 103 symbols are common between the synchronization preamble and the contiguous block consisting of the reinserted preamble and the mini-probe that immediately precedes it. The 103 symbols of known data (including the 31 mini-probe symbols of the preceding data frame) are shown in MIL-STD-188-110B, table C-11, where the data symbols D0, D1, and D2 again take one of 30 sets of values chosen from MIL-STD-188-110B, table C-9, to indicate the data rate and interleaver settings as described in the Synchronization Preamble section above. The first 31 of these symbols are the immediately preceding mini-probe, which follows the last of the 72 data blocks.

Note that the three-Bit Mappings for Interleaver Length of 000 or 111 may result in an S_0 to S_8 pattern that could be confused with the fixed (- - - - - - - +) mini probe pattern. For this reason, these mappings are referred to as “illegal” in MIL-STD-188-110B, table C-10, MIL-STD-188-110B, paragraph C.5.2.1.2.

o. Mini-probes. Mini-probes 31 symbols in length shall be inserted following every 256-symbol data block and at the end of each preamble (where they are considered to be part of the preamble). Using the 8-PSK symbol mapping, each mini-probe shall be based on the repeated Frank-Heimiller sequence. The sequence that shall be used, specified in terms of the 8-PSK symbol numbers, is given by:

0, 0, 0, 0, 0, 2, 4, 6, 0, 4, 0, 4, 0, 6, 4, 2, 0, 0, 0, 0, 0, 2, 4, 6, 0, 4, 0, 4, 0, 6, 4.

This mini-probe will be designated ‘+’.

The phase-inverted version of this is:

4, 4, 4, 4, 4, 6, 0, 2, 4, 0, 4, 0, 4, 2, 0, 6, 4, 4, 4, 4, 4, 6, 0, 2, 4, 0, 4, 0, 4, 2, 0

Mini-probes using this sequence will be designated ‘-’, as the phase of each symbol has been rotated 180 degrees from the ‘+’.

There are a total of 73 mini-probes for each set of 72 data blocks. For convenience, each mini-probe will be sequentially numbered, with mini-probe 0 being defined as the last 31 symbols of the preceding (reinserted) preamble, mini-probe number 1 following the first data block after a (reinserted) preamble. Mini-probe 72 follows the 72nd data block and is also the first 31 symbols of the next 103 symbol reinserted preamble. Mini-probes 0 and 72 have been defined as part of the reinsertion preamble to have the signs - and +, respectively. The data rate and interleaver length information encoded into the synchronization and reinserted preambles shall also be encoded into mini-probes 1 through 72. These 72 mini-probes are grouped into four sets of 18 consecutive mini-probes (1 to 18, 19 to 36, 37 to 54, and 55 to 72). Note that the 256-symbol data block that immediately follows the 18th mini-probe, in each of the first three sets, is also the 1st data block of an interleaver block with frame lengths of 1, 3, 9, and 18. The length 36 interleaver block begins after the second set and a reinserted preamble begins after the fourth set. This structure permits data to begin to be demodulated as soon as the interleaver boundary becomes known.

Each 18 mini-probe sequence shall consists of seven "–" signs, a "+" sign, followed by six sign values that are dependent on the data rate and interleaver length, three sign values that specify which of the four sets of 18 mini-probes it is, and then finally a "+" sign. For the fourth set, this final "+" sign (mini-probe 72) is also the initial mini-probe of the next reinserted preamble (which uses the + phase).

Pictorially, this length 18 sequence is: - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 +, where the first six Si sign values are defined in table C-12. Note that these 6-bit patterns (+ is a 0) correspond to the concatenation of the three-bit mappings from MIL-STD-188-110B, table C-10, for the data rate (S0 S1 S2) and the interleaver length (S3 S4 S5). The final three Si sign values which specify the mini-probe set (count) are defined in MIL-STD-188-110B, table C-13.

The first eight mini-probes in each set (- - - - - - - +) uniquely locate the starting point for the following nine Si values. This is possible since the Si sequences used contain at most runs of four + or - phases. This makes it impossible for a sequence of seven mini-probes with the same phase followed by one with a phase reversal to occur anywhere else except at the beginning of one of the 18 mini-probe sequences. Once this fixed eight mini-probe pattern is located, the 0 or 180 degree phase ambiguity is also resolved so that the following nine mini-probes can be properly matched to the data rate, interleaver length, and mini-probe set count. The entire mini-probe sequence shall therefore be as follows:

[rp] - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 +

- - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 [rp]

where the [rp] represents the 103 reinserted preamble symbols (includes mini-probes 72 and 0), MIL-STD-188-110B, paragraph C.5.2.2.

p. Coding and interleaving. The interleaver used shall be a block interleaver. Each block of input data shall also be encoded using a block encoding technique with a code block size equal to the size of the block interleaver. Thus, the input data bits will be sent as successive blocks of bits that span the duration of the interleaver length selected. MIL-STD-188-110B, table C-14, shows the number of input data bits per block as a function of both data rate and interleaver length. Note that an "input data block" should not be confused with the 256-symbol data block that is part of a data frame in the waveform format. The bits from an input data block will be mapped through the coding and interleaving to the number of data frames and thus 256 symbol data blocks that define the interleaver length, MIL-STD-188-110B, paragraph C.5.3.

q. Block boundary alignment. Each code block shall be interleaved within a single interleaver block of the same size. The boundaries of these blocks shall be aligned such that the beginning of the first data frame following each reinserted preamble shall coincide with an interleaver boundary. Thus for an interleaver length of three frames, the first three data frames following a reinserted preamble will contain all of the encoded bits for a single input data block. The first data symbol from the first data frame in each interleaver set shall have as its MSB the first bit fetched from the interleaver. This is no different from what would normally be expected, but is a requirement, MIL-STD-188-110B, paragraph C.5.3.1.

r. Block encoding. The full-tail-biting and puncturing techniques shall be used with a rate 1/2 convolutional code to produce a rate 3/4-block code that is the same length as the interleaver, MIL-STD-188-110B, paragraph C.5.3.2.

s. Rate 1/2 convolutional code. A constraint length 7, rate 1/2 convolutional code shall be used prior to puncturing. This shall be the same code as is used in the single-tone waveform described in MIL-STD-188-110B, section 5.3.2. MIL-STD-188-110B, figure C-7, is a pictorial representation of the encoder.

The two summing nodes in the figure represent modulo 2 addition. For each bit input to the encoder, two bits are taken from the encoder, with the upper output bit, T1(x), taken first, MIL-STD-188-110B, paragraph C.5.3.2.1.

t. Full-tail-biting encoding. To begin encoding each block of input data, the encoder shall be preloaded by shifting in the first six input data bits without taking any output bits. These six input bits shall be temporarily saved so that they can be used to “flush” the encoder. The first two coded output bits shall be taken after the seventh bit has been shifted in, and shall be defined to be the first two bits of the resulting block code. After the last input data bit has been encoded, the first six “saved” data bits shall be encoded. Note that the encoder shift register should not be changed before encoding these saved bits; i.e., it should be filled with the last seven input data bits. The six “saved” data bits are encoded by shifting them into the encoder one at a time, beginning with the earliest of the six. The encoding thus continues by taking the two resulting coded output bits as each of the saved six bits is shifted in. These encoded bits shall be the final bits of the resulting (unpunctured) block code. Prior to puncturing, the resulting block code will have exactly twice as many bits as the input information bits. Puncturing of the rate 1/2 code to the required rate 3/4 shall be done prior to sending bits to the interleaver.

Puncturing to rate 3/4. In order to obtain a rate 3/4 code from the rate 1/2 code used, the output of the encoder must be punctured by not transmitting one bit out of every three. Puncturing shall be performed by using a puncturing mask of 1 1 1 0 0 1, applied to the bits output from the encoder. In this notation, a 1 indicates that the bit is retained and a 0 indicates that the bit is not transmitted. For an encoder generated sequence of

T1(k), T2(k), T1(k+1), T2(k+1), T1(k+2), T2(k+2) . . .

the transmitted sequence shall be

T1(k), T2(k), T1(k+1), T2(k+2) . . .

Defining T1(0), T2(0) to be the first two bits of the block code generated as defined in paragraph C.5.3.2, then the value of k in the above sequences shall be an integral multiple of 3. The block code shall be punctured in this manner before being input to the interleaver, MIL-STD-188-110B, paragraph C.5.3.2.2.

u. Interleaver load. The punctured block code bits shall be loaded into the interleaver array beginning with location 0. The location for loading each successive bit shall be obtained from the previous location by incrementing by the "Interleaver Increment Value" specified in MIL-STD-188-110B, table C-16, modulo the "Interleaver Size in Bits."

Defining the first punctured block code bit to be B(0), then the load location for B(n) is given by:

Load Location = (n * Interleaver Increment Value) Modulo (Interleaver Size in Bits)

Thus for 3200 bps, with a one frame interleaver (512 bit size with an increment of 97), the first eight interleaver load locations are

0, 97, 194, 291, 388, 485, 70, and 167

These increment values have been chosen to ensure that the combined cycles of puncturing and assignment of bit positions in each symbol for the specific constellation being used is the same as if there had been no interleaving. This is important, because each symbol of a constellation contains "strong" and "weak" bit positions, except for the lowest data rate. Bit position refers to the location of the bit, ranging from MSB to LSB, in the symbol mapping. A strong bit position is one that has a large average distance between all the constellation points where the bit is a 0 and the closest point where it is a 1. Typically, the MSB is a strong bit and the LSB a weak bit. An interleaving strategy that did not evenly distribute these bits in the way they occur without interleaving could degrade performance, MIL-STD-188-110B, paragraph C.5.3.3.2.

v. Interleaver fetch. The fetching sequence for all data rates and interleaver lengths shall start location 0 of the interleaver array and increment the fetch location with by 1. This is a simple linear fetch from beginning to end of the interleaver array, MIL-STD-188-110B, paragraph C.5.3.3.3.

w. Conventional asynchronous interface. The modem shall be capable of interfacing with an asynchronous DTE. In this case, the DTE provides (accepts) asynchronous Words consisting of a Start Bit, an N bit Character, and some minimum number of Stop Bits. Additional Stop Bits are provided (accepted) by the DTE between

Words as necessary to accommodate gaps between their occurrences. Interoperability shall be provided for those cases where the value of N, the number of bits in the character, is 5, 6, 7, or 8 (including any parity bits), and the minimum number of Stop Bits is 1 or 2. Hence, interoperability is defined for those cases where the number of Bits in the Word is N+2 and N+3. In these cases, the entire N+2 or N+3 bits of the Word shall be conveyed contiguously in the modulated signal. Additional Stop Bits shall be conveyed, as necessary, to accommodate gaps in data from the DTE; there shall be no modem-defined null character incorporated into the modulated signal, MIL-STD-188-110B, paragraph C.5.4.1.1.

x. High-speed asynchronous user interface with flow control. Certain high-speed user interfaces provide data to (and accept data from) the modem in units of 8-bit bytes. Furthermore, the Input Data Blocks shown in MIL-STD-188-110B, table C-14, are all multiples of 8-bit bytes. An optional mode shall be provided to accommodate the special case of an 8-bit character (which includes any parity check bits) and a 1.0 unit interval Stop Bit. In this optional mode, the 8-bit character shall be aligned with the 256-symbol modem frame boundary and no Start or Stop Bits shall be transmitted. In this mode of operation, it is assumed that the DTE data rate is greater than that which can be accommodated by the modem. Consequently, flow control shall be used to temporarily stop data flow from the DTE to the modem when the modem's input buffer becomes full. Conversely, when the modem's input buffer becomes empty, the modem shall assume that the DTE has finished its message, and the modem shall initiate its normal message-termination procedure. This method of operation obviates the need for the transmission of Null characters for the purpose of "rate padding." Consequently, no Null characters shall be transmitted for this purpose, MIL-STD-188-110B, paragraph C.5.4.1.2.

y. Onset of transmission. The modem shall begin a transmission no later than 100 msec after it has received an entire input data block (enough bits to fill a coded and interleaved block), or upon receipt of the last input data bit, whichever occurs first. The latter would only occur when the message is shorter than one interleaver block. A transmission shall be defined as beginning with the keying of the radio, followed by the output of the preamble waveform after the configured pre-key delay, if any.

The delay between when the modem receives the first input data bit and the onset of transmission will be highly dependent on the means for delivery of the input data bits to the modem. A synchronous serial interface at the user data rate will have the greatest delay. For this reason, it is recommended that a high-speed asynchronous interface (serial or Ethernet port) with flow-control be used if this delay is of concern for the deployed application, MIL-STD-188-110B, paragraph C.5.4.2.

z. End-of-message (EOM). The use of an EOM in the transmit waveform shall be a configurable option. When the use of an EOM has been selected, a 32-bit EOM pattern shall be appended after the last input data bit of the message. The EOM, expressed in hexadecimal notation is 4B65A5B2, where the left-most bit is sent first. If the last bit of the EOM does not fill out an input data block, the remaining bits in the input data block shall be set to zero before encoding and interleaving the block.

If the use of an EOM has been inhibited, and the last input data bit does not fill out an input data block, the remaining bits in the input data block shall be set to zero before encoding and interleaving the block. It is anticipated that the use of an EOM will only be inhibited when an Automatic Repeat Request (ARQ) data protocol uses ARQ blocks that completely fill (or nearly so) the selected input data block size (interleaver block). Without this feature, the use of an EOM would require the transmission of an additional interleaver block under these circumstances, MIL-STD-188-110B, paragraph C.5.4.3.

aa. Termination of a transmission. Upon receipt of a radio silence (or equivalent) command, the modem shall immediately un-key the radio and terminate its transmit waveform.

In normal operation, the modem shall terminate a transmission only after the transmission of the final data frame, including a mini-probe, associated with the final interleaver block. Note that a data frame consists of a 256-symbol data block followed by a mini-probe. Note that any signal processing and/or filter delays in the modem and the HF transmitter must be accounted for (as part of the key line control timing) to ensure that the entire final mini-probe is transmitted before the transmitter power is turned off, MIL-STD-188-110B, paragraph C.5.4.4.

bb. Detection of EOM. The HF modem shall always scan all of the decoded bits for the 32-bit EOM pattern defined in MIL-STD-188-110B, paragraph C.5.4.3. Upon detection of the EOM the modem shall return to the acquisition mode. The modem shall continue to deliver decoded bits to the user (DTE) until the final bit immediately preceding the EOM has been delivered, MIL-STD-188-110B, paragraph C.5.4.5.1.

cc. Command to return to acquisition. Upon receipt of a command to terminate reception, the HF modem shall return to the acquisition mode and terminate the delivery of decoded bits to the user (DTE), MIL-STD-188-110B, paragraph C.5.4.5.2.

dd. Initiation of a transmission. If, and only if, the HF Modem is configured to operate in the half-duplex mode with transmit override, the initiation of a transmission by the user (DTE) shall cause the HF modem to terminate the receive processing and the delivery of decoded bits to the user (DTE), MIL-STD-188-110B, paragraph C.5.4.5.4.

ee. Remote control. The remote control interface (see MIL-STD-188-110B, section 5.3.1.5) shall provide the capability to specify the following parameters and commands:

(1) High-rate waveform parameters:
The 5 data rates for the high-rate waveform.
The 6 interleaver lengths for the high-rate waveform.

(2) A command to select the usage of the optional EOM in the transmit

waveform. Note that the receiving modem must always scan for the EOM regardless of this setting.

(3) A command to specify the maximum message duration measured in number of Input Data Blocks (interleaver blocks). The value of zero for this parameter shall specify that an unlimited number may be received.

(4) A command to cause the modem to terminate receive data processing and return to acquisition mode, MIL-STD-188-110B, paragraph C.5.4.6.

8.3 Test Procedures

a. Test Equipment Required

(1) BERT (2)

(2) Oscilloscope

(3) Modem (with MIL-STD-188-110B, appendix C Waveform)

(4) Spectrum Analyzer

(5) Vector Signal Analyzer

(6) Attenuator

(7) HF Radio Transmitter

(8) HF Radio Receiver

(9) Personal Computer with LabVIEW V6.1 Software

(10) UUT (modem supporting MIL-STD-188-110B, appendix C Waveform)

b. Test Configuration. Figures 8.1, 8.2, and 8.3 show the equipment setup for this subtest.

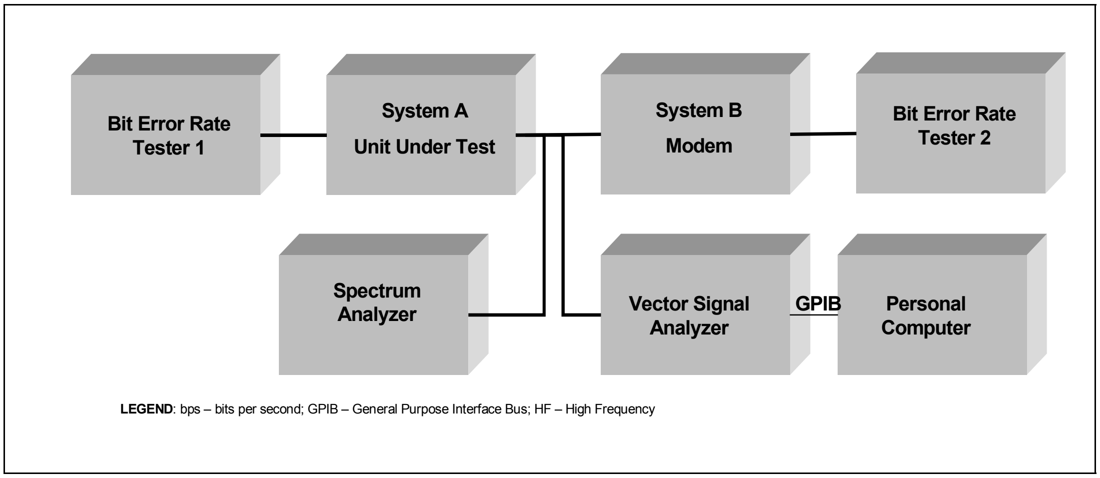

Figure 8.1. Equipment Configuration to Measure HF Modem Waveforms at Data Rates Above 2400 bps

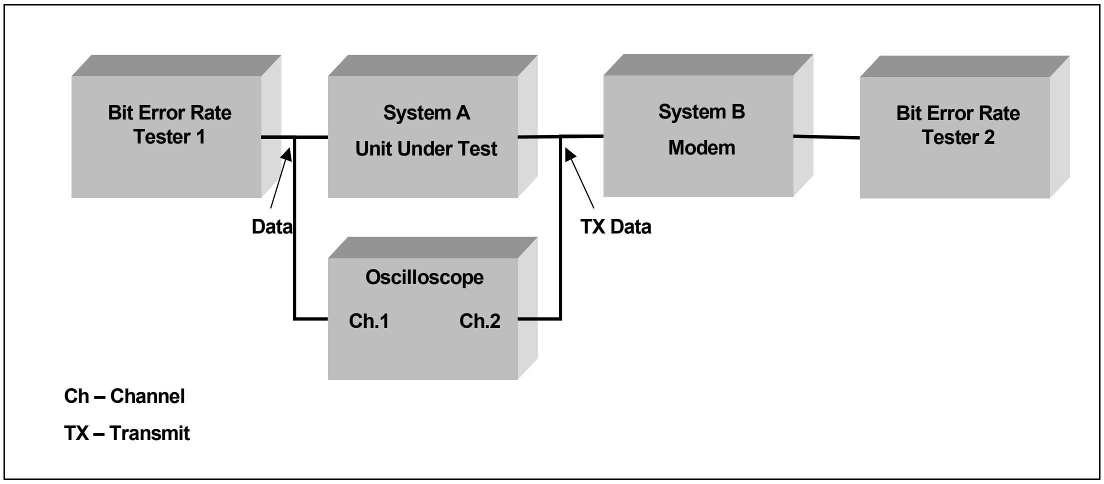

Figure 8.2. Equipment Configuration to Measure Transmit Time Delay

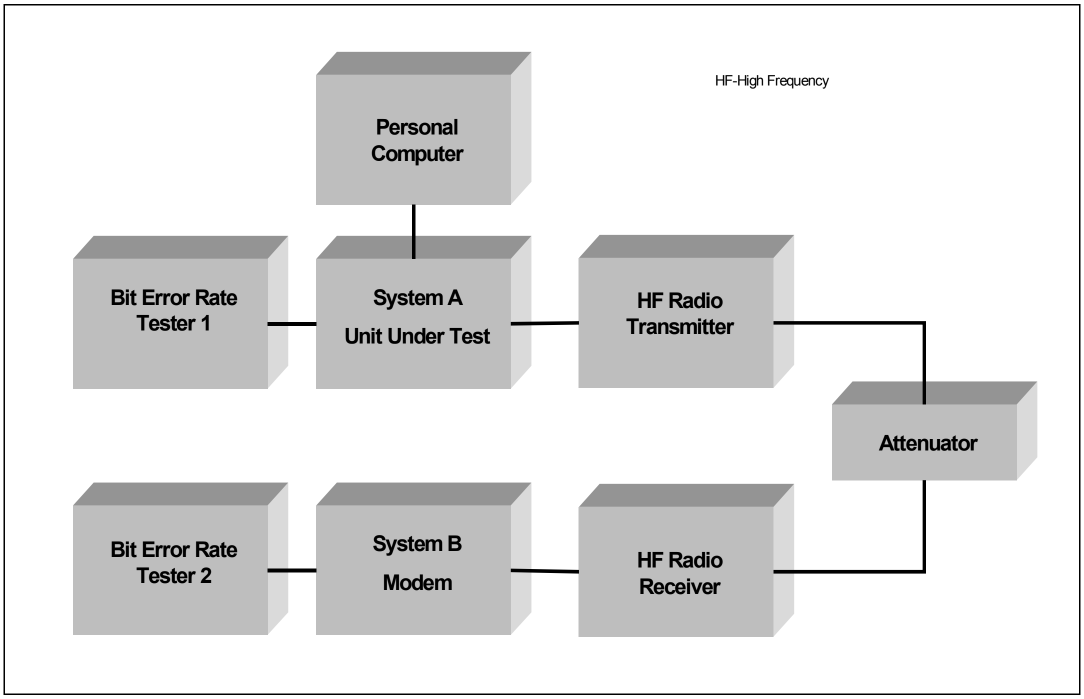

Figure 8.3. Equipment Configuration for Remote Control Operation

c. Test Conduct. The procedures for this subtest are listed in table 8.2.

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures

Step	Action	Settings/Action	Result
The following procedure is for reference numbers 83 and 94.			
1	Set up equipment.	See figure 8.1.	
2	Set up vector signal analyzer.	Frequency Center: 1.8 kHz Span: 3.6 kHz Time Result Length: 2000 symbols Search Length: 850 msec Sync Setup Offset: 0 symbols Instrument Mode Digital Demodulation Demodulation Setup Demodulation Format: 3200 bps: QPSK, 4800 bps: 8-PSK, 6400 bps: 16-QAM, 8000 bps: 32-QAM, 9600 bps: 64-QAM. Symbol Rate: 2.4 kHz Result Length: 1800 symbols Reference Filter: Gaussian Sweep: Single Trigger Trigger Type: IF CH1	

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
3	Set up UUT.	Program UUT to send data at 3200 bps with US interleaver setting. Transmit level out of UUT should be set to 0 dBm.	
4	Begin sending serial data from the UUT to the vector signal analyzer.		
5	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of table 8.1. Expected values for 3200 bps using US interleaver settings are: D0 = 0, D1 = 0, D2 = 4. Note: Of the 287 preamble symbols, D0, D1 and D2 are represented by preamble symbol numbers 217-229, 230-242, and 243-255, respectively. The vector signal analyzer displays the preamble in binary. The remaining 248 preamble symbols (identified in MIL-STD-188-110B, table C-8) should not change.	Preamble D0= D1= D2=
6	Repeat steps 3-5 using the Very Short (VS) interleaver setting.	Expected values: D0 = 0, D1 = 2, D2 = 6.	Preamble D0= D1= D2=
7	Repeat steps 3-5 using the Short (S) interleaver setting.	Expected values: D0 = 0, D1 = 2, D2 = 4.	Preamble D0= D1= D2=
8	Repeat steps 3-5 using the Medium (M) interleaver setting.	Expected values: D0 = 2, D1 = 0, D2 = 6.	Preamble D0= D1= D2=
9	Repeat steps 3-5 using the Long (L) interleaver setting.	Expected values: D0 = 2, D1 = 0, D2 = 4.	Preamble D0= D1= D2=
10	Repeat steps 3-5 using the Very Long (VL) interleaver setting.	Expected values: D0 = 2, D1 = 2, D2 = 6.	Preamble D0= D1= D2=
11	Set up UUT.	Program UUT to send data using the serial tone waveform at 4800 bps with US interleaver setting.	
12	Begin sending serial data from the UUT to the vector signal analyzer.		

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
13	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of table 8.1. Expected values: D0 = 0, D1 = 6, D2 = 2.	Preamble D0= D1= D2=
14	Repeat steps 11-13 using the VS interleaver setting.	Expected values: D0 = 0, D1 = 4, D2 = 0.	Preamble D0= D1= D2=
15	Repeat steps 11-13 using the S interleaver setting.	Expected values: D0 = 0, D1 = 4, D2 = 2.	Preamble D0= D1= D2=
16	Repeat steps 11-13 using the M interleaver setting.	Expected values: D0 = 2, D1 = 6, D2 = 0.	Preamble D0= D1= D2=
17	Repeat steps 11-13 using the L interleaver setting.	Expected values: D0 = 2, D1 = 6, D2 = 2.	Preamble D0= D1= D2=
18	Repeat steps 11-13 using the VL interleaver setting.	Expected values: D0 = 2, D1 = 4, D2 = 0.	Preamble D0= D1= D2=
19	Set up UUT.	Program UUT to send data using the serial tone waveform at 6400 bps with Ultra Short (US) interleaver setting.	
20	Begin sending serial data from the UUT to the vector signal analyzer.		
21	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of table 8.1. Expected values: D0 = 0, D1 = 6, D2 = 4	Preamble D0= D1= D2=
22	Repeat steps 19-21 using the VS interleaver setting.	Expected values: D0 = 0, D1 = 4, D2 = 6.	Preamble D0= D1= D2=
23	Repeat steps 19-21 using the S interleaver setting.	Expected values: D0 = 0, D1 = 4, D2 = 4.	Preamble D0= D1= D2=
24	Repeat steps 19-21 using the M interleaver setting.	Expected values: D0 = 2, D1 = 6, D2 = 6.	Preamble D0= D1= D2=

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
25	Repeat steps 19-21 using the L interleaver setting.	Expected values: D0 = 2, D1 = 6, D2 = 4.	Preamble D0= D1= D2=
26	Repeat steps 19-21 using the VL interleaver setting.	Expected values: D0 = 2, D1 = 4, D2 = 6.	Preamble D0= D1= D2=
27	Set up UUT.	Program UUT to send data using the serial tone waveform at 8000 bps with Ultra Short (US) interleaver setting.	
28	Begin sending serial data from the UUT to the vector signal analyzer.		
29	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of table 8.1. Expected values: D0 = 6, D1 = 0, D2 = 2.	Preamble D0= D1= D2=
30	Repeat steps 27-29 using the VS interleaver setting.	Expected values: D0 = 6, D1 = 2, D2 = 0.	Preamble D0= D1= D2=
31	Repeat steps 27-29 using the S interleaver setting.	Expected values: D0 = 6, D1 = 2, D2 = 2.	Preamble D0= D1= D2=
32	Repeat steps 27-29 using the M interleaver setting.	Expected values: D0 = 4, D1 = 0, D2 = 0.	Preamble D0= D1= D2=
33	Repeat steps 27-29 using the L interleaver setting.	Expected values: D0 = 4, D1 = 0, D2 = 2.	Preamble D0= D1= D2=
34	Repeat steps 27-29 using the VL interleaver setting.	Expected values: D0 = 4, D1 = 2, D2 = 0.	Preamble D0= D1= D2=
35	Set up UUT.	Program UUT to send data using the serial tone waveform at 9600 bps with Ultra Short (US) interleaver setting.	
36	Begin sending serial data from the UUT to the vector signal analyzer.		

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
37	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of table 8.1. Expected values: D0 = 6, D1 = 0, D2 = 4.	Preamble D0= D1= D2=
38	Repeat steps 35-37 using the VS interleaver setting.	Expected values: D0 = 6, D1 = 2, D2 = 6.	Preamble D0= D1= D2=
39	Repeat steps 35-37 using the S interleaver setting.	Expected values: D0 = 6, D1 = 2, D2 = 4.	Preamble D0= D1= D2=
40	Repeat steps 35-37 using the M interleaver setting.	Expected values: D0 = 4, D1 = 0, D2 = 6.	Preamble D0= D1= D2=
41	Repeat steps 35-37 using the L interleaver setting.	Expected values: D0 = 4, D1 = 0, D2 = 4.	Preamble D0= D1= D2=
42	Repeat steps 35-37 using the VL interleaver setting.	Expected values: D0 = 4, D1 = 2, D2 = 6.	Preamble D0= D1= D2=
43	Set up UUT.	Program UUT to send data using the serial tone waveform at 12800 bps with Ultra Short (US) interleaver setting.	
44	Begin sending serial data from the UUT to the vector signal analyzer.		
45	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of table 8.1. Expected values: D0 = 6, D1 = 6, D2 = 2.	Preamble D0= D1= D2=
The following procedure is for reference numbers 82, 83, 86-88, 89-93, and 95-103.			
46	The following procedures use automated software to review data (at rates above 2400 bps) from the UUT. The test operator must program BERT 1 to transmit a 1:1 test pattern. The automated software is available for download from the JITC website: http://jitc.fhu.disa.mil/it/hf.htm	Successful data review validates that the following requirements have been met: preamble length, trans-coding, constellations, coding and interleaving, data scrambling, frame structure, reinstated preamble, mini-probes, block encoding, rate ½ convolutional code, and full-tail-biting encoding.	

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
47	Copy and paste MIL_STD_188_110BAppC.vi file onto hard disk of personal computer containing LabVIEW software.	Copy and paste INTVvstate file onto a 3.5-inch floppy disk. Insert floppy disk into drive a: of vector signal analyzer.	
48	Connect the UUT to channel 1 of the vector signal analyzer.	Connect the vector signal analyzer to personal computer via the GPIB interface.	
49	Load LabVIEW software.	Open MIL_STD_188_110BAppC.vi	
50	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
51	Program UUT to send data at 3200 bps using US interleaver.	Set the transmit level of the UUT to 0 dBm.	
52	Run MIL_STD_188_110BAppC.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem (via BERT) and begin sending data.	
53	Automated software will run for several minutes.	Record results of data review. (Note that the operator may choose to view the raw data captured on the vector signal analyzer.) Save encoded data to file.	
54	Repeat steps 46-53 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
55	Repeat steps 46-53 using S interleaver setting.	Record results of data review. Save encoded data to file.	
56	Repeat steps 46-53 using M interleaver setting.	Record results of data review. Save encoded data to file.	
57	Repeat steps 46-53 using L interleaver setting.	Record results of data review. Save encoded data to file.	
58	Repeat steps 46-53 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
59	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
60	Program UUT to send data at 4800 bps using US interleaver.		
61	Run MIL_STD_188_110BAppC.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem and begin sending data.	
62	Automated software will run for several minutes.	Record results of data review. Save encoded data to file.	
63	Repeat steps 59-62 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
64	Repeat steps 59-62 using S interleaver setting.	Record results of data review. Save encoded data to file.	
65	Repeat steps 59-62 using M interleaver setting.	Record results of data review. Save encoded data to file.	
66	Repeat steps 59-62 using L interleaver setting.	Record results of data review. Save encoded data to file.	

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
67	Repeat steps 59-62 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
68	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
69	Program UUT to send data at 6400 bps using US interleaver.		
70	Run MIL_STD_188_110BAppC.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
71	Automated software will run for several minutes.	Record results of data review. Save encoded data to file.	
72	Repeat steps 68-71 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
73	Repeat steps 68-71 using S interleaver setting.	Record results of data review. Save encoded data to file.	
74	Repeat steps 68-71 using M interleaver setting.	Record results of data review. Save encoded data to file.	
75	Repeat steps 68-71 using L interleaver setting.	Record results of data review. Save encoded data to file.	
76	Repeat steps 68-71 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
77	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
78	Program UUT to send data at 8000 bps using US interleaver.		
79	Run MIL_STD_188_110BAppC.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	
80	Automated software will run for several minutes.	Record results of data review. Save encoded data to file.	
81	Repeat steps 77-80 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
82	Repeat steps 77-80 using S interleaver setting.	Record results of data review. Save encoded data to file.	
83	Repeat steps 77-80 using M interleaver setting.	Record results of data review. Save encoded data to file.	
84	Repeat steps 77-80 using L interleaver setting.	Record results of data review. Save encoded data to file.	
85	Repeat steps 77-80 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
86	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
87	Program UUT to send data at 9600 bps using US interleaver.		
88	Run MIL_STD_188_110BAppC.vi file.	Observe vector signal analyzer. When Analyzer displays "Waiting for Trigger," key the modem and begin sending data.	

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
89	Automated software will run for several minutes.	Record results of data review. Save encoded data to file.	
90	Repeat steps 86-89 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
91	Repeat steps 86-89 using S interleaver setting.	Record results of data review. Save encoded data to file.	
92	Repeat steps 86-89 using M interleaver setting.	Record results of data review. Save encoded data to file.	
93	Repeat steps 86-89 using L interleaver setting.	Record results of data review. Save encoded data to file.	
94	Repeat steps 86-89 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
The following procedure is for reference number 104.			
95	Set up BERTs and modems to operate in asynchronous mode.	Program UUT to operate at 3200 bps, using short interleaver.	
96	Program the value of N (number of bits in the character) to 5, and the minimum number of Stop Bits to 1.		
97	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
98	Program the value of N (number of bits in the character) to 5, and the minimum number of Stop Bits to 2.		
99	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
100	Program the value of N to 6, and the minimum number of Stop Bits to 1.		
101	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
102	Program the value of N to 6, and the minimum number of Stop Bits to 2.		
103	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
104	Program the value of N to 7, and the minimum number of Stop Bits to 1.		
105	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
106	Program the value of N to 7, and the minimum number of Stop Bits to 2.		
107	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
108	Program the value of N to 8, and the minimum number of Stop Bits to 1.		

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
109	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
110	Program the value of N to 8, and the minimum number of Stop Bits to 2.		
111	Send data from system A to system B for 60 seconds.	Record the BER from BERT 2.	
The following procedure is for reference number 106.			
112	Set up equipment.	See figure 8.2.	
113	Set up oscilloscope.	Channel 1: Data into UUT. Channel 2: TX data from UUT.	
114	Set up UUT.	Data rate: 3200 bps Interleaver: Ultra Short	
115	Send synchronous data from the BERT into the UUT.	Using the oscilloscope, capture the transmit time delay. The transmit time delay is the time difference from when the modem receives data from the BERT to when the modem begins transmitting the preamble waveform, after the configured pre-key delay, if any.	
116	Measure the transmit time delay using the oscilloscope's vertical delta markers.	Subtract 0.16 seconds from the transmit time delay. This is the time it takes to fill the Ultra Short Interleaver at 3200 bps. Record result.	
117	Set up UUT.	Data rate: 9600 bps Interleaver: Very Long	
118	Send approximately 2 seconds of data from the BERT into the UUT.	Using the oscilloscope, measure and record the transmit time delay. The transmit time delay is the time difference from when the modem stops receiving data from the BERT until the modem begins transmitting the preamble waveform, after the configured pre-key delay, if any.	
The following procedure is for reference number 107.			
119	Configure the to send an end-of-message sequence at the end of data transmission.	Send data from system A to system B for 20 seconds.	
120	Observe systems A and B at the end of data transmission.	Record observations.	
121	Configure the UUT so that it does not send an end-of-message sequence at the end of data transmission.	Send data from system A to system B for 20 seconds.	
122	Observe systems A and B at the end of data transmission.	Record observations.	
The following procedure is for reference numbers 105, 109, 110, and 111.			
123	Set up UUT to receive data from system B at 3200 bps.	The UUT should be configured to deliver the decoded bits to the user (DTE).	

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
124	Send ‘the quick brown fox’ to the UUT followed by an EOM.	When the UUT receives the EOM, it should return to the acquisition mode. The UUT should continue to deliver decoded bits to the user (DTE) until the final bit immediately preceding the EOM has been delivered. Observe operation of UUT and record results. Record BER recorded by BERT 2.	
125	Send a block of data to the UUT followed by a command to terminate reception.	When the UUT receives the command to terminate reception, it should return to the acquisition mode and terminate the delivery of decoded bits to the user (DTE). Observe operation of the UUT and record results.	
126	Configure the UUT to operate in the half-duplex mode with transmit override enabled.		
127	Send a block of data to the UUT. While the UUT is receiving data, initiate a transmission from the UUT.	The UUT should terminate the receive processing and the delivery of decoded bits to the user (DTE). Observe operation of the UUT and record results.	
128	Disable the transmit override function of the UUT.		
129	Send a block of data to the UUT. While the UUT is receiving data, initiate a transmission from the UUT.	Initiating a transmission should not cause the UUT to terminate the receive processing. Observe operation of the UUT and record results.	
130	Set up BERT 1 and UUT to interface using high-speed asynchronous interface with flow control. Program BERT 1 to send a 2047 test pattern at 4.8 kHz using 8-bit characters, 1 parity check bit, and 1 stop bit. Program UUT to operate at 3200 bps.	Observe CTS light on BERT 1. Use a stop watch to measure the time from when the CTS light first appears (at the beginning of data transmission) to the time when the CTS light goes off.	
131	Program BERT 1 to send a 2047 test pattern. Program UUT to operate at 9600 bps.	Observe CTS light on BERT 1. Use a stop watch to measure the time from when the CTS light first appears (at the beginning of data transmission) to the time when the CTS light goes off. Compare to time measurement taken in step 131. (Expected result: CTS light remains on longer when UUT is operating at higher data rates.)	

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
The following procedure is for reference number 108.			
132	Set up equipment.	See figure 8.3.	
133	Use UUT to on/off key a radio while sending data.	During normal operation, the UUT should terminate a transmission only after transmission of the final data frame. Observe the UUT during normal operation, and record observations.	
134	While the data is being sent, send a radio silence (or equivalent) command to the UUT.	The UUT should immediately un-key the radio and terminate its transmit waveform. Record observed result.	
The following procedure is for reference number 82.			
135	Set up equipment as shown in figure 8.1.		
136	Set the data rate of the UUT and send data with UUT.	Program UUT to send data using the serial tone waveform at 4800 bps View signal on spectrum analyzer. Measure the modulator output signal level at 1800 Hz.	
137	Measure the highest out of band peak level(s) below 200 Hz and above 3400 Hz.	Subtract the highest out of band level(s) from the modulator output signal level at 1800 Hz recorded in step 137.	
138	Measure the passband ripple from 800 Hz to 2800 Hz.		
139	Measure the frequency at which the subcarrier(s) is/are centered.		
140	Set up spectrum analyzer.	Max Hold: On	
141	Set the data rate of the UUT and send data with UUT.	Program UUT to send data using the serial tone waveform at 6400 bps View signal on spectrum analyzer. Measure the modulator output signal level at 1800 Hz.	
142	Measure the highest out of band peak level(s) below 200 Hz and above 3400 Hz.	Subtract the highest out of band level(s) from the modulator output signal level at 1800 Hz recorded in step 142.	
143	Measure the passband ripple from 800 Hz to 2800 Hz.		
144	Measure the frequency at which the subcarrier(s) is/are centered.		
The following procedure is for reference number 112.			
145	Set up equipment as shown in figure 8.3.	Configure UUT for remote control operation.	
146	Use the remote control interface to program the UUT for operation at 3200 bps.	Observe and record action of UUT.	
147	Use the remote control interface to program the UUT for operation at 4800 bps.	Observe and record action of UUT.	
148	Use the remote control interface to program the UUT for operation at 6400 bps.	Observe and record action of UUT.	

Table 8.2. HF Data Modem Waveforms for Data Rates Above 2400 bps Test Procedures (continued)

Step	Action	Settings/Action	Result
149	Use the remote control interface to program the UUT for operation at 8000 bps.	Observe and record action of UUT.	
150	Use the remote control interface to program the UUT for operation at 9600 bps.	Observe and record action of UUT.	
151	Use the remote control interface to program the UUT to operate using the Ultra Short Interleaver.	Observe and record action of UUT.	
152	Use the remote control interface to program the UUT to operate using the Very Short Interleaver.	Observe and record action of UUT.	
153	Use the remote control interface to program the UUT to operate using the Short Interleaver.	Observe and record action of UUT.	
154	Use the remote control interface to program the UUT to operate using the Medium Interleaver.	Observe and record action of UUT.	
155	Use the remote control interface to program the UUT to operate using the Long Interleaver.	Observe and record action of UUT.	
156	Use the remote control interface to program the UUT to operate using the Very Long Interleaver.	Observe and record action of UUT.	
157	Use the remote control interface to select the usage of the optional EOM in the transmit waveform.	Observe and record action of UUT.	
158	Use the remote control interface to specify the maximum message duration measured in number of Input Data Blocks (interleaver blocks).	The value of 0 for this parameter should specify that an unlimited number may be received. Observe and record action of UUT.	
159	Use the remote control interface to cause the modem to terminate receive data processing and return to acquisition mode.	Observe and record action of UUT.	

LEGEND:

AGC – Automatic Gain Control
BER – Bit Error Rate
BERT – Bit Error Rate Tester
bps – Bits Per Second
CH – Channel
CTS – Clear-to-Send
dBm – decibels referenced to one milliwatt
DTE – Data Terminal Equipment
EOM – End-of-Message
GPIB – General Purpose Interface Bus
HF – High Frequency
Hz – hertz
JITC – Joint Interoperability Test Command
kHz – kilohertz
L – Long
M – Medium
MIL-STD – Military Standard
msec – millisecond
mV – millivolt
PSK – Phase-Shift Keying
QAM – Quadrature Amplitude Modulation
QPSK – Quadrature Phase-Shift Keying
S – Short
Sync – Synchronization
TX – Transmit
US – Ultra Short
UUT – Unit Under Test
VL – Very Long
VS – Very Short

8.4 Presentation of Results. The results will be shown in table 8.3 indicating the requirement and measured value or indications of capability.

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
82	C.5.1	Modulation. The symbol rate for all symbols shall be 2400 symbols-per-second, which shall be accurate to a minimum of ±0.24 (10 ppm) symbols-per-second when the transmit data clock is generated by the modem and not provided by the data terminal equipment (DTE). Phase-Shift Keying (PSK) and quadrature amplitude modulation (QAM) modulation techniques shall be used. The sub-carrier (or pair of quadrature sub-carriers in the case of QAM) shall be centered at 1800 Hz accurate to a minimum of 0.018 Hz (10 ppm). The phase of the Quadrature sub-carrier relative to the In-phase carrier shall be 90 degrees. The correct relationship can be achieved by making the In-phase sub-carrier cos (1800 Hz) and the Quadrature sub-carrier–sin (1800 Hz). The power spectral density of the modulator output signal should be constrained to be at least 20 dB below the signal level measured at 1800 Hz, when tested outside of the band from 200 Hz to 3400 Hz. The filter employed shall result in a ripple of no more than ±2 dB in the range from 800 Hz to 2800 Hz.	2400 symbols-per-second within 10 ppm. PSK QAM 1800 Hz within 10 ppm. PSD (<200 Hz and >3400 Hz) 20 dB below signal level at 1800 Hz. ±2 dB Ripple from 800 Hz to 2800 Hz.			
83	C.5.1.1	Known symbols. For all known symbols, the modulation used shall be PSK, with the symbol mapping shown in table C-1 and figure C-1. No scrambling shall be applied to the known symbols.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
86	C.5.1.2.1.1	QPSK symbol mapping. For the 3200 bps user data rate, trans-coding shall be achieved by linking one of the symbols specified in table C-1 to a set of two consecutive data bits (dibit) as shown in table C-3. In this table, the leftmost bit of the dibit shall be the older bit; i.e., fetched from the interleaver before the rightmost bit.	Successful data review using JITC developed automated data review software.			
87	C.5.1.2.1.2	8-PSK symbol mapping. For the 4800 bps user data rate, trans-coding shall be achieved by linking one symbol to a set of three consecutive data bits (tribit) as shown in table C-4. In this table, the leftmost bit of the tribit shall be the oldest bit; i.e., fetched from the interleaver before the other two, and the rightmost bit is the most recent bit.	Successful data review using JITC developed automated data review software.			
88	C.5.1.2.2	QAM data symbols. For the QAM constellations, no distinction is made between the number formed directly from the data bits and the symbol number. Each set of 4 bits (16-QAM), 5 bits (32-QAM) or 6 bits (64-QAM) is mapped directly to a QAM symbol. For example, the four-bit grouping 0111 would map to symbol 7 in the 16-QAM constellation while the 6 bits 100011 would map to symbol 35 in the 64-QAM constellation. Again, in each case the leftmost bit shall be the oldest bit, i.e. fetched from the interleaver before the other bits, and the rightmost bit is the most recent bit. The mapping of bits to symbols for the QAM constellations has been selected to minimize the number of bit errors incurred when errors involve adjacent signaling points in the constellation.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
89	C.5.1.2.2.1	The 16-QAM constellation. The constellation points that shall be used for 16-QAM, are shown in figure C-2 and specified in terms of their In-phase and Quadrature components in table C-5. As can be seen in the figure, the 16-QAM constellation is comprised of two PSK rings: 4-PSK inner and 12-PSK outer.	Successful data review using JITC developed automated data review software.			
90	C.5.1.2.2.2	The 32-QAM constellation. The constellation points that shall be used for 32-QAM are shown in figure C-3 and specified in terms of their In-phase and Quadrature components in table C-6. This constellation contains an outer ring of 16 symbols and an inner square of 16 symbols.	Successful data review using JITC developed automated data review software.			
91	C.5.1.2.2.3	The 64-QAM constellation. The constellation points that shall be used for the 64-QAM modulation are shown in figure C-4 and specified in terms of their In-phase and Quadrature components in table C-7. This constellation is a variation on the standard 8 x 8 square constellation, which achieves better peak-to-average without sacrificing the very good pseudo-Gray code properties of the square constellation.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
92	C.5.1.3	Data scrambling. Data symbols for the 8-PSK symbol constellation (3200 bps, 4800 bps) shall be scrambled by modulo 8 addition with a scrambling sequence. The data symbols for the 16-QAM, 32-QAM, and 64-QAM constellations shall be scrambled by using an Exclusive OR (XOR) operation. Sequentially, the data bits forming each symbol (4 for 16-QAM, 5 for 32-QAM, and 6 for 64-QAM) shall be XOR'd with an equal number of bits from the scrambling sequence. In all cases, the scrambling sequence generator polynomial shall be $x^9 + x^4 + 1$ and the generator shall be initialized to 1 at the start of each data frame. A block diagram of the scrambling sequence generator is shown in figure C-5. For 8-PSK symbols (3200 bps and 4800 bps), the scrambling shall be carried out taking the modulo 8 sum of the numerical value of the binary triplet consisting of the last (rightmost) three bits in the shift register, and the symbol number (trans-coded value). For example, if the last three bits in the scrambling sequence shift register were 010 which has a numerical value equal 2, and the symbol number before scrambling was 6, symbol 0 would be transmitted since: (6+2) Modulo 8 = 0.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
93	C.5.2	Frame structure. The frame structure that shall be used for the waveforms specified in this appendix is shown in figure C-6. An initial 287-symbol preamble is followed by 72 frames of alternating data and known symbols. Each data frame shall consist of a data block consisting of 256 data symbols, followed by a mini-probe consisting of 31 symbols of known data. After 72 data frames, a 72-symbol subset of the initial preamble is reinserted to facilitate late acquisition, Doppler shift removal, and sync adjustment. It should be noted that the total length of known data in this segment is actually 103 symbols: the 72 reinserted preamble symbols plus the preceding 31 symbol mini-probe segment which follows the last 256 symbol data block.	Successful data review using JITC developed automated data review software.			
94	C.5.2.1.1	Synchronization preamble. The synchronization preamble shall consist of two parts. The first part shall consist of at least N blocks of 184 8-PSK symbols to be used exclusively for radio and modem AGC. The value of N shall be configurable to range from values of 0 to 7 (for N=0 this first section is not sent at all). These 184 symbols shall be formed by taking the complex conjugate of the first 184 symbols of the sequence specified below for the second section. The second section shall consist of 287 symbols. The first 184 symbols are intended exclusively for synchronization and Doppler offset removal purposes while the final 103 symbols, which are common with the reinserted preamble, also carry information regarding the data rate and interleaver settings.	Preamble is verified (using JITC developed MIL-STD-188-110B appendix C software).			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
94	C.5.2.1.1	Expressed as a sequence of 8-PSK symbols, using the symbol numbers given in table C-1 the synchronization preamble shall be as shown in table C-8 where the data symbols D0, D1, and D2 take one of 30 sets of values chosen from table C-9 to indicate the data rate and interleaver settings. The Modulo operations are meant to signify that each of the D values are used to shift the phase of a length 13-bit Barker code (0101001100000) by performing modulo 8 addition of the D value with each of the Barker code 13 phase values (0 or 4). This operation can encode 6 bits of information using QPSK modulation of the 13-bit (chip) Barker codes. Since the three-Barker code sequences only occupy 39 symbols, the 31 symbol mini-probes are lengthened to 32 symbols each to provide the additional 2 symbols required to pad the three 13-symbol Barker codes up to a total of 41 symbols. The mapping chosen to create table C-9 uses three-bits each to specify the data rate and interleaver length. The three data rate bits are the three most significant bits (MSB) of thrre-dibit symbols and the interleaver length bits are the least significant bits (LSB). The phase of the Barker code is determined from the three resulting dibit words using table C-3, the dibit trans-coding table. The three-bit data rate and interleaver length mappings are shown in table C-10. Note that the trans-coding has the effect of placing the three interleaver length bits in quadrature with the three data rate bits.	Preamble is verified (using JITC developed MIL-STD-188-110B appendix C software).			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
95	C.5.2.1.2	Reinserted preamble. The reinserted preamble shall be identical to the final 72 symbols of the synchronization preamble. In fact, the final 103 symbols are common between the synchronization preamble and the contiguous block consisting of the reinserted preamble and the mini-probe that immediately precedes it. The 103 symbols of known data (including the 31 mini-probe symbols of the preceding data frame) are shown in table C-11 where the data symbols D0, D1, and D2 again take one of 30 sets of values chosen from table C-9 to indicate the data rate and interleaver settings as described in the Synchronization Preamble section above. The first 31 of these symbols are the immediately preceding mini-probe, which follows the last of the 72 data blocks. Note that the three-Bit Mappings for Interleaver Length of 000 or 111 may result in an S_0 to S_8 pattern that could be confused with the fixed (- - - - - - - +) mini probe pattern. For this reason, these mappings are referred to as “illegal” in table C-10.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
96	C.5.2.2	Mini-probes. Mini-probes 31 symbols in length shall be inserted following every 256-symbol data block and at the end of each preamble (where they are considered to be part of the preamble). Using the 8-PSK symbol mapping, each mini-probe shall be based on the repeated Frank-Heimiller sequence. The sequence that shall be used, specified in terms of the 8-PSK symbol numbers, is given by: 0, 0, 0, 0, 0, 2, 4, 6, 0, 4, 0, 4, 0, 6, 4, 2, 0, 0, 0, 0, 0, 2, 4, 6, 0, 4, 0, 4, 0, 6, 4. This mini-probe will be designated '+'. The phase inverted version of this is: 4, 4, 4, 4, 4, 6, 0, 2, 4, 0, 4, 0, 4, 2, 0, 6, 4, 4, 4, 4, 4, 6, 0, 2, 4, 0, 4, 0, 4, 2, 0 and mini-probes using this sequence will be designated '-', as the phase of each symbol has been rotated 180 degrees from the '+'. There are a total of 73 mini-probes for each set of 72 data blocks. For convenience, each mini-probe will be sequentially numbered, with mini-probe 0 being defined as the last 31 symbols of the preceding (reinserted) preamble, mini-probe number 1 following the first data block after a (reinserted) preamble. Mini-probe 72 follows the 72nd data block, and is also the first 31 symbols of the next 103 symbol reinserted preamble. Mini-probes 0 and 72 have been defined as part of the reinsertion preamble to have the signs - and + respectively.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
96	C.5.2.2	The 1st eight mini-probes in each set (- - - - - - - +) uniquely locate the starting point for the following nine Si values. This is possible since the Si sequences used contain at most runs of four + or - phases. This makes it impossible for a sequence of 7 mini-probes with the same phase followed by one with a phase reversal to occur anywhere else except at the beginning of one of the 18 mini-probe sequences. Once this fixed 8 mini-probe pattern is located, the 0 or 180 degree phase ambiguity is also resolved so that the following 9 mini-probes can be properly matched to the data rate, interleaver length, and mini-probe set count. The entire mini-probe sequence shall therefore be as follows: [rp] - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 [rp] where the [rp] represents the 103 reinserted preamble symbols (includes mini-probes 72 and 0).	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
97	C.5.3	Coding and interleaving. The interleaver used shall be a block interleaver. Each block of input data shall also be encoded using a block encoding technique with a code block size equal to the size of the block interleaver. Thus, the input data bits will be sent as successive blocks of bits that span the duration of the interleaver length selected. Table C-14 shows the number of input data bits per block as function of both data rate and interleaver length. Note that an "input data block" should not be confused with the 256-symbol data block that is part of a data frame in the waveform format. The bits from an input data block will be mapped through the coding and interleaving to the number of data frames, and thus 256-symbol data blocks, that define the interleaver length.	Successful data review using JITC developed automated data review software.			
98	C.5.3.1	Block boundary alignment. Each code block shall be interleaved within a single interleaver block of the same size. The boundaries of these blocks shall be aligned such that the beginning of the first data frame following each reinserted preamble shall coincide with an interleaver boundary. Thus, for an interleaver length of three frames, the first three data frames following a reinserted preamble will contain all of the encoded bits for a single input data block. The first data symbol from the first data frame in each interleaver set shall have as its MSB the first bit fetched from the interleaver. This is no different from what would normally be expected, but is a requirement.	Successful data review using JITC developed automated data review software.			
99	C.5.3.2	Block encoding. The full-tail-biting and puncturing techniques shall be used with a rate 1/2 convolutional code to produce a rate 3/4-block code that is the same length as the interleaver.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
100	C.5.3.2.1	Rate 1/2 convolutional code. A constraint length 7, rate 1/2 convolutional code shall be used prior to puncturing. This shall be the same code as is used in the single-tone waveform described in section 5.3.2 of this standard. Figure C-7 is a pictorial representation of the encoder. The two summing nodes in the figure represent modulo 2 addition. For each bit input to the encoder, two bits are taken from the encoder, with the upper output bit, T1(x), taken first.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
101	C.5.3.2.2	Full-tail-biting encoding. To begin encoding each block of input data, the encoder shall be preloaded by shifting in the first six input data bits without taking any output bits. These six input bits shall be temporarily saved so that they can be used to "flush" the encoder. The first two coded output bits shall be taken after the seventh bit has been shifted in, and shall be defined to be the first two bits of the resulting block code. After the last input data bit has been encoded, the first six "saved" data bits shall be encoded. Note that the encoder shift register should not be changed before encoding these saved bits; i.e., it should be filled with the last seven input data bits. The six "saved" data bits are encoded by shifting them into the encoder one at a time, beginning with the earliest of the six. The encoding thus continues by taking the two resulting coded output bits as each of the saved six bits is shifted in. These encoded bits shall be the final bits of the resulting (unpunctured) block code. Prior to puncturing, the resulting block code will have exactly twice as many bits as the input information bits. Puncturing of the rate 1/2 code to the required rate 3/4 shall be done prior to sending bits to the interleaver.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
102	C.5.3.3.2	Interleaver load. The punctured block code bits shall be loaded into the interleaver array beginning with location 0. The location for loading each successive bit shall be obtained from the previous location by incrementing by the "Interleaver Increment Value" specified in table C-16, modulo the "Interleaver Size in Bits." Defining the first punctured block code bit to be B(0), then the load location for B(n) is given by: Load Location = (n * Interleaver Increment Value) Modulo (Interleaver Size in Bits) Thus for 3200 bps, with a one frame interleaver (512 bit size with an increment of 97), the first 8 interleaver load locations are: 0, 97, 194, 291, 388, 485, 70, and 167. These increment values have been chosen to ensure that the combined cycles of puncturing and assignment of bit positions in each symbol for the specific constellation being used is the same as if there had been no interleaving. This is important, because each symbol of a constellation contains "strong" and "weak" bit positions, except for the lowest data rate. Bit position refers to the location of the bit, ranging from MSB to LSB, in the symbol mapping. A strong bit position is one that has a large average distance between all the constellation points where the bit is a 0 and the closest point where it is a 1. Typically, the MSB is a strong bit and the LSB a weak bit. An interleaving strategy that did not evenly distribute these bits in the way they occur without interleaving could degrade performance.	Successful data review using JITC developed automated data review software.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
103	C.5.3.3.3	Interleaver fetch. The fetching sequence for all data rates and interleaver lengths shall start location 0 of the interleaver array and increment the fetch location with by 1. This is a simple linear fetch from beginning to end of the interleaver array.	Successful data review using JITC developed automated data review software.			
104	C.5.4.1.1	Conventional asynchronous interface. The modem shall be capable of interfacing with an asynchronous DTE. In this case, the DTE provides (accepts) asynchronous Words consisting of a Start Bit, an N bit Character, and some minimum number of Stop Bits. Additional Stop Bits are provided (accepted) by the DTE between Words, as necessary, to accommodate gaps between their occurrences. Interoperability shall be provided for those cases where the value of N, the number of Bits in the Character, is 5, 6, 7, or 8 (including any parity bits), and the minimum number of Stop Bits is 1 or 2. Hence, interoperability is defined for those cases where the number of Bits in the Word is N+2 and N+3. In these cases the entire N+2 or N+3 bits of the Word shall be conveyed contiguously in the modulated signal. Additional Stop Bits shall be conveyed as necessary to accommodate gaps in data from the DTE; there shall be no modem-defined null character incorporated into the modulated signal.	Capable of interfacing with asynchronous DTE. Interoperability in cases where N is 5, 6, 7, or 8, and minimum number of Stop Bits is 1 or 2.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
105	C.5.4.1.2	High-speed asynchronous user interface with flow control. Certain high-speed user interfaces provide data to (and accept data from) the modem in units of 8 bit bytes. Furthermore, the Input Data Blocks shown in table C-14 are all multiples of 8 bit bytes. An optional mode shall be provided to accommodate the special case of an 8-bit character (which includes any parity check bits) and a 1.0 unit interval Stop Bit. In this optional mode, the 8-bit character shall be aligned with the 256-symbol modem frame boundary, and no Start or Stop Bits shall be transmitted. In this mode of operation, it is assumed that the DTE data rate is greater than that which can be accommodated by the modem. Consequently, flow control shall be used to temporarily stop data flow from the DTE to the modem when the modem's input buffer becomes full. Conversely, when the modem's input buffer becomes empty, the modem shall assume that the DTE has finished its message, and the modem shall initiate its normal message-termination procedure. This method of operation obviates the need for the transmission of Null characters for the purpose of "rate padding." Consequently, no Null characters shall be transmitted for this purpose.	Accommodate 8-bit character (which includes any parity check bits) and a 1.0 unit interval Stop Bit.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
106	C.5.4.2	Onset of transmission. The modem shall begin a transmission no later than 100 msec after it has received an entire input data block (enough bits to fill a coded and interleaved block), or upon receipt of the last input data bit, whichever occurs first. The latter would only occur when the message is shorter than one interleaver block. A transmission shall be defined as beginning with the keying of the radio, followed by the output of the preamble waveform after the configured pre-key delay, if any. The delay between when the modem receives the first input data bit and the onset of transmission will be highly dependent on the means for delivery of the input data bits to the modem. A synchronous serial interface at the user data rate will have the greatest delay. For this reason, it is recommended that a high-speed asynchronous interface (serial or Ethernet port) with flow-control be used if this delay is of concern for the deployed application.	100 msec after receiving an input data block, or upon receipt of the last input data bit.			
107	C.5.4.3	End-of-message. The use of an end-of-message (EOM) in the transmit waveform shall be a configurable option. When the use of an EOM has been selected, a 32-bit EOM pattern shall be appended after the last input data bit of the message. The EOM, expressed in hexadecimal notation is 4B65A5B2, where the left most bit is sent first. If the last bit of the EOM does not fill out an input data block, the remaining bits in the input data block shall be set to zero before encoding and interleaving the block.	Optional EOM: (hex) 4B65A5B2			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
108	C.5.4.4	Termination of a transmission. Upon receipt of a radio silence (or equivalent) command, the modem shall immediately un-key the radio and terminate its transmit waveform. In normal operation, the modem shall terminate a transmission only after the transmission of the final data frame, including a mini-probe, associated with the final interleaver block. Note that a data frame consists of a 256-symbol data block followed by a mini-probe. Note that any signal processing and/or filter delays in the modem and the HF transmitter must be accounted for (as part of the key line control timing) to ensure that the entire final mini-probe is transmitted before the transmitter power is turned off.	Immediately un-key radio and terminate transmit waveform.			
109	C.5.4.5.1	Detection of EOM. The HF modem shall always scan all of the decoded bits for the 32-bit EOM pattern defined in paragraph C.5.4.3. Upon detection of the EOM the modem shall return to the acquisition mode. The modem shall continue to deliver decoded bits to the user (DTE) until the final bit immediately preceding the EOM has been delivered.	Return to the acquisition mode.			
110	C.5.4.5.2	Command to return to acquisition. Upon receipt of a command to terminate reception, the HF modem shall return to the acquisition mode and terminate the delivery of decoded bits to the user (DTE).	Return to acquisition mode and terminate bit delivery.			
111	C.5.4.5.4	Initiation of a transmission. If, and only if, the HF Modem is configured to operate in the half-duplex mode with transmit override, the initiation of a transmission by the user (DTE) shall cause the HF modem to terminate the receive processing and the delivery of decoded bits to the user (DTE).	Terminate receive processing and delivery of bits.			

Table 8.3. HF Data Modem Waveforms for Data Rates Above 2400 bps Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
112	C.5.4.6	Remote control. The remote control interface (see section 5.3.1.5) shall provide the capability to specify the following parameters and commands: a. High-rate waveform parameters: The five data rates for the high-rate waveform. The six interleaver lengths for the high-rate waveform. b. A command to select the usage of the optional EOM in the transmit waveform. Note that the receiving modem must always scan for the EOM regardless of this setting. c. A command to specify the maximum message duration measured in number of Input Data Blocks (interleaver blocks). The value of 0 (zero) for this parameter shall specify that an unlimited number may be received. d. A command to cause the modem to terminate receive data processing and return to acquisition mode.	Remote control capability: a. Waveform parameters. b. EOM. c. Max message duration. d. Terminate receive command.			

LEGEND:

AGC – Automatic Gain Control	Hz – hertz	PSD – Power Spectral Density
bps – bits per second	JITC – Joint Interoperability Test Command	PSK – Phase-Shift Keying
dB – decibels	LSB – Least Significant Bit	QAM – Quadrature Amplitude Modulation
DTE – Data Terminal Equipment	MIL-STD – Military Standard	QPSK – Quadrature Phase-Shift Keying
EOM – End-of-Message	MSB – Most Significant Bit	XOR – Exclusive OR
HF – High Frequency	msec – millisecond	

SUBTEST 9. HF DATA MODEM FOR MULTIPLE CHANNEL SYSTEMS

9.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B, reference numbers 116-129.

9.2 Criteria

a. Multiple channel operation with multiple modems. (Optional). When Independent Sideband (ISB) radios and channel allocations are available, but ISB modems with a matching number of audio channels are not available, multiple modems may be employed as shown in MIL-STD-188-110B, figure F-2. The upper diagram illustrates the case of unencrypted user data and link-level encryption (as in the previous section). The lower diagram depicts application-layer (end-to-end) encryption.

The first bit of data to be sent shall be delivered to the modem associated with the highest over-the-air frequency, with succeeding bits delivered to modems with decreasing frequencies. When M modems are attached to a single ISB radio ($M = 2$ shown), all modems shall operate at a single data rate and modem i ($i = 0 .. M - 1$) shall carry bits numbered $i + nM$ ($n = 0, 1, \ldots$).

This architecture also may be applied to multiple radios operating on unrelated frequencies. However, performance may not be satisfactory if the characteristics of the various channels are not sufficiently similar to support a common maximum data rate. Bit ordering shall be as specified above, with the identity of the modem associated with the highest over-the-air frequency determined when the link is initially established, regardless of subsequent frequency changes while linked.

In the bit-synchronous approach described above, it is understood that the multiplexer and modems share a common clock. In addition, the multiplexer provides a short synchronization header in the bit stream to each modem prior to the payload data. Note that this header is transparent to the ARQ or other modem-user process. The header is used by the multiplexer at the receive end to establish bit-order integrity. This header is required since a bit-synchronous transmit (TX) modem interface does not generally guarantee that the first bit out of the receiving modem is the first bit out of the transmitting DTE following assertion of CTS.

Alternatively, the High Speed Asynchronous Interface with Flow Control that is described in MIL-STD-188-110B, section C.5.4.1 may be used. In this case, data to successive modems from the multiplexer will be successive bytes rather than successive bits, MIL-STD-188-110B, paragraph F.4.1.2.

b. HF data modem waveform for two-independent-sideband applications. This subtest presents a modem waveform and coding specification for data transmission over two HF sidebands for data rates from 9.6 up to 19.2 kilobits per second (kbps). As in appendix C, a block interleaver is used to obtain six interleaving lengths ranging from 0.12 s to 8.64 s. The waveforms in this appendix have been designed to be compatible with the appendix C waveforms, and use identical preamble processing with the exception that these waveforms employ settings for specifying data rate and interleaver that are reserved in MIL-STD-188-110B, appendix C.

Data rate and interleaver settings are explicitly transmitted as a part of the waveform, both as part of the initial preamble and then periodically as a reinserted preamble and in the periodic known symbol blocks (“mini-probes”). This “auto baud” feature is critical in developing an efficient ARQ protocol for HF channels. The receive modem is required to be able to deduce the data rate and interleaver setting from either the preamble or the subsequent data portion of the waveform.

A block diagram of the 2-ISB modem with 2-ISB radios is shown in MIL-STD-188-110B, figure F-4. In all applications of this modem, the quasi-analog signal designated channel 0 shall be connected to the radio equipment so that the sideband that it produces is higher in frequency than the sideband produced by the quasi-analog signal designated channel 1. In particular, with 2-ISB radios channel 0 shall use the upper sideband and channel 1 shall use the lower sideband, MIL-STD-188-110B, paragraph F.4.2.

c. Modulation. Each of the channels shall be modulated independently. The modulation of each of the channels is identical, with a few specified exceptions, to that specified in MIL-STD-188-110B, appendix C, for the high data rate single sideband option. The transmit data clock for both of the channels shall be synchronized so that there is no drift in the relative clocks for each of the channels.

The power spectral density of each modulator output signal should be constrained to be at least 20-dB below the signal level measured at 1800 Hz, when tested outside of the band from 200 Hz to 3400 Hz. The filter employed shall result in a ripple of no more than ±2 dB in the range from 800 Hz to 2800 Hz, MIL-STD-188-110B, paragraph F.5.1.

d. Known symbols. For all known symbols, the modulation used shall be PSK, with the symbol mapping shown in MIL-STD-188-110B, table C-1 and figure C-1. No scrambling shall be applied to the known symbols, MIL-STD-188-110B, paragraph F.5.1.1.

e. QPSK symbol mapping. For QPSK symbols, used in the preamble and reinserted preamble to specify data rate and interleaving, trans-coding shall be achieved by linking one of the symbols specified in MIL-STD-188-110B, table C-1, to a set of two consecutive data bits (dibit) as shown in MIL-STD-188-110B, table C-3. In this table, the leftmost bit of the dibit shall be the older bit; i.e., fetched from the interleaver before the rightmost bit, MIL-STD-188-110B, paragraph F.5.1.2.1.1.

f. 8-PSK symbol mapping. For the 9600-bps user data rate, trans-coding shall be achieved by linking one symbol to a set of three consecutive data bits (tribit) as shown in MIL-STD-188-110B, table C-4. In this table, the leftmost bit of the tribit shall be the oldest bit; i.e., fetched from the interleaver before the other two, and the rightmost bit is the most recent bit, MIL-STD-188-110B, paragraph F.5.1.2.1.2.

g. QAM data symbols. For the QAM constellations, no distinction is made between the number formed directly from the data bits and the symbol number. Each set of 4 bits (16-QAM), 5 bits (32-QAM), or 6 bits (64-QAM) is mapped directly to a QAM symbol. For example, the 4-bit grouping 0111 would map to symbol seven in the 16-QAM constellation, while the 6-bit grouping 100011 would map to symbol 35 in the 64-QAM constellation. Again, in each case the leftmost bit shall be the oldest bit, i.e., fetched from the interleaver before the other bits and the rightmost bit is the most recent bit, MIL-STD-188-110B, paragraph F.5.1.2.2.

h. Data scrambling. Data symbols for the 8-PSK symbol constellation shall be scrambled by modulo 8 addition with a scrambling sequence. The data symbols for the 16-QAM, 32-QAM, and 64-QAM constellations shall be scrambled by using an XOR operation. Sequentially, the data bits forming each symbol (4 for 16-QAM, 5 for 32-QAM, and 6 for 64-QAM) shall be XOR'd with an equal number of bits from the scrambling sequence. In all cases, the scrambling sequence generator polynomial shall be $x^9 + x^4 + 1$ and the generator shall be initialized to 1 at the start of each data frame. A block diagram of the scrambling sequence generator is shown in MIL-STD-188-110B, figure C-5. Further details of the operation of the data scrambler may be found in MIL-STD-188-110B, paragraph C.5.1.3, MIL-STD-188-110B, paragraph F.5.1.3.

i. Frame structure. The frame structure shall be as described in MIL-STD-188-110B, paragraph C.5.2, except that the data symbols D0, D1, and D2 (used in the preambles and encoded in the mini-probes) take on values distinct from those used for the MIL-STD-188-110B, appendix C, Single Sideband (SSB) modes.

For the two-sideband option, the three-bits used for data rate in SSB are fixed at 000. The bits normally used for interleaver setting in SSB are employed as specified in MIL-STD-188-110B, table F-2, using both channels, to select data rate and interleaver settings. Channel 0 carries the code for the combined data rate and channel 1 carries the code for the common interleaver. Recall that channel 0 is always the lower of the two sidebands. Unused codings are reserved and shall not be used until standardized, MIL-STD-188-110B, paragraph F.5.2.

j. Coding and interleaving. The interleaver used shall be a block interleaver. Each block of input data shall be encoded using a block encoding technique with a code block size equal to the size of the block interleaver. Thus, the input data bits will be sent as successive blocks of bits on both channels that together span the duration of the interleaver length selected.

MIL-STD-188-110B, table F-3, shows the number of input data bits per block as a function of both data rate and interleaver length. Note that an "input data block" should not be confused with the 256-symbol data block that is part of a data frame in the waveform format. The bits from an input data block will be mapped through the coding and interleaving to the number of data frames, and thus 256 symbol data blocks, that define the interleaver length, MIL-STD-188-110B, paragraph F.5.3.

k. Block boundary alignment. Each code block shall be interleaved within a single interleaver block of the same size. The boundaries of these blocks shall be aligned such that the beginning of the first data frame following each reinserted preamble shall coincide with an interleaver boundary. Thus for an interleaver length of three frames, the first three data frames following a reinserted preamble will contain all of the encoded bits for a single input data block. The first data symbol from the first data frame in each interleaver set shall have as its MSB the first bit fetched from the interleaver. This is no different from what would normally be expected, but is a requirement, MIL-STD-188-110B, paragraph F.5.3.1.

l. Interleaver size in bits. The interleaver shall consist of a single dimension array, numbered from 0 to its size in bits –1. The array size shall depend on both the data rate and interleaver length selected as shown in MIL-STD-188-110B, table F-4, MIL-STD-188-110B, paragraph F.5.3.3.1.

m. Interleaver load. The punctured block code bits shall be loaded into the interleaver array beginning with location 0. The location for loading each successive bit shall be obtained from the previous location by incrementing by the interleaver increment value "Inc" specified in MIL-STD-188-110B, table F-4, modulo the interleaver size in bits, "Size."

Defining the first punctured block code bit to be B(0), then the load location for B(n) is given by:

Load Location = (n * Inc) modulo (Size)

MIL-STD-188-110B, paragraph F.5.3.3.2.

n. Interleaver fetch. The fetching sequence for all data rates and interleaver lengths shall start with location 0 of the interleaver array and increment the fetch location by 1. The first bit fetched from the interleaver shall be sent to the symbol formation module for channel 0, the second bit fetched shall be sent to the symbol formation module for channel 1, and this pattern shall continue until all bits have been fetched from the interleaver. This is a linear fetch from beginning to end of the interleaver array with even numbered bits delivered to channel 0 and odd numbered bits to channel 1, MIL-STD-188-110B, paragraph F.5.3.3.3.

9.3 Test Procedures

a. Test Equipment Required

(1) BERT (2 ea)
(2) ISB Radios

(3) Modem

(4) Vector Signal Analyzer

(5) Spectrum Analyzer

(6) Attenuator

(7) UUT

b. Test Configuration. Figures 9.1 and 9.2 show the equipment setup for this subtest.

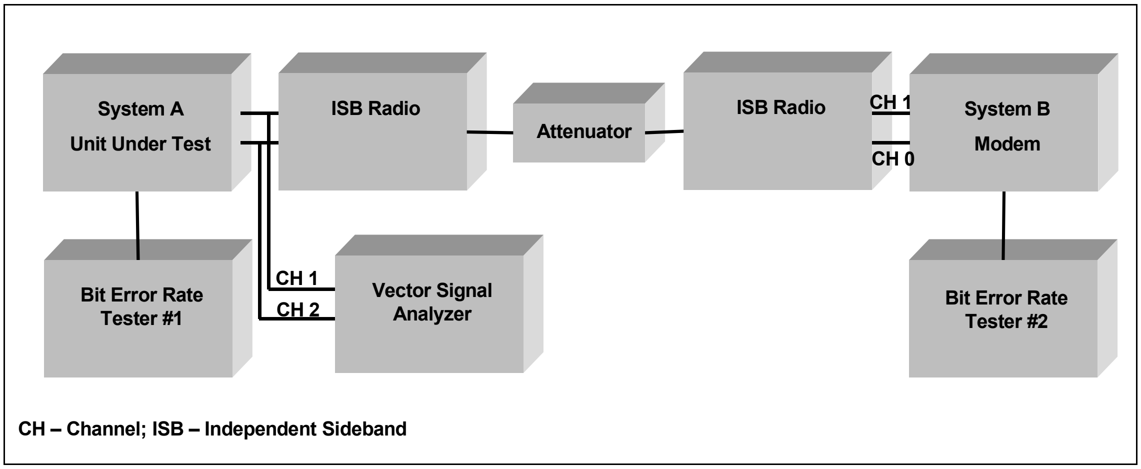

Figure 9.1. Equipment Configuration for 2-ISB Modems

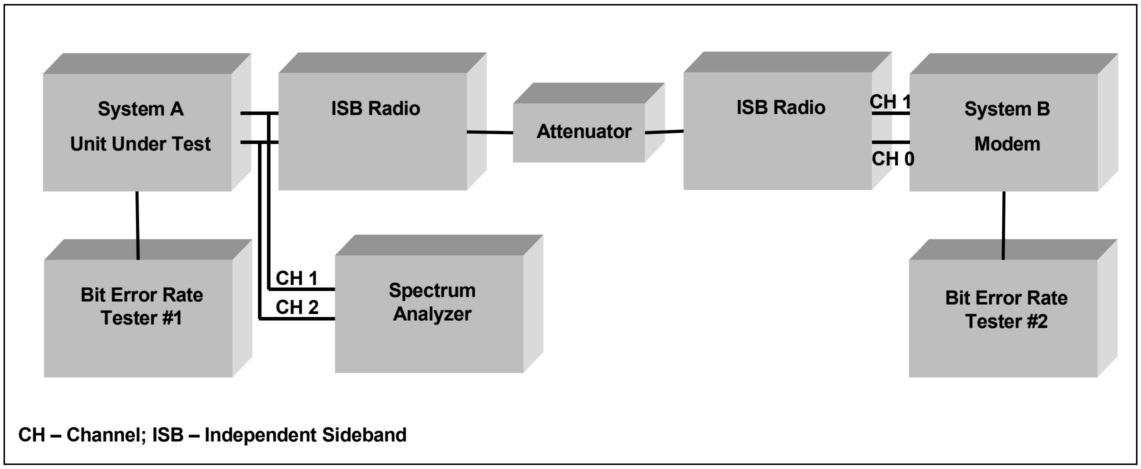

Figure 9.2. Equipment Configuration for Spectrum Analysis of the Multiple Channel System

c. Test Conduct. The procedures for this subtest are listed in table 9.1.

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures

Step	Action	Settings/Action	Result
The following procedure is for reference numbers 117 and 119.			
1	Set up equipment.	See figure 9.1.	
2	Set up vector signal analyzer.	Frequency Center: 1.8 kHz Span: 3.6 kHz Time Result Length: 2000 symbols Search Length: 850 msec Sync Setup Offset: 0 symbols Instrument Mode Digital Demodulation Demodulation Setup Demodulation Format: known symbols: PSK, 9600 bps: 8-PSK, 12800 bps: 16-QAM, 16000 bps: 32-QAM, 19200 bps: 64-QAM. Symbol Rate: 2.4 kHz Result Length: 1800 symbols Reference Filter: Gaussian Sweep: Single Trigger Trigger Type: IF CH1	
3	Set up UUT.	Program UUT to send data at 9600 bps with Ultra Short (US) interleaver setting. Transmit level out of UUT should be set to 0 dBm.	

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
4	Begin sending serial data from the UUT to the vector signal analyzer.	Use vector signal analyzer to capture data, in turn, from channel 0 and channel 1.	
5	The vector signal analyzer will display the preamble sent by the UUT. (The first few bits of the preamble will be highlighted at the beginning of the display.)	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of MIL-STD-188-110B, table F-2. Expected values for 9600 bps using US interleaver settings are: channel 0: D0 = 0, D1 = 0, D2 = 2. channel 1: D0 = 0, D1 = 0, D2 = 2. The vector signal analyzer displays the preamble in binary.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
6	Repeat steps 3-5 using the Very Short (VS) interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 0, D2 = 2. Channel 1: D0 = 0, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
7	Repeat steps 3-5 using the Short (S) interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 0, D2 = 2. D0 = 0, D1 = 2, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
8	Repeat steps 3-5 using the Medium (M) interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 0, D2 = 2. D0 = 2, D1 = 0, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
9	Repeat steps 3-5 using the Long (L) interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 0, D2 = 2. D0 = 2, D1 = 0, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
10	Repeat steps 3-5 using the Very Long (VL) interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 0, D2 = 2. D0 = 2, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
11	Set up UUT.	Program UUT to send data using the serial tone waveform at 12800 bps with US interleaver setting.	
12	Begin sending serial data from the UUT to the vector signal analyzer.		
13	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Each D value sent by the UUT corresponds with those of MIL-STD-188-110B, table F-2. Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 0. Channel 1: D0 = 0, D1 = 0, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
14	Repeat steps 11-13 using the VS interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 0. Channel 1: D0 = 0, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
15	Repeat steps 11-13 using the S interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 0. Channel 1: D0 = 0, D1 = 2, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
16	Repeat steps 11-13 using the M interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 0. Channel 1: D0 = 2, D1 = 0, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
17	Repeat steps 11-13 using the L interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 0. Channel 1: D0 = 2, D1 = 0, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
18	Repeat steps 11-13 using the VL interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 0. Channel 1: D0 = 2, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
19	Set up UUT.	Program UUT to send data using the serial tone waveform at 16000 bps with Ultra Short (US) interleaver setting.	
20	Begin sending serial data from the UUT to the vector signal analyzer.		
21	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Expected D values: Channel 0: D0 = 0, D1 = 2, D2 = 2. Channel 1: D0 = 0, D1 = 0, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
22	Repeat steps 19-21 using the VS interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 2. Channel 1: D0 = 0, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
23	Repeat steps 19-21 using the S interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 2. Channel 1: D0 = 0, D1 = 2, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
24	Repeat steps 19-21 using the M interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 2. Channel 1: D0 = 2, D1 = 0, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
25	Repeat steps 19-21 using the L interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 2. Channel 1: D0 = 2, D1 = 0, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
26	Repeat steps 19-21 using the VL interleaver setting.	Expected values: Channel 0: D0 = 0, D1 = 2, D2 = 2. Channel 1: D0 = 2, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
27	Set up UUT.	Program UUT to send data using the serial tone waveform at 19200 bps with Ultra Short (US) interleaver setting.	
28	Begin sending serial data from the UUT to the vector signal analyzer.		
29	The vector signal analyzer will display the preamble sent by the UUT.	Print results. Use software developed by JITC to validate that the UUT is sending the correct preamble. Expected D values: Channel 0: D0 = 2, D1 = 0, D2 = 0. Channel 1: D0 = 0, D1 = 0, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
30	Repeat steps 27-29 using the VS interleaver setting.	Expected values: Channel 0: D0 = 2, D1 = 0, D2 = 0. Channel 1: D0 = 0, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
31	Repeat steps 27-29 using the S interleaver setting.	Expected values: Channel 0: D0 = 2, D1 = 0, D2 = 0. Channel 1: D0 = 0, D1 = 2, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
32	Repeat steps 27-29 using the M interleaver setting.	Expected values: Channel 0: D0 = 2, D1 = 0, D2 = 0. Channel 1: D0 = 2, D1 = 0, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
33	Repeat steps 27-29 using the L interleaver setting.	Expected values: Channel 0: D0 = 2, D1 = 0, D2 = 0. Channel 1: D0 = 2, D1 = 0, D2 = 2.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
34	Repeat steps 27-29 using the VL interleaver setting.	Expected values: Channel 0: D0 = 2, D1 = 0, D2 = 0. Channel 1: D0 = 2, D1 = 2, D2 = 0.	Preamble Ch0: D0= D1= D2= Ch1: D0= D1= D2=
The following procedure is for reference numbers 116, 120, and 121-129.			
35	The following procedures use automated software to review data from the UUT. The test operator must program BERT 1 to transmit a 1:1 test pattern. The automated software is available for download from the JITC website: http://jitc.fhu.disa.mil/it/hf.htm	Successful data review validates that the following requirements have been met: preamble length, trans-coding, constellations, coding and interleaving, data scrambling, frame structure, reinstated preamble, mini-probes, block encoding, rate ½ convolutional code, and full-tail-biting encoding.	

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
36	Copy and paste MIL_STD_188_110BAppC.vi file onto hard disk of personal computer containing LabVIEW software.	Copy and paste INTVvstate file onto a 3.5-inch floppy disk. Insert floppy disk into drive a: of vector signal analyzer.	
37	Connect channel 0 of the UUT to channel 1 of the vector signal analyzer. Connect channel 1 of the UUT to channel 2 of the vector signal analyzer.	Connect the vector signal analyzer to personal computer via the GPIB interface.	
38	Load LabVIEW software.	Open MIL_STD_188_110BappC.vi.	
39	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
40	Program UUT to send data at 9600 bps using US interleaver.	Set the transmit level of the UUT to 0 dBm.	
41	Run MIL_STD_188_110BappC.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem (via BERT) and begin sending data.	
42	Automated software will run for several minutes.	Record results of data review. (Note that the operator may choose to view the raw data captured on the vector signal analyzer.) Save encoded data to file.	
43	Repeat steps 39-42 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
44	Repeat steps 39-42 using S interleaver setting.	Record results of data review. Save encoded data to file.	
45	Repeat steps 39-42 using M interleaver setting.	Record results of data review. Save encoded data to file.	
46	Repeat steps 39-42 using L interleaver setting.	Record results of data review. Save encoded data to file.	
47	Repeat steps 39-42 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
48	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
49	Program UUT to send data at 12800 bps using US interleaver.		
50	Run MIL_STD_188_110BappC.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem and begin sending data.	
51	Automated software will run for several minutes.	Record results of data review. Save encoded data to file.	
52	Repeat steps 48-51 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
53	Repeat steps 48-51 using S interleaver setting.	Record results of data review. Save encoded data to file.	
54	Repeat steps 48-51 using M interleaver setting.	Record results of data review. Save encoded data to file.	

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
55	Repeat steps 48-51 using L interleaver setting.	Record results of data review. Save encoded data to file.	
56	Repeat steps 48-51 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
57	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
58	Program UUT to send data at 16000 bps using US interleaver.		
59	Run MIL_STD_188_110BappC.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem and begin sending data.	
60	Automated software will run for several minutes.	Record results of data review. Save encoded data to file.	
61	Repeat steps 57-60 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
62	Repeat steps 57-60 using S interleaver setting.	Record results of data review. Save encoded data to file.	
63	Repeat steps 57-60 using M interleaver setting.	Record results of data review. Save encoded data to file.	
64	Repeat steps 57-60 using L interleaver setting.	Record results of data review. Save encoded data to file.	
65	Repeat steps 57-60 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
66	Use Test Information box to select data rate and interleaver type.	Ensure that the UUT is in the idle state (not sending data).	
67	Program UUT to send data at 19200 bps using US interleaver.		
68	Run MIL_STD_188_110BappC.vi file.	Observe vector signal analyzer. When Analyzer displays “Waiting for Trigger,” key the modem and begin sending data.	
69	Automated software will run for several minutes.	Record results of data review. Save encoded data to file.	
70	Repeat steps 66-69 using VS interleaver setting.	Record results of data review. Save encoded data to file.	
71	Repeat steps 66-69 using S interleaver setting.	Record results of data review. Save encoded data to file.	
72	Repeat steps 66-69 using M interleaver setting.	Record results of data review. Save encoded data to file.	
73	Repeat steps 66-69 using L interleaver setting.	Record results of data review. Save encoded data to file.	
74	Repeat steps 66-69 using VL interleaver setting.	Record results of data review. Save encoded data to file.	
The following procedure is for reference number 118.			
75	Set up equipment.	See figure 9.2.	
76	Set up spectrum analyzer.	Center Frequency: 1800 Hz Span: 3600 Hz Max Hold: On	

Table 9.1. HF Data Modems for Multiple Channel Systems Test Procedures (continued)

Step	Action	Settings/Action	Result
77	Send data with UUT. View signal on spectrum analyzer.	Measure the modulator output signal level at 1800 Hz.	
78	Measure the highest out of band peak level(s) from 200 Hz to 3400 Hz.	Subtract the highest out of band level(s) from the modulator output signal level at 1800 Hz recorded in step 77.	
79	Measure the passband ripple from 800 Hz to 2800 Hz.		
80	Measure the frequency that the subcarrier(s) is/are centered at.		

LEGEND:

AGC – Automatic Gain Control
BER – Bit Error Rate
BERT – Bit Error Rate Tester
bps – Bits Per Second
CH – Channel
CTS – Clear-to-Send
dBm – decibels referenced to one milliwatt
DTE – Data Terminal Equipment
GPIB – General Purpose Interface Bus
HF – High Frequency
Hz – hertz
IF – Intermediate Frequency
JITC – Joint Interoperability Test Command
kHz – kilohertz
L – Long
M – Medium
MIL-STD – Military Standard
msec – millisecond
mV – millivolt
PSK – Phase-Shift Keying
QAM – Quadrature Amplitude Modulation
S – Short
Sync – Synchronization
US – Ultra Short
UUT – Unit Under Test
VL – Very Long
VS – Very Short

9.4 Presentation of Results. The results will be shown in table 9.2 indicating the requirement and measured value or indications of capability.

Table 9.2. HF Data Modems for Multiple Channel Systems Results

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
116	F.4.1.2	Multiple channel operation with multiple modems. (Optional) When ISB radios and channel allocations are available, but ISB modems with a matching number of audio channels are not available, multiple modems may be employed as shown in figure F-2. The upper diagram illustrates the case of unencrypted user data and link-level encryption (as in the previous section). The lower diagram depicts application-layer (end-to-end) encryption. The first bit of data to be sent shall be delivered to the modem associated with the highest over-the-air frequency, with succeeding bits delivered to modems with decreasing frequencies. When *M* modems are attached to a single ISB radio (*M* = 2 shown), all modems shall operate at a single data rate, and modem *i* (*i* = 0 .. *M* - 1) shall carry bits numbered *i* + *nM* (*n* = 0, 1,…). This architecture also may be applied to multiple radios operating on unrelated frequencies. However, performance may not be satisfactory if the characteristics of the various channels are not sufficiently similar to support a common maximum data rate. Bit ordering shall be as specified above, with the identity of the modem associated with the highest over-the-air frequency determined when the link is initially established, regardless of subsequent frequency changes while linked.	First data bit delivered to modem associated with the highest over-the-air frequency. All modems operate at single data rate.			

Table 9.2. HF Data Modems for Multiple Channel Systems Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
117	F.4.2	Data rate and interleaver settings are explicitly transmitted as a part of the waveform, both as part of the initial preamble and then periodically as a reinserted preamble and in the periodic known symbol blocks ("mini-probes"). This "auto baud" feature is critical in developing an efficient (ARQ) protocol for high frequency (HF) channels. The receive modem is required to be able to deduce the data rate and interleaver setting from either the preamble or the subsequent data portion of the waveform. A block diagram of the 2-ISB modem with 2-ISB radios is shown in figure F-4. In all applications of this modem, the quasi-analog signal designated Channel 0 shall be connected to the radio equipment so that the sideband that it produces is higher in frequency than the sideband produced by the quasi-analog signal designated Channel 1. In particular, with 2-ISB radios Channel 0 shall use the upper sideband and Channel 1 shall use the lower sideband.	Successful data review using JITC developed automated data review software.			

Table 9.2. HF Data Modems for Multiple Channel Systems Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
118	F.5.1	Modulation. Each of the channels shall be modulated independently. The modulation of each of the channels is identical, with a few specified exceptions, to that specified in appendix C for the high data rate single sideband option. The transmit data clock for both of the channels shall be synchronized so that there is no drift in the relative clocks for each of the channels. The power spectral density of each modulator output signal should be constrained to be at least 20 dB below the signal level measured at 1800 Hz, when tested outside of the band from 200 Hz to 3400 Hz. The filter employed shall result in a ripple of no more than ±2 dB in the range from 800 Hz to 2800 Hz.	Each channel modulated independently. Sync transmit data clocks. Ripple: no more than ±2 dB in the range from 800 Hz to 2800 Hz.			
119	F.5.1.1	Known symbols. For all known symbols, the modulation used shall be PSK, with the symbol mapping shown in table C-1 and figure C-1. No scrambling shall be applied to the known symbols.	Successful data review using JITC developed automated data review software.			
120	F.5.1.2.1.1	QPSK symbol mapping. For QPSK symbols, used in the preamble and reinserted preamble to specify data rate and interleaving, trans-coding shall be achieved by linking one of the symbols specified in table C-1 to a set of two consecutive data bits (dibit) as shown in table C-3. In this table, the leftmost bit of the dibit shall be the older bit; i.e., fetched from the interleaver before the rightmost bit.	Successful data review using JITC developed automated data review software.			
121	F.5.1.2.1.2	8-PSK symbol mapping. For the 9600 bps user data rate, trans-coding shall be achieved by linking one symbol to a set of three consecutive data bits (tribit) as shown in table C-4. In this table, the leftmost bit of the tribit shall be the oldest bit; i.e., fetched from the interleaver before the other two, and the rightmost bit is the most recent bit.	Successful data review using JITC developed automated data review software.			

Table 9.2. HF Data Modems for Multiple Channel Systems Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
122	F.5.1.2.2	QAM data symbols. For the QAM constellations, no distinction is made between the number formed directly from the data bits and the symbol number. Each set of 4 bits (16-QAM), 5 bits (32-QAM) or 6 bits (64-QAM) is mapped directly to a QAM symbol. For example, the four-bit grouping 0111 would map to symbol 7 in the 16-QAM constellation while the 6 bit grouping 100011 would map to symbol 35 in the 64-QAM constellation. Again, in each case the leftmost bit shall be the oldest bit, i.e. fetched from the interleaver before the other bits, and the rightmost bit is the most recent bit.	Successful data review using JITC developed automated data review software.			
123	F.5.1.3	Data scrambling. Data symbols for the 8-PSK symbol constellation shall be scrambled by modulo 8 addition with a scrambling sequence. The data symbols for the 16-QAM, 32-QAM, and 64-QAM constellations shall be scrambled by using an Exclusive OR (XOR) operation. Sequentially, the data bits forming each symbol (4 for 16-QAM, 5 for 32-QAM, and 6 for 64-QAM) shall be XOR'd with an equal number of bits from the scrambling sequence. In all cases, the scrambling sequence generator polynomial shall be $x^9 + x^4 + 1$ and the generator shall be initialized to 1 at the start of each data frame. A block diagram of the scrambling sequence generator is shown in figure C-5. Further details of the operation of the data scrambler may be found in C.5.1.3	Successful data review using JITC developed automated data review software.			

Table 9.2. HF Data Modems for Multiple Channel Systems Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
124	F.5.2	Frame structure. The frame structure shall be as described in C.5.2 except that the data symbols D0, D1, and D2 (used in the preambles and encoded in the mini-probes) take on values distinct from those used for the appendix C SSB modes. For the two-sideband option, the three-bits used for data rate in SSB are fixed at 000. The bits normally used for interleaver setting in SSB are employed as specified in table F-2, using both channels, to select data rate and interleaver settings. Channel 0 carries the code for the combined data rate and Channel 1 carries the code for the common interleaver. Recall that channel 0 is always the lower of the two sidebands. Unused codings are reserved and shall not be used until standardized.	Successful data review using JITC developed automated data review software.			
125	F.5.3	Coding and interleaving. The interleaver used shall be a block interleaver. Each block of input data shall be encoded using a block encoding technique with a code block size equal to the size of the block interleaver. Thus, the input data bits will be sent as successive blocks of bits on both channels that together span the duration of the interleaver length selected. Table F-3 shows the number of input data bits per block as function of both data rate and interleaver length. Note that an “input data block” should not be confused with the 256-symbol data block that is part of a data frame in the waveform format. The bits from an input data block will be mapped through the coding and interleaving to the number of data frames, and thus 256 symbol data blocks, that define the interleaver length.	Successful data review using JITC developed automated data review software.			

Table 9.2. HF Data Modems for Multiple Channel Systems Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
126	F.5.3.1	Block boundary alignment. Each code block shall be interleaved within a single interleaver block of the same size. The boundaries of these blocks shall be aligned such that the beginning of the first data frame following each reinserted preamble shall coincide with an interleaver boundary. Thus for an interleaver length of 3 frames, the first three data frames following a reinserted preamble will contain all of the encoded bits for a single input data block. The first data symbol from the first data frame in each interleaver set shall have as its MSB the first bit fetched from the interleaver. This is no different from what would normally be expected, but is a requirement.	Successful data review using JITC developed automated data review software.			
127	F.5.3.3.1	Interleaver size in bits. The interleaver shall consist of a single dimension array, numbered from 0 to its size in bits –1. The array size shall depend on both the data rate and interleaver length selected as shown in table F-4.	Successful data review using JITC developed automated data review software.			
128	F.5.3.3.2	Interleaver load. The punctured block code bits shall be loaded into the interleaver array beginning with location 0. The location for loading each successive bit shall be obtained from the previous location by incrementing by the interleaver increment value “Inc” specified in table F-4, modulo the interleaver size in bits, “Size.” Defining the first punctured block code bit to be B(0), then the load location for B(n) is given by: Load Location = (n * Inc) modulo (Size)	Successful data review using JITC developed automated data review software.			

Table 9.2. HF Data Modems for Multiple Channel Systems Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
129	F.5.3.3.3	Interleaver fetch. The fetching sequence for all data rates and interleaver lengths shall start with location 0 of the interleaver array and increment the fetch location by 1. The first bit fetched from the interleaver shall be sent to the symbol formation module for channel 0, the second bit fetched shall be sent to the symbol formation module for channel 1, and this pattern shall continue until all bits have been fetched from the interleaver. This is a linear fetch from beginning to end of the interleaver array with even numbered bits delivered to channel 0 and odd numbered bits to channel 1.	Successful data review using JITC developed automated data review software.			

LEGEND:

ARQ – Automatic Repeat Request
dB – decibels
HF – High Frequency
Hz – hertz
ISB – Independent Sideband
JITC – Joint Interoperability Test Command
MIL-STD – Military Standard
MSB – Most Significant Bit
PSK – Phase-Shift Keying
QAM – Quadrature Amplitude Modulation
QPSK – Quadrature Phase-Shift Keying
SSB – Single Sideband
Sync – Synchronization
XOR – Excluive OR

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SUBTEST 10. PERFORMANCE REQUIREMENTS

10.1 Objective. To determine the extent of compliance to the requirements of MIL-STD-188-110B, reference numbers 48, 64, 79, 113, 114, and 115.

10.2 Criteria

a. Performance requirements. The measured performance of the serial (single-tone) mode, using fixed-frequency operation and employing the maximum interleaving period, shall be equal to or better than the coded BER performance in table 10.1. Performance verification shall be tested using a baseband HF simulator patterned after the Watterson Model in accordance with International Telecommunications Union Recommendation (ITU-R) F.520-2. The modeled multipath spread values and fading (two sigma) bandwidth (BW) values in table 10.1 shall consist of two independent but equal average power Rayleigh paths. For frequency-hopping operation, an additional 2 dB in Signal-to-Noise Ratio (SNR) shall be allowed.

Table 10.1. Serial (Single-Tone) Mode Minimum Performance

User Bit Rate	Channel Paths	Multipath (msec)	Fading (Note 1) BW (Hz)	SNR (Note 2) (dB)	Coded BER
4800	1 Fixed	-	-	17	1.0 E-3
4800	2 Fading	2	0.5	27	1.0 E-3
2400	1 Fixed	-	-	10	1.0 E-5
2400	2 Fading	2	1	18	1.0 E-5
2400	2 Fading	2	5	30	1.0 E-3
2400	2 Fading	5	1	30	1.0 E-5
1200	2 Fading	2	1	11	1.0 E-5
600	2 Fading	2	1	7	1.0 E-5
300	2 Fading	5	5	7	1.0 E-5
150	2 Fading	5	5	5	1.0 E-5
75	2 Fading	5	5	2	1.0 E-5

LEGEND:

BER – Bit Error Rate	Hz – hertz	msec – millisecond
BW – Bandwidth	ITU-R – International Telecommunications Union Recommendation	SNR – Signal-to-Noise Ratio
dB – decibels	kHz – kilohertz	

NOTES: 1. Per ITU-R F.520-2.
2. Both signal and noise powers are measured in a 3-kHz bandwidth.

b. 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 10.2.

Table 10.2. 39-Tone Parallel Mode Minimum Performance

	Probability of bit error	
Signal-to-Noise Ratio (dB in 3-kHz bandwidth)	2400 bps	1200 bps
5	8.6 E-2	6.4 E-2
10	3.5 E-2	4.4 E-3
15	1.0 E-2	3.4 E-4
20	1.0 E-3	9.0 E-6
30	1.8 E-4	2.7 E-6
	Probability of bit error	
Signal-to-Noise Ratio (dB in 3-kHz bandwidth)	300 bps	75 bps
0	1.8 E-2	4.4 E-4
2	6.4 E-3	5.0 E-5
4	1.0 E-3	1.0 E-6
6	5.0 E-5	1.0 E-6
8	1.5 E-6	1.0 E-6

LEGEND: bps – bits per second; dB – decibels; kHz - kilohertz

c. <u>BER performance.</u> The measured performance of the high data rate mode, using fixed-frequency operation and employing the maximum interleaving period (the 72-frame "Very Long" interleaver), shall achieve coded BER of no more than 1.0E-5 under each of the conditions listed in table 10.3.

Table 10.3. High Data Rate Mode Minimum Performance

User Data Rate (bps)	**Average SNR (dB) for BER ≤ 1.0E-5**	
	AWGN Channel	**ITU-R Poor Channel**
12800	27	-
9600	21	33
8000	19	28
6400	16	24
4800	13	20
3200	9	15

LEGEND:

AWGN – Additive White Gaussian Noise
BER – Bit Error Rate
bps – bits per second
dB – decibels
ITU-R – International Telecommunications Union Recommendation
SNR – Signal-to-Noise Ratio

Performance shall be tested using a baseband HF simulator patterned after the Watterson Model in accordance with ITU-R 520-2. The Additive White Gaussian Noise (AWGN) channel shall consist of a single, non-fading path. Each condition shall be measured for at least 60 minutes. The ITU-R Poor channel shall consist of two independent but equal average power Rayleigh fading paths, with a fixed 2-msec delay between paths, and with a fading (two sigma) bandwidth of 1 Hz. Each condition shall be measured for at least 5 hours. Both signal and noise power shall be measured in a 3-kHz bandwidth. Note that the average power of QAM symbols is different from that of the 8-PSK mini-probes and reinserted preambles; the measured signal power shall be the long-term average of user data, mini-probe, and reinserted preamble symbols.

d. Doppler shift test. The modem shall acquire and maintain synchronization for at least 5 minutes with a test signal having the following characteristics: 9600 bps/Very Long interleaver, 75 Hz frequency offset, 2-msec delay spread, a fading BW of 1 Hz, and an average SNR of 30 dB. The test shall be repeated with a –75 Hz frequency offset. No BER test is required.

e. Doppler sweep performance. The AWGN BER test at 9600 bps from table 10.3 shall be repeated with a test signal having a frequency offset that continuously varies at a rate of 3.5 hertz per second (Hz/s) between the limits of -75 and +75 Hz, such that a plot of frequency offset verses time describes a periodic “triangle” waveform having a period of (300/3.5) seconds. Over a test duration of 1 hour, the modem shall achieve a BER of 1.0E-5 or less at an SNR of 24 dB.

10.3 Test Procedures

a. Test Equipment Required

(1) HF Channel Simulator

(2) BERT (2 ea)

(3) Modem

(4) UUT

b. Test Configuration. Configure the equipment as shown in figure 10.1.

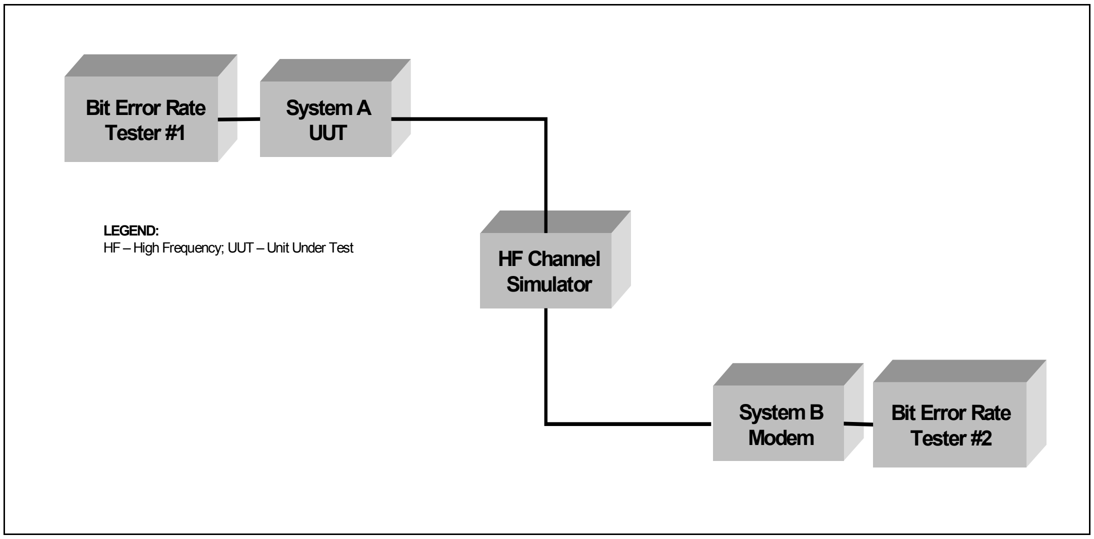

Figure 10.1. Equipment Configuration for Performance Requirements Test

c. Test Conduct. The procedures for this subtest are listed in table 10.4.

Table 10.4. Performance Requirements Test Procedures

Step	Action	Settings/Action	Result
The following procedure is for reference number 48.			
1	Set up equipment.	See figure 10.1.	
2	Program system A to send serial (single-tone) data at 4800 bps.	Program channel simulator as follows: Channel paths: 1 Fixed SNR: 17 dB	
3	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
4	Program system A to send data at 4800 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 2 msec Fading BW: 0.5 Hz SNR: 27 dB	
5	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
6	Program system A to send data at 2400 bps.	Program channel simulator as follows: Channel paths: 1 Fixed SNR: 10 dB	
7	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	

Table 10.4. Performance Requirements Test Procedures (continued)

Step	Action	Settings/Action	Result
8	Program system A to send data at 2400 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 2 msec Fading BW: 1 Hz SNR: 18 dB	
9	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
10	Program system A to send data at 2400 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 2 msec Fading BW: 5 Hz SNR: 30 dB	
11	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
12	Program system A to send data at 2400 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 5 msec Fading BW: 1 Hz SNR: 30 dB	
13	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
14	Program system A to send data at 1200 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 2 msec Fading BW: 1 Hz SNR: 11 dB	
15	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
16	Program system A to send data at 600 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 2 msec Fading BW: 1 Hz SNR: 7 dB	
17	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
18	Program system A to send data at 300 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 5 msec Fading BW: 5 Hz SNR: 7 dB	
19	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	

Table 10.4. Performance Requirements Test Procedures (continued)

Step	Action	Settings/Action	Result
20	Program system A to send data at 150 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 5 msec Fading BW: 5 Hz SNR: 5 dB	
21	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
22	Program system A to send data at 75 bps.	Program channel simulator as follows: Channel paths: 2 Fading Multipath: 5 msec Fading BW: 5 Hz SNR: 2 dB	
23	Send a 2047 test pattern from system A to system B (serial data) for 1 hour.	Record the coded BER (from BERT 2) after 1 hour of operation.	
The following procedure is for reference number 79.			
24	Program systems A and B to operate in 39-tone parallel mode.		
25	Program system A to send 39-tone data at 2400 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 5 dB.	
26	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
27	Program system A to send 39-tone data at 2400 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 10 dB.	
28	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
29	Program system A to send 39-tone data at 2400 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 15 dB.	
30	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
31	Program system A to send 39-tone data at 2400 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 20 dB.	
32	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
33	Program system A to send 39-tone data at 2400 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 30 dB.	
34	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
35	Program system A to send 39-tone data at 1200 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 5 dB.	
36	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
37	Program system A to send 39-tone data at 1200 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 10 dB.	

Table 10.4. Performance Requirements Test Procedures (continued)

Step	Action	Settings/Action	Result
38	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
39	Program system A to send 39-tone data at 1200 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 15 dB.	
40	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
41	Program system A to send 39-tone data at 1200 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 20 dB.	
42	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
43	Program system A to send 39-tone data at 1200 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 30 dB.	
44	Send a 2047 test pattern from system A to system B (39-tone data) for one hour.	Record the BER (from BERT 2) after one hour of operation.	
45	Program system A to send 39-tone data at 300 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 0 dB.	
46	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
47	Program system A to send 39-tone data at 300 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 2 dB.	
48	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
49	Program system A to send 39-tone data at 300 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 4 dB.	
50	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
51	Program system A to send 39-tone data at 300 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 6 dB.	
52	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
53	Program system A to send 39-tone data at 300 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 8 dB.	
54	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
55	Program system A to send 39-tone data at 75 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 0 dB.	
56	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
57	Program system A to send 39-tone data at 75 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 2 dB.	

Table 10.4. Performance Requirements Test Procedures (continued)

Step	Action	Settings/Action	Result
58	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
59	Program system A to send 39-tone data at 75 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 4 dB.	
60	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
61	Program system A to send 39-tone data at 75 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 6 dB.	
62	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
63	Program system A to send 39-tone data at 75 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 8 dB.	
64	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
The following procedure is for reference number 64.			
65	Program system A to send 39-tone data at 75 bps.	Program channel simulator with an SNR (3-kHz bandwidth) of 8 dB. Frequency offset varies at 1 Hz/s between –20 and +20 Hz.	
66	Send a 2047 test pattern from system A to system B (39-tone data) for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
The following procedure is for reference number 113.			
67	Program systems A and B to operate in high data rate mode.	Systems should operate in fixed-frequency mode and employ the maximum interleaving period (the Very Long interleaver).	
68	Program system A to send data at 12800 bps.	Program channel simulator for an AWGN Channel with an SNR of 27 dB. The AWGN channel should consist of a single, non-fading path.	
69	Send a 2047 test pattern from system A to system B for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
70	Program system A to send data at 9600 bps.	Program channel simulator for an AWGN Channel with an SNR of 21 dB.	
71	Send a 2047 test pattern from system A to system B for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
72	Program system A to send data at 8000 bps.	Program channel simulator for an AWGN Channel with an SNR of 19 dB.	
73	Send a 2047 test pattern from system A to system B for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
74	Program system A to send data at 6400 bps.	Program channel simulator for an AWGN Channel with an SNR of 16 dB.	
75	Send a 2047 test pattern from system A to system B for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
76	Program system A to send data at 4800 bps.	Program channel simulator for an AWGN Channel with an SNR of 13 dB.	

Table 10.4. Performance Requirements Test Procedures (continued)

Step	Action	Settings/Action	Result
77	Send a 2047 test pattern from system A to system B for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
78	Program system A to send data at 3200 bps.	Program channel simulator for an AWGN Channel with an SNR of 9 dB.	
79	Send a 2047 test pattern from system A to system B for 1 hour.	Record the BER (from BERT 2) after 1 hour of operation.	
80	Program system A to send data at 9600 bps.	Program channel simulator for an ITU-R Poor channel with an SNR of 33 dB. The ITU-R Poor channel should consist of two independent but equal average power Rayleigh fading paths, with a 2-msec delay between paths, and with a fading bandwidth of 1 Hz.	
81	Send a 2047 test pattern from system A to system B for 5 hours.	Record the BER (from BERT 2) after 5 hours of operation.	
82	Program system A to send data at 8000 bps.	Program channel simulator for an ITU-R Poor channel with an SNR of 28 dB.	
83	Send a 2047 test pattern from system A to system B for 5 hours.	Record the BER (from BERT 2) after 5 hours of operation.	
84	Program system A to send data at 6400 bps.	Program channel simulator for an ITU-R Poor channel with an SNR of 24 dB.	
85	Send a 2047 test pattern from system A to system B for 5 hours.	Record the BER (from BERT 2) after 5 hours of operation.	
86	Program system A to send data at 4800 bps.	Program channel simulator for an ITU-R Poor channel with an SNR of 20 dB.	
87	Send a 2047 test pattern from system A to system B for 5 hours.	Record the BER (from BERT 2) after 5 hours of operation.	
88	Program system A to send data at 3200 bps.	Program channel simulator for an ITU-R Poor channel with an SNR of 15 dB.	
89	Send a 2047 test pattern from system A to system B for 5 hours.	Record the BER (from BERT 2) after 5 hours of operation.	
The following procedure is for reference number 114.			
90	Set up system A to send data at 9600 bps using the Very Long interleaver.	Program HF simulator with a 75 Hz frequency offset, 2-msec delay spread, fading BW of 1 Hz, and an average SNR of 30 dB.	
91	Send a 2047 test pattern from system A to system B.	Verify that the modems are able to acquire and maintain synchronization for at least 5 minutes.	
92	Repeat steps 88 and 89 using a –75 Hz frequency offset.	Verify that the modems are able to acquire and maintain synchronization for at least 5 minutes.	
The following procedure is for reference number 115.			

Table 10.4. Performance Requirements Test Procedures (continued)

Step	Action	Settings/Action	Result
93	Set up system A to send data at 9600 bps using the Very Long interleaver.	Program HF simulator: AWGN Channel Frequency offset varies at 3.5 Hz/s between –75 and +75 Hz. SNR: 24 dB	
94	Send a 2047 test pattern from system A to system B for 1 hour.	Measure the BER from BERT 2 after 1 hour of operation.	

LEGEND:

AWGN – Additive White Gaussian Noise
BER – Bit Error Rate
BERT – Bit Error Rate Tester
bps – Bits Per Second
BW – bandwidth
dB – decibels
HF – High Frequency
Hz – hertz
Hz/s – hertz per second
ITU-R – International Telecommunications Union Recommendation
kHz – kilohertz
msec – millisecond
SNR – Signal-to-Noise Ratio

10.4 Presentation of Results. The results will be shown in table 10.5 indicating the requirement and measured value or indications of capability.

Table 10.5. Performance Results

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
48	5.3.2.5	Performance requirements. The measured performance of the serial (single-tone) mode, using fixed-frequency operation and employing the maximum interleaving period, shall be equal to or better than the coded BER performance in table 20. Performance verification shall be tested using a baseband HF simulator patterned after the Watterson Model in accordance with International Telecommunications Union (ITU) ITU-R F.520-2. The modeled multipath spread values and fading (two sigma) bandwidth (BW) values in table 20 shall consist of two independent but equal average power Rayleigh paths. For frequency-hopping operation, an additional 2 dB in Signal-to-Noise Ratio (SNR) shall be allowed.	See table 10.1.			

Table 10.5. Performance Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
64	B.5.4.2	When operating with the extended preamble, the minimum Doppler correction shall be ±20 Hz.	±20 Hz			
79	B.6	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 B-12.	See table 10.2.			

Table 10.5. Performance Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
113	C.6.1	BER performance. The measured performance of the high data rate mode, using fixed-frequency operation and employing the maximum interleaving period (the 72-frame "Very Long" interleaver), shall achieve coded BER of no more than 1.0E-5 under each of the conditions listed in table C-17. Performance shall be tested using a baseband HF simulator patterned after the Watterson Model in accordance with ITU-R 520-2. The AWGN channel shall consist of a single, non-fading path. Each condition shall be measured for at least 60 minutes. The ITU-R Poor channel shall consist of two independent but equal average power Rayleigh fading paths, with a fixed 2-msec delay between paths, and with a fading (two sigma) bandwidth (BW) of 1 Hz. Each condition shall be measured for at least 5 hours. Both signal and noise power shall be measured in a 3-kHz bandwidth. Note that the average power of QAM symbols is different from that of the 8-PSK mini-probes and reinserted preambles; the measured signal power shall be the long-term average of user data, mini-probe, and reinserted preamble symbols.	See table 10.3.			
114	C.6.3	Doppler shift test. The modem shall acquire and maintain synchronization for at least 5 minutes with a test signal having the following characteristics: 9600 bps/Very Long interleaver, 75 Hz frequency offset, 2-msec delay spread, a fading BW of 1 Hz, and an average SNR of 30 dB. The test shall be repeated with a –75 Hz frequency offset. No BER test is required.	Sync for 5 minutes.			

Table 10.5. Performance Results (continued)

Reference Number	MIL-STD Paragraph	Requirement	Result		Finding	
			Required Value	Measured Value	Met	Not Met
115	C.6.4	Doppler sweep performance. The AWGN BER test at 9600 bps from table C-17 shall be repeated with a test signal having a frequency offset that continuously varies at a rate of 3.5 Hz/s between the limits of -75 and +75 Hz, such that a plot of frequency offset vs. time describes a periodic “triangle” waveform having a period of (300/3.5) seconds. Over a test duration of 1 hour, the modem shall achieve a BER of 1.0E-5 or less at an SNR of 24 dB.	BER of 1.0E-5.			

LEGEND:

AWGN – Additive White Gaussian Noise
BER – Bit Error Rate
bps – bits per second
BW – Bandwidth
dB – decibels
HF – High Frequency
Hz – hertz
Hz/s – hertz per second
ITU – International Telecommunications Union Recommendation
kHz – kilohertz
MIL-STD – Military Standard
msec – millisecond
PSK – Phase-Shift Keying
QAM – Quadrature Amplitude Modulation
SNR – Signal-to-Noise Ratio
Sync – Synchronization

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APPENDIX A

ACRONYMS

μA	microamp
Ω	ohm
AGC	Automatic Gain Control
ALC	Automatic Level Control
ALE	Automatic Link Establishment
ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise
Bd	baud
BER	Bit Error Rate
BERT	Bit Error Rate Tester
bps	bits per second
BW	bandwidth
CJCSI	Chairman Joint Chiefs of Staff Instruction
COMSEC	Communications Security
CTS	Clear-to-Send
CVSD	Continuously Variable Slope Delta
CW	Continuous Wave
dB	decibel
dBm	decibels referenced to 1 milliwatt
dBm0	decibels referenced to zero transmission level point
dc	direct current
DISA	Defense Information Systems Agency
DISAC	Defense Information Systems Agency Circular
DO	Design Objective
DOD	Department of Defense
DODISS	Department of Defense Index of Specifications and Standards
DPSK	Differential Phase-Shift Keying
DSN	Digital Switched Network
DSP	Digital Signal Processing
DTE	Data Terminal Equipment
ea	each
EOM	End-of-Message
FCC	Federal Communications Commission

ACRONYMS (continued)

FEC	Forward Error Correction
FED-STD	Federal Standard
FIPS PUB	Federal Information Processing Standard Publication
FSK	Frequency Shift Keying
GF	Galois Field
HDR	Header
HF	High Frequency
HFTF	High Frequency Test Facility
Hz	hertz
Hz/s	hertz per second
ISB	Independent Sideband
ITU	International Telecommunications Union
ITU-R	International Telecommunications Union Recommendation
JITC	Joint Interoperability Test Command
kbps	kilobits per second
kHz	kilohertz
LAN	Local Area Network
LSB	(1)Lower Sideband (2)Least Significant Bit
mA	milliamperes
MF	Medium Frequency
MGD	Modified-Gray Decoder
MHz	megahertz
MILSTAR	Military Strategic and Tactical Relay Satellite
MIL-STD	Military Standard
msec	milliseconds
MSB	Most Significant Bit
N/A	Not applicable
NATO	North Atlantic Treaty Organization
ppm	parts per million
PSK	Phase-Shift Keying
PSN	Public Switched Network
PTT	Push-to-Talk

ACRONYMS (continued)

PVC	polyvinyl chloride
QAM	Quadrature Amplitude Modulation
QDPSK	Quadrature Differential Phase-Shift Keying
QPSK	Quadrature Phase-Shift Keying
rms	root-mean-square
RP	Reinserted Preamble
RTS	Request-to-Send
s	seconds
SNR	Signal-to-Noise Ratio
SSB	Single Sideband
STANAG	Standardization Agreement
sync	Synchronization
TLP	Transmission Level Point
TX	Transmit
UHF	Ultra High Frequency
U.S.	United States
USB	Upper Sideband
UUT	Unit Under Test
V	volts
VF	Voice Frequency
VHF	Very High Frequency
XOR	Exclusive OR

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APPENDIX B

MIL-STD-188-110B REQUIREMENTS MATRIX

Table B-1. MIL-STD-188-110B Requirements Matrix

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	4.	General requirements.	
	4.1	Functional employment. Data modulators - demodulators (modems) are employed in long-haul and tactical communications systems and subsystems. Delineation between long-haul and tactical communications systems can be found in Federal Standard (FED-STD)-1037. Data modems employ a variety of techniques for converting digital signals into quasi-analog signals for transmission over analog channels. Various modulation techniques have been standardized and no single optimum technique has been found for all applications. This section covers general requirements for both long-haul and tactical data modems operating over voice frequency (VF) and radio channels. A representative list is given in table 1 with the modulation types and data rates noted for each channel category listed.	
	4.2	Common Parameters. All data modems shall comply with the applicable requirements of 4.2.1 through 4.2.6.	
1	4.2.1	Modulation and data signaling rates and tolerance. The modulation rates expressed in baud (Bd) and the data signaling rates expressed in bits per second (bps) at the standard interfaces shown on figure 1 shall be as listed: a. 50 Bd or bps b. 75 X 2^m Bd or bps, up to and including 9600 Bd or bps Except where specified otherwise, signaling rates shall not deviate from the nominal values by more than ± 0.01%.	1
2	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 2 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.	1
3	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 military standard MIL-STD-188-114.	3

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
4	4.2.4.1	Modems used in multi-channel subsystems. For modems used in long-haul systems and in tactical subsystem types I, II, and III (see table 3), the terminal impedance at the modulator output and the demodulator input shall be 600 ohms, balanced to ground, with a minimum return loss of 26 decibels (dB) against a 600-ohm resistance over the frequency band of interest. The electrical symmetry shall be sufficient to suppress longitudinal currents to a level that is at least 40 dB below reference level (-40 dB referred to one milliwatt measured at zero transmission level point (dBm0)).	2
5	4.2.4.2	Modems used in single channel radio subsystems. For modems used with radio equipment of single channel radio subsystems, the terminal impedance at the modulator output shall be 150 ohms, unbalanced to ground, with a minimum return loss of 20 dB against a 150-ohm resistance over the frequency band of interest. The terminal impedance at the demodulator input shall be 600 ohms, balanced to ground, with a minimum return loss of 26 dB against a 600-ohm resistance over the frequency band of interest. The electrical symmetry shall be sufficient to suppress longitudinal currents to a level that is at least 40-dB below reference level.	2
	4.2.5	Quasi-analog signal levels.	
6	4.2.5.1	Modems used in multi-channel subsystems. For modems used in long-haul systems and in tactical subsystem types I, II, and III (see table 3), the quasi-analog signal level at the modulator output shall be adjustable from at least -18 dB referred to one milliwatt (dBm) to +3 dBm. The difference in the output levels between the MARK and SPACE binary signals shall be less than 1dB. The demodulator shall be capable of operating, without degradation of performance, with a received quasi-analog signal level ranging from at least -35 dBm to +3 dBm. a. For long-haul systems and tactical subsystem types I and III, the transmitted quasi-analog signal level of telegraph and data equipment (modem, multiplexer, etc.) shall be adjustable from at least -18 dBm to +3 dBm to provide -13 dBm0 (e.g., -13 dBm at a zero transmission level point (0 TLP)) at the input terminals of a data trunk or switch. For multitone data signals, the level of each data tone with reference to -13 dBm, shall be equal to -13 - (10 log t), measured in dBm, where t is the number of tones.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
6	4.2.5.1 (continued)	b. For tactical subsystem type II, the transmitted quasi-analog signal level of telegraph and data equipment (modem, multiplexer, etc.) shall be adjustable from at least -18 dBm to +3 dBm to provide -6 dBm0 (e.g., -10 dBm at a - 4 TLP) at the input terminals of a data trunk or switch. For multitone data signals, the level of each data tone with reference to -10 dBm shall be equal to -10 - (10 log t), measured in dBm, where t is the number of tones.	2
	4.2.5.2	Modems used in single channel radio subsystems. Standards for the quasi-analog signal levels of modulators and demodulators are documented in MIL-STD-188-141.	
	4.2.6	Clock equipment, control, and timing. All data modems shall have the capability to accept external timing signals. The clock is the device that provides the time base for controlling operation of digital equipment. An equipment clock provides the peculiar needs of its equipment and in some cases may control the flow of data at its equipment interface. A master or station clock, regardless of its physical location, controls two or more equipments that are linked together as a system. The following subparagraphs, 4.2.6.1 through 4.2.6.3, are primarily concerned with master or station clocks.	
	4.2.6.1	Transmission modes. All future communications equipment requiring a stable clock or precise character interval control shall make provisions for operating from station clocks in any or all of the following states, specified in subparagraphs 4.2.6.1.1 through 4.2.6.1.3.1.	
7	4.2.6.1.1	Bit synchronous. In bit synchronous operation, clock timing shall be delivered at twice the data modulation rate. (For this purpose “data” includes information bits plus all bits added to the stream for whatever purpose they may serve in the system; i.e., error control, framing, etc.). The device shall release one bit within the duration of one clock cycle. It shall be assumed that, during periods of communication difficulty, a clock signal might be delivered to a send device occasionally or not at all for periods extending to hours. During periods when the sending equipment has no traffic to send, an idle pattern or all “ones” may be transmitted.	1

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	4.2.6.1.2	Bit-by-bit asynchronous. In bit-by-bit asynchronous operation, it is assumed that rapid manual, semi-automatic or automatic shifts in the data modulation rate will be accomplished by gating or slewing the clock modulation rate. It is possible that equipment may be operated at 50 bps one moment and the next moment at 1200 bps or 2400 bps, etc. It shall be assumed that, during periods of communication difficulty, a clock signal might be delivered to a send device occasionally or not at all for periods extending to hours. During periods when the sending equipment has no traffic to send, an idle pattern or all “ones” may be transmitted.	
8	4.2.6.1.3	Character interval synchronous. In character interval synchronized equipment, any character interval from 4 to 16 unit intervals per character interval shall be permitted. It is assumed that, having programmed a given facility for a particular character interval, no other character interval operation would be expected except by reprogramming. An example of such operation would be 7.0 units per character interval tape reader being stepped at 8.0 units per character interval.	1
	4.2.6.2	Clock characteristics.	
9	4.2.6.2.1	Modulation rates. The standard clock modulation rates for compatibility with modulation or data signaling rates shall be two times the standard rates specified in subparagraph 4.2.1.	1
10	4.2.6.2.2	Modulation rate stability. The stability of synchronized or crook timing supplied in all synchronous digital transmission, switching, terminal, and security equipment shall be sufficient to ensure that synchronization is maintained within ±25 percent of the unit interval between transmitted and received signals for periods of not less than 100,000 consecutive seconds.	1
11	4.2.6.2.3	Modulation rate phase adjustment. Means shall be provided in all digital transmission, switching, terminal, and security equipment so that, at the applicable modulation rates, a shift in phase of the incoming data stream with relation to the clocking pulse shall be possible over a period of three unit intervals (i.e., a shift of 1.5 unit intervals early or late from theoretical center of the unit interval at the applicable modulation rate).	1

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
12	4.2.6.2.4	Output signal. The output of the clock shall be an alternating symmetrically-shaped wave at the required clock modulation rate. In the case of an unbalanced digital interface, the clock output signal shall comply with the voltage and wave-shaping requirement of subparagraphs 4.3.1.3.3.4 and 4.3.1.3.3.5, respectively. In the case of a balanced digital interface, the clock output signal shall comply with the voltage requirements of subparagraph 4.3.1.3.4.4 and shall contain no points of inflection prior to reaching the maximum amplitudes. When the clock is quiescent, the clock signal state shall be negative.	1
13	4.2.6.2.5	Clock period. A clock period or cycle is defined as having one half-cycle of positive polarity (sense) and one half-cycle of negative polarity (sense). The duty cycle shall be 60 percent ±1.0 percent. Thus, in the binary sense, each clock period or cycle is composed of two clock unit intervals, and it follows that a clock rate of 50 Hz is a clock modulation rate of 100 Bd.	1
14	4.2.6.3	Clock/data phase relationship. Arrangements, which may be used to supply clock pulses to sources and syncs, are shown in subparagraph 4 3.1.6.3.1. Typical standard arrangements are shown from which one may be selected to meet a specific application. For those digital devices operated at dc baseband that are interconnected by metallic wire (or other equipment which provides in effect the same function as a metallic wire), the following clock/data phase relationships apply if, and only if, interface circuit lengths permit. It is noted that, due to signal propagation delay time differences over different dc wire circuits or dc equivalent circuits at data modulation rates higher than 2400 Bd, there may be a significant relative clock/data phase-shift which must be adjusted in accordance with subparagraph 4.3.1.6.2.3. Practical operating experience indicates that typical multiple pair paper cable or polyvinyl chloride (PVC) insulated exchange grade telephone cable may be expected to function at modulation rates of 4800 Bd data/9600 Bd clock at distances up to 3000 cable feet without any need for concern over relative pulse shift or noise if the standard low level digital interface is applied to both clock and data signals in accordance with subparagraph 4 3.1.3.	1

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
14	4.2.6.3 (continued)	All data transition emitted by a source under direct control of an external clock shall occur on (be caused by) negative to positive transitions of that clock. The design objective is a minimum delay between the clock transition and the resulting data transition, but in no case shall this delay exceed 12.5 percent of the duration of the data unit interval. For each equipment, once this delay is fixed in hardware, it shall be consistent within ±1 percent of itself for each clock transition. These delay limits shall apply directly at the driver interface. Sampling of the data signal by the external clock at a sync interface shall occur on (be caused by) positive to negative clock transitions. When the clock is used for controlling intermittent data transmission, data may not change state except when requested by a negative to positive clock transition. The quiescent state of the clock shall be at negative voltage. The quiescent state of the data shall be that state resulting from the last negative to positive clock transition. The phase relationship between external clock and data is not specified for devices in which the external clock is related only indirectly to the source data; for example, to maintain synchronism between a data source and data sync for a signal with a constant modulation rate. However, whatever the phase delay, it shall be consistent to within ±1 percent at the data unit interval at the applicable modulation rate. If the clock at twice the modulation rate at the same data is also supplied as an output, then data transitions shall coincide within ±1 percent of the data unit interval with the negative to positive transitions of the output clock (see figure 4.3-9). Direct control means control of the data by a clock signal at twice the modulation rate of the data. Indirect control means use of a clock at some higher standard modulation rate; e.g., 4, 8, 128 times the modulation rate.	1
	4.3	General design requirements. The general design requirements of 4.3.1 through 4.3.2.3 involve documents outside of the mandatory MIL-STD-188 series. Extreme care must be used to ensure that these documents are tailored to select only the provisions applicable to a given design task.	
	4.3.1	Federal maritime interoperability requirements. Ship-to-ship and shore-to-ship medium frequency (MF) and high frequency (HF) radio teletypewriter system (RATT) operation shall be in accordance with the requirements of FED-STD-1035.	
	4.3.2	International interoperability requirements.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

<table>
<tr><th>Reference Number</th><th>MIL-STD Paragraph</th><th>Requirements</th><th>Subtest Number</th></tr>
<tr><td></td><td>4.3.2.1</td><td>Shore-to-ship broadcast systems. 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.</td><td></td></tr>
<tr><td></td><td>4.3.2.2</td><td>Maritime air communications systems. 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.</td><td></td></tr>
<tr><td></td><td>4.3.2.3</td><td>Radio teletypewriter systems. For interoperation among American, British, Canadian, Australian (ABCA) armies, the electrical characteristics of data modems employed in HF and very high frequency (VHF) RATT operations shall comply with the applicable requirements of Quadripartite Standardization Agreement (QSTAG)-303.</td><td></td></tr>
<tr><td></td><td>4.4</td><td>Data link protocol (optional). When an ARQ protocol is used it shall be in accordance with appendix E.</td><td></td></tr>
<tr><td></td><td>5.</td><td>Detailed requirements.</td><td></td></tr>
<tr><td></td><td>5.1</td><td>Frequency shift keying (FSK) data modulators-demodulators (modems) for single channel radio equipment (optional). Non-diversity FSK modems used primarily with single channel (3 kHz) radio equipment shall comply with the applicable requirements of 4.2, 4.3, 5.1.1, 5.1.2, and 5.1.3.</td><td></td></tr>
<tr><td>15</td><td>5.1.1</td><td>Narrow-shift FSK modem. For single-radio operation with binary narrow-shift FSK modulation, a shift of 170 hertz (Hz) shall be used with the characteristic frequencies given in table 4. The tolerance of each characteristic frequency shall be ±4 Hz.
TABLE 4. Characteristic Frequencies of FSK Data Modems for Single-Channel Radio Equipment
<table>
<tr><th>Channel</th><th>Mark Frequency (Hz)</th><th>Center Frequency (Hz)</th><th>Space Frequency (Hz)</th></tr>
<tr><td>LF radio</td><td>915</td><td>1000</td><td>1085</td></tr>
<tr><td>MF radio</td><td>1615</td><td>1700</td><td>1785</td></tr>
<tr><td>HF radio</td><td>1575</td><td>2000</td><td>2425</td></tr>
<tr><td>UHF radio</td><td>500</td><td>600</td><td>700</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
</table>
</td><td>4</td></tr>
</table>

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
16	5.1.2	Wide-shift FSK modem. For single channel telegraph operation over high frequency (HF) radio links operating under 150 baud (Bd), the use of FSK with an 850-Hz shift is not consistent with the requirement that the U.S. operate its HF communication services in accordance with International Telecommunication Union (ITU) recommendations. However, where 850-Hz wide-shift FSK is used, the characteristic frequencies given in table 4 shall apply. The tolerance of each characteristic frequency shall be ±4 Hz.	4
17	5.1.3	Speech-plus-telegraph operation. For speech-plus-telegraph operation, the modem shall use binary FSK modulation with a shift of 85 Hz at the characteristic frequencies shown in table 5. The tolerance of each characteristic frequency shall be ±1 Hz.	4
18	5.2	FSK data modems for voice frequency (VF) channel operation. Non-diversity FSK modems used primarily in point-to-point (switched or non-switched) connections over VF channels shall comply with the applicable requirements of 4.2, 4.3, and 5.2.1 through 5.2.2.2. The modems shall exhibit a Bit Error Rate (BER) of not more than 1 bit error in 10^5 (design objective (DO): 10^6) data bits 99 percent of the time when operating over a military C1 type circuit as defined in Defense Information Systems Agency Circular (DISAC) 300-175-9. As a DO, during 99 percent of the time that the network is in use the user throughput should be equal to or greater than 50 percent.	4
19	5.2.1	FSK data modems for 150 bits per second (bps) or less. Non-diversity FSK modems used primarily for single channel telegraph with data signaling rates of 150 bps or less shall comply with 5.2.1.1 through 5.2.1.4.	4
20	5.2.1.1	Operational characteristics. The modem shall be capable of 2-wire half-duplex and 4-wire full-duplex operation. When the modem is connected for 2-wire half-duplex operation, the modem shall be capable of generating a break-in signal (see 5.2.1.4) that stops the transmission from the remote modem and allows the direction of data flow to be reversed.	4
21	5.2.1.2	Modulation characteristics. The modem shall use binary FSK modulation with a shift of 85 Hz at the characteristic frequencies shown in table 6. The tolerance of each characteristic frequency shall be ±4 Hz. The modem shall have a ready means of reversing the signaling sense of MARK and SPACE conditions to facilitate interoperation with older modems.	4
22	5.2.1.3	Carrier suppression. During periods of no transmission, the modulator output shall be removed automatically. The carrier suppression time delay shall be such that the modulator output persists for 2.5 seconds (s), ±0.5 s.	4

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
23	5.2.1.4	Break-in signal characteristics. The frequency of the break-in signal shall be 1180 Hz, ±3 Hz. The nominal level of the break-in signal shall be the same as the nominal level of the quasi-analog data signal at the modulator output. The break-in frequency detector of the demodulator shall operate with signal levels ranging at least from -35 decibels referenced to 1 milliwatt (dBm) to -5 dBm.	4
	5.2.2	FSK data modems for 1200 bps or less.	
24	5.2.2.1	Modulation characteristics. The modem shall use phase-continuous FSK with a shift of 400 Hz for data signaling rates of 600 bps or less, and a shift of 800 Hz for a data signaling rate of 1200 bps. The characteristic frequencies shall comply with those listed in table 7 and shall have a tolerance of ±5 Hz.	4
25	5.2.2.2	Modulator output spectrum. The transmitted spectrum energy of the quasi-analog signal, measured at the modulator output, shall be suppressed for all frequencies above 3400 Hz to a level that is at least 40 decibels (dB) below the level of the maximum spectrum energy. This requirement shall apply to all modulation rates for which the modem was designed.	4
	5.3	HF data modems. The serial (single tone) transmit waveform described in this paragraph establishes the minimum essential interoperability and performance requirements for new HF modems.	
	5.3.1	General requirements.	
26	5.3.1.1	Capability. The HF modems shall be capable of modulating and demodulating serial binary data into/from a serial (single-tone) waveform. This waveform is transmitted received over HF radio operating in either fixed-frequency or frequency-hopping modes of operation. The minimum acceptable performance and joint service interoperability shall be at 75, 150, 300, 600, 1200, and 2400 bps using the fixed-frequency Phase-Shift Keying (PSK) serial waveform specified herein. Uncoded serial tone modem operation at 4800 bps is a design objective (DO). Note that this is a less robust mode of operation at 4800 than that capability specified in appendix C.	5
	5.3.1.2	Voice digitization. When integrated within the data modem, voice digitization functions shall be in accordance with North Atlantic Treaty Organization (NATO) Standardization Agreement (STANAG) 4198.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	5.3.1.3	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 and 4481. The data link protocol for NATO interoperation is specified in appendix E. b. Binary FSK mode. If included, this mode shall be in accordance with 5.1. c. Advanced narrowband digital voice terminal (ANDVT) (thirty-nine tone) mode. If included, this mode shall be in accordance with MIL-C-28883 and STANAG 4197. d. Sixteen-tone Differential Phase-Shift Keying (DPSK) mode. If included this mode shall be in accordance with appendix A. e. Thirty-nine-tone DPSK mode. If included, this mode shall be in accordance with appendix B. f. Sixteen-tone DPSK mode for digital data applications. If included, the mode shall be in accordance with MIL-C-28883.	
	5.3.1.3	g. High data rate mode (3200 – 9600 bps). If included, this mode shall be in accordance with Appendix C. Note that in NATO documents (AC/322-D/17) data rates from 1200 through 9600 bps are termed “Medium Data Rate.” h. Multiple channel mode (two independent sidebands, or 2-IS i. Robust 75 bps mode. If included, this mode shall be in accordance with STANAG 4415. j. Frequency-hopping mode. If included, this mode shall be in accordance with the PSK serial (single-tone) waveform contained herein and the data training and timing format provided in MIL-STD-188-148. k. STANAG 4529. When narrowband operation is required, it shall be in accordance with STANAG 4529.	
	5.3.1.4	Interface requirements.	
	5.3.1.4.1	Line-side data characteristics. Line-side data interfaces shall be in accordance with MIL-STD-188-114.	
	5.3.1.4.2	LAN interface (DO). If an additional Ethernet LAN interface is provided (see Joint Technical Architecture, 2.3.2.2.2.1: Local Area Network (LAN) Access), the modem should be capable of performing both line side and Remote Control (see 5.3.1.5) interface functions over the LAN including transport of user data.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	5.3.1.4.3	Equipment side characteristics. Modems shall be designed to provide the required performance (see 5.3.2.5) using the single channel bandwidth and characteristics as given in MIL-STD-188-141. As a DO, modems should be capable of transmitting and receiving the quasi-analog signals over unconditioned 3-kHz VF lines while maintaining the performance established in 5.3.2.5.	
	5.3.1.4.4	Transmit override. When operating in other than full-duplex mode, data presented for transmission at the line-side or LAN interface shall cause the modem to commence transmit operation, overriding any reception of data on the equipmen. An option may be provided to disable transmit override, so t side that CTS is delayed after the assertion of RTS until a reception in progress is complete.	
	5.3.1.4.5	Buffering in synchronous serial mode. When transferring line-side data in the synchronous mode, the modem shall transmit all user data that occur after the assertion of CTS by the modem and before the de-assertion of RTS by the DTE. At the receive end of the link, all of the bits that occur in this interval shall be delivered by the modem to the DTE. Transmission and reception of user bits that fall outside this interval is not precluded.	
27	5.3.1.5	Remote control interface. A remote control interface is mandatory for all new procurements of HF data modems.	1
	5.3.1.5.1	Electrical interface. The electrical interface for remote control of the modem shall comply with the specified industrial or military interface standard.	
	5.3.1.5.2	Optional modem control driver. As an option a software remote control driver shall be supplied for installation in a remote control unit that provides a standardized Application Programming Interface (API) to communications software.	
	5.3.2	Serial (single-tone) mode.	
28	5.3.2.1	This mode shall employ M-ary Phase-Shift Keying (PSK) on a single carrier frequency as the modulation technique for data transmission. 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 5.3.1.1. Selectable interleaver settings shall be provided. This 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	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	5.3.2.2	Sequencing of time phases. Figure 2 illustrates the functional block diagram for fixed-frequency and frequency-hopping operation.	
29	5.3.2.2.1	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 figure 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 data terminal equipment (DTE). Switches S2 and S3 shall be in the SYNC position. The transmitting modem shall send the required sync preamble sequence (see 5.3.2.3.7.2) to achieve time and frequency sync with the receiving modem. The length of the sync preamble sequence pattern shall be 0.6 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. For radio frequency hopping operation, S4 and the data fetch controller shall provide the required traffic dead time at the beginning of each hop by disabling the modem output. The dead time shall be equal to the duration of 96 symbols. Switch S4 shall be placed in the through position during fixed-frequency operation. Referring to figure 3, the sequence of events for synchronous and asynchronous operation is as follows: a. For fixed-frequency, full-duplex data operation, upon receipt of the message request-to-send (RTS) signal from the DTE, the modem shall simultaneously perform the following;	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
29	5.3.2.2.1 (continued)	(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 5.3.2.3.7.2 and 5.3.2.3.8.2. b. For fixed-frequency 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 fixed-frequency full-duplex operation. c. Fixed-frequency 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 commence sending the special sync pattern described in 5.3.2.3.7.2 and 5.3.2.3.8.2.	5
30	5.3.2.2.2	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 (figure 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 5.3.2.3.7.1.2). The period of dwell in each switch position shall be as follows:	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
30	5.3.2.2.2 (continued)	a. For frequency-hopping operation, the dwell is a function of bit rate and time duration of the hop. MIL-STD-188-148 gives the required timing of switches S2 and S4 during each hop time as a function of data rate and dead time. b. For fixed-frequency operation, the period of dwell shall be a function of bit rate only. At 2400 and 4800 bps, 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 bps, the two durations shall be 20 symbols in each position. At 75 bps, 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
31	5.3.2.2.3	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 (figure 2) shall be switched to the EOM position. This shall cause a fixed 32-bit pattern (see 5.3.2.3.1) to be sent to the FEC encoder. Function switches S2 and S3 (and also S4 in frequency-hopping operation) shall continue to operate as established for the data phase.	5
32	5.3.2.2.4	FEC coder and interleaver flush phase. Immediately upon completion of the EOM phase, S1 (figure 2 shall be switched to the FLUSH position causing input of flush bits (see 5.3.2.3.2) to the FEC encoder).	5
	5.3.2.3	Functional descriptions. The following subparagraphs provide figure 2 block descriptions.	
33	5.3.2.3.1	EOM sequence. The eight-digit hexadecimal number, 4B65A5B2 shall represent the EOM sequence. The bits shall be transmitted with the most significant digit first. Thus the first eight bits are, left to right, 0100 1011.	5
34	5.3.2.3.2	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 interleaved matrix data block (see 5.3.2.3.4 for data block size) containing the last coder flush bit. Flush bits shall be set to “0”. If the interleaver is in a bypass (0.0 s) state, only the coder flush bits are transmitted.	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
35	5.3.2.3.3	FEC encoder. The FEC encoder shall be used for data rates up to and including 2400 bps. The FEC encoder block diagram for frequency-hopping and fixed-frequency operation is shown on figure 4. For frequency-hopping operation, the FEC encoder function shall be accomplished by a constraint length 7 convolutional coder with repeat coding used at the 75, 150, and 300 bps rates. 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 $T_I(x)$ being taken first. For the 2400 bps rate, every fourth bit (the second value of $T_2(x)$ shall be omitted at the interleaver output to form a punctured rate 2/3 convolutional rate. At all other rates, the convolutional coder shall be rate 1/2. Coded bit streams of 3600, 2400, and 1200 bps shall be generated for the input data rates of 2400, 1200, and 600 bps, respectively. For the 300, 150, and 75 bps input data rates, a 1200 bps 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, $T_I(x)$, followed by repetitions of the second $T_2(x)$. Error-correction coding for frequency-hopping operation shall be in accordance with table 8.	5
35	5.3.2.3.3 (continued)	b. For fixed-frequency operation, the FEC encoder function shall be accomplished by a single rate 1/2 constraint length 7 convolutional coder with repeat coding used at 150 and 300 bps. The two summing nodes shall operate as given for frequency-hopping operation; that is, for each bit input to the encoder, two bits shall be taken as output from the encoder. Coded bit streams of 4800, 2400, and 1200 bps shall be generated for input data rates of 2400, 1200, and 600 bps, respectively. For 300 bps and 150 bps input data rates, repeating the pairs of output bits the appropriate number of times shall generate a 1200 bps coded bit stream. 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 bps, a different transmit format (see 5.3.2.3.7.1.1) is used and the effective code rate of 1/2 shall be employed to produce a 150 bps coded stream. Error-correction coding for fixed-frequency operation shall be in accordance with table 9. c. For 4800 bps fixed-frequency operation, the FEC encoder shall be bypassed.	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
36	5.3.2.3.4	The interleaver, when used, shall be a matrix block type that 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 interleaves is contained in the transmitted sync pattern (see 5.3.2.3.7.2). The short interleaves shall be switch selectable to be either 0.0 s or 0.6 s (see 5.3.2.3.7.2.1). To maintain the interleave delay at a constant value, the block size shall be scaled by bit rate. Table 10 lists the interleaver matrix dimensions (rows and columns) that shall be allocated for each required bit rate and interleave delay. Note: For frequency-hopping operation at rates of 300, 150, and 75 bps, the number of bits required for a constant time delay is the same as that for 600 bps due to repeat coding. For fixed-frequency operation, repeat coding is used with only the 300 bps and 150 bps rates. 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 bps fixed-frequency operation. For fixed-frequency operation at 75 bps only, the following changes to the above description shall apply: a. When the interleaver setting is on long, the procedure is the same, but the row number shall be advanced by 7 modulo 20.	5
36	5.3.2.3.4 (continued)	b. When the interleaver 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

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
37	5.3.2.3.5	Interleave 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 bps with a long interleave 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. The interleaver fetch process shall be the same for frequency-hopping and fixed-frequency operation except as follows: a. For frequency-hopping operation (as stated in 5.3.2.3.3), the puncture process at 2400 bps shall occur during the fetch routine by omitting every fourth bit from the interleaver output. b. For fixed-frequency operation at the 75 bps 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 11.	5
38	5.3.2.3.6	Modified-Gray decoder. At 4800 and 2400 bps, the channel bits are effectively transmitted with 8-ary channel symbols. At 1200 bps and 75 bps (fixed frequency), the channel bits are effectively transmitted with 4-ary channel symbols. Modified-Gray decoding of the 2400 bps, 4800 bps (tribit), and 75 bps (fixed frequency) 1200 bps (dibit) channel symbols shall be in accordance with tables 12 and 13 respectively. When one-bit channel symbols are used (600-150 bps, and 75 bps (frequency-hopping operation)) the MGD does not modify the unknown data bit stream.	5
	5.3.2.3.7	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.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
39	5.3.2.3.7.1	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 frequency-hopping and fixed-frequency operation data rates, the output of the symbol formation shall be scrambled with pseudo-random 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 5.3.2.3.9.	5
40	5.3.2.3.7.1.1	Unknown data. At all frequency-hopping operation rates and rates above 75 bps for fixed-frequency operation, 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, figure 5. When one bit channel symbols are used (600-150 bps, and 75 bps (frequency-hopping)), the symbol formation output shall be tribit numbers 0 and 4. At the 1200 bps rate, the dibit channel symbol formation shall use tribit numbers 0, 2, 4, and 6. At the 4800 bps and 2400 bps rates, all the tribit numbers (0-7) shall be used for symbol formation. At 75 bps fixed-frequency operation, 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 14. The mapping in table 14a 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 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 14b. In any case, the resultant output is one of four orthogonal waveforms produced for each of the possible dibits of information. As before, these values will be scrambled later to take on all 8-phase states.	5
40	5.3.2.3.7.1.1	Note: Each set consists of 32-tribit numbers. The receive modem shall use the modification of the known data at interleaver boundaries to synchronize without a preamble and determine the correct date rate and mode of operation.	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
41	5.3.2.3.7.1.2	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 interleaved block. The block length shall be 1440-tribit channel symbols for short interleave setting and 11520-tribit channels 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 15 of 5.3.2.3.7.2.1 and table 17 of 5.3.2.3.7.2.2. The two known symbol patterns are repeated twice rather than four times as they are in table 17 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).	5
	5.3.2.3.7.2	Sync preamble sequence.	
42	5.3.2.3.7.2.1	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 (msec) segments (depending on whether either zero, short, or long interleave periods are used). Each 200-msec segment shall consist of a transmission of 15 three bit channel symbols as described in 5.3.2.3.7.2.2. 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 15 gives the assignment of these values. If a demodulator receives any D1, D2 combination that it does not implement, it shall not synchronize but shall continue to search for synchronization. Note: The short interleave can be selected to either 0.0 s (bypassed) or 0.6 s. The short interleave generally should be set to 0.6 s. If the 0.0s 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.	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
42	5.3.2.3.7.2.1 (continued)	The three count symbols C1, C2, and C3 shall represent a count of the 200 msec 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. Adding a “1” before the two-bit value does this so that this “1” becomes the most significant bit. This conversion shall be as shown in table 16.	5
43	5.3.2.3.7.2.2	Preamble pattern generation. The sync preamble pattern shall be a sequence of channel symbols containing three bits each (see 5.3.2.3.7.2.1). These channel symbols shall be mapped into thirty two-tribit numbers as given in table 17. Note: When the two known symbol patterns preceding the transmission of each new interleaves block are transmitted, the patterns in table 17 are repeated twice rather than four times to produce 8 pattern of 16-tribit numbers.	5
44	5.3.2.3.8	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
45	5.3.2.3.8.1	Data sequence randomizing generator. The data sequence randomizing generator shall be a 12-bit shift register with the functional configuration shown on figure 6. At the start of the data phase, the shift register shall be loaded with the initial pattern shown in figure 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.	5
46	5.3.2.3.8.2	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 5.3.2.3.8.1 and this paragraph shall be modulo 8 added to the output of the symbol formation function.	5

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

<table>
<tr><th>Reference Number</th><th>MIL-STD Paragraph</th><th>Requirements</th><th>Subtest Number</th></tr>
<tr><td>47</td><td>5.3.2.3.9</td><td>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 sine wave. 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.
b. Clock accuracy for generation of the 1800-Hz carrier shall be within ±1 Hz.</td><td>5</td></tr>
<tr><td></td><td>5.3.2.4</td><td>Waveform summary. For frequency-hopping and fixed-frequency operation, tables 18 and 19 summarize the data phase characteristics of the transmitted formats that shall be used for each bit rate.</td><td></td></tr>
<tr><td>48</td><td>5.3.2.5</td><td>Performance requirements. The measured performance of the serial (single-tone) mode, using fixed-frequency operation and employing the maximum interleaving period, shall be equal to or better than the coded BER performance in table 20. Performance verification shall be tested using a baseband HF simulator patterned after the Watterson Model in accordance with International Telecommunications Union (ITU) Recommendation ITU-R F.520-2. The modeled multipath spread values and fading (two sigma) bandwidth (BW) values in table 20 shall consist of two independent but equal average power Rayleigh paths. For frequency-hopping operation, an additional 2 dB in Signal-to-Noise Ratio (SNR) shall be allowed.</td><td>5</td></tr>
<tr><td>48</td><td>5.3.2.5
(continued)</td><td>TABLE 20. Serial (single-tone) mode minimum performance
<table>
<tr><th>User Bit Rate</th><th>Channel Paths</th><th>Multipath (msec)</th><th>Fading (Note 1) BW (Hz)</th><th>SNR (Note 2) (dB)</th><th>Coded BER</th></tr>
<tr><td>4800</td><td>1 Fixed</td><td>-</td><td>-</td><td>17</td><td>1.0 E-3</td></tr>
<tr><td>4800</td><td>2 Fading</td><td>2</td><td>0.5</td><td>27</td><td>1.0 E-3</td></tr>
<tr><td>2400</td><td>1 Fixed</td><td>-</td><td>-</td><td>10</td><td>1.0 E-5</td></tr>
<tr><td>2400</td><td>2 Fading</td><td>2</td><td>1</td><td>18</td><td>1.0 E-5</td></tr>
<tr><td>2400</td><td>2 Fading</td><td>2</td><td>5</td><td>30</td><td>1.0 E-3</td></tr>
<tr><td>2400</td><td>2 Fading</td><td>5</td><td>1</td><td>30</td><td>1.0 E-5</td></tr>
<tr><td>1200</td><td>2 Fading</td><td>2</td><td>1</td><td>11</td><td>1.0 E-5</td></tr>
<tr><td>600</td><td>2 Fading</td><td>2</td><td>1</td><td>7</td><td>1.0 E-5</td></tr>
<tr><td>300</td><td>2 Fading</td><td>5</td><td>5</td><td>7</td><td>1.0 E-5</td></tr>
<tr><td>150</td><td>2 Fading</td><td>5</td><td>5</td><td>5</td><td>1.0 E-5</td></tr>
<tr><td>75</td><td>2 Fading</td><td>5</td><td>5</td><td>2</td><td>1.0 E-5</td></tr>
</table></td><td>5</td></tr>
<tr><td></td><td>5.3.3</td><td>Frequency hopping mode (optional). See MIL-STD-188-148 (S).</td><td></td></tr>
</table>

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
49	5.3.4	Robust serial tone mode for severely degraded HF links (optional). The optional robust serial tone mode shall employ the waveform specified above for 75 bps operation, and shall meet the performance requirements of STANAG 4415.	5
	5.4	Wireline data modems. Wireline data modems shall be capable of operation in private line (leased) point-to-point circuits and in the public switched network (PSN) dial-up circuits. General and specific requirements for these applications are provided below in 5.4.1 and 5.4.2, respectively.	
	5.4.1	General requirements.	
	5.4.1.1	Interface requirements. The modem shall be directly connectable to the PSN in conformance with Part 68 of the Federal Communications Commission (FCC) Rules and Regulations.	
50	5.4.1.2	Output power level. The total power transmitted by the modem to the line shall be adjustable in no greater than 1 Db steps from at least –12 dBm to –3 dBm.	5
	5.4.2	Performance requirements.	
	5.4.2.1	General. As a minimum, wireline data modems shall be evaluated using BER and user throughput as standardized measures. During 99 percent of the time that the network is in use, the user throughput shall be equal to or greater than 50 percent. BER requirements for private line (leased) service point-to-point circuits and PSN circuits are given below in 5.4.2.2 and 5.4.2.3, respectively.	
	5.4.2.2	BER for private line (leased) service point-to point circuits. The BER shall not exceed one bit error in 10^5 (DO: 10^6) bits 99 percent of the time when operating over a military C1 type circuit at 600 or 1200 bps, or over a military C2 type circuit at the higher bit rates. C1 and C2 type circuits are defined in DISAC-300-175-9.	
	5.4.2.3	BER and other parameters for PSN service dial-up circuits. The BER for PSN service dial-up circuits shall not exceed one bit error in 10^5 bits 95 percent of the time when operating over a military C3 type circuit. The C3 type circuit is defined in DISAC 300-175-9. Modem performance shall be evaluated in accordance with the channel impairment combinations specified in Telecommunications Industries Association (TIA) (formerly Electronic Industries Association (EIA)) Standard EIA-496-A, Section 5, Data Transmission Evaluation Criteria.	
	5.4.2.4	Automatic answering and calling sequence for PSN. PSN wireline modems shall perform the automatic answering and calling sequence in accordance with International Telecommunication Union (ITU) Recommendation V.25.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	5.4.3	Data modems for 600 bps or 1200 bps. Full-duplex modems used for transmitting data with signaling rates of 600 bps or 1200 bps over nominal 4 kilohertz (kHz) VF channels terminated by 2-wire circuits shall comply with the applicable requirements of Federal Standard FIPS-PUB-136 as modified by 5.4 above. FIPS-PUB-136 is based on ITU Recommendation V.22.	
	5.4.4	Data modems for 2400 bps. The data modems used for transmitting data with signaling rates of 2400 bps over nominal 4-kHz VF channels shall comply with the applicable requirements of FIPS-PUB-133. FIPS-PUB-133 is based on ITU Recommendation V.22 bis, V.26, and V.26 bis. As a DO, the modem should be capable of expansion to include the following, optional mode: a 2-wire DPSK full-duplex modem with optional fallback rate to 1200 bps in accordance with ITU Recommendation V.26.	
	5.4.5	Data modems for 4800 bps. Non-diversity DPSK modems used for transmitting data with signaling rates of 4800 bps over nominal 4-kHz VF channels shall comply with the applicable requirements of FIPS-PUB-134-1 as modified by 5.4 above. FIPS-PUB-134-1 is based on techniques described in ITU Recommendations V.27bis, V.27 ter ad V.32.	
	5.4.5.1	If 2400 bps fallback operation is required, it shall be in accordance with one of the two alternative modes of FIPS-PUB-134-1.	
	5.4.5.2	Optional modes. As a DO, the modem should be capable of expansion to include one or more of the following additional modes. 2-wire half-duplex and 4-wire full-duplex mode in accordance with ITU Recommendation V.27 ter. 2-wire full-duplex mode in accordance with ITU Recommendation V.32. 2-wire half-duplex and 4-wire full-duplex mode in accordance with ITU Recommendation V.29.	
	5.4.6	Data modems for 9600 bps.	
	5.4.6.1	Private line operation. Quadrature amplitude modulation (QAM) 4-wire full-duplex modems, used for transmitting data with signaling rates of 9600 bps with optional fallback rates of 7200 bps and 4800 bps over nominal 4-kHz VF channels, shall comply with the applicable requirements of FIPS-PUB-135 as modified by 5.4 above.	
	5.4.6.2	Fallback operation. If 4800 bps fallback operation is required, it shall be in accordance with option 2 in FIPS-PUB-135.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	5.4.6.3	Switched network operation (U.S. PSN, foreign push-to-talk (PTT) and Digital Switched Network (DSN)). The modem shall be capable of operation at 9600 bps in accordance with ITU Recommendation V.32 and provide a level of performance in accordance with section 5 of EIA-496A. (DO: 14.4 kbps).	
	5.4.7	Data modems with data signaling rates greater than 9600 bps. Requirements for wireline data modems with data signaling rates greater than 9600 bps are not standardized here.	
MIL-STD-188-110B Supplemental Requirements Matrix			
	Appendix A	16-Tone Differential Phase-Shift Keying (DPSK) Mode	
	A.1.1	Scope. This appendix describes the 16-tone differential Phase-Shift Keying (DPSK) mode.	
	A.1.2	Applicability. This appendix is a non-mandatory part of MIL-STD-188-110B; however, when the optional 16-tone DPSK mode is used, it shall be implemented in accordance with this appendix.	
	A.3	Definitions. See section 3.	
	A.4	General requirements.	
	A.4.1	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.	
51	A.4.2	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 (bps).	6
	A.5	Detailed requirements.	
52	A.5.1	Modulator output signal. The modulator output signal shall contain 16 DPSK data tones (table A-1). The 16 data tones shall be simultaneously keyed to produce a signal element interval of 13 1/3 milliseconds (msec) 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 bps. The modulator shall provide a separate tone combination to initiate synchronization and, if required, a separate tone for Doppler correction.	6
53	A.5.2	Data tone frequencies. The frequency of each data tone shall be as listed in table A-2. The tone frequencies shall maintain an accuracy of ±0.1 hertz (Hz).	6

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
54	A.5.3	Phase modulation and encoding. For data signaling rates of 75, 150, 300, or 600 bps at the modulator input, each data tone signal element shall be two-phase (biphase) modulated (see figure A-1a). 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 A-2. For data signaling rates of 1200 or 2400 bps at the modulator input, each data-tone signal element shall be four-phase (quadrature-phase) modulated (see figure A-1b). 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 A-2. The phase changes of the data tone signal elements specified in table A-2 shall be relative to the phase of the immediately preceding signal element.	6
55	A.5.4	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 msec, corresponding to a duration of five to 32 data tone signal elements. The 605-Hz tone shall be 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-	6
55	A.5.4 (continued)	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 msec) 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.	6
56	A.5.5	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.	6

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
57	A.5.6	In-band diversity combining. In-band diversity combining shall be accomplished at data signaling rates from 75 bps to 1200 bps. The data tones shall be combined in accordance with table A-1. The degree of diversity combining shall be as listed in table A-2.	6
58	A.5.7	Demodulator signal alarm. Provisions shall be made in the demodulator to activate an alarm when the incoming signals from the HF radio link decreases below a preset level.	6
	Appendix B	39-Tone Parallel Mode (optional)	
	B.1	General.	
	B.1.1	Scope. This appendix describes the 39-tone parallel mode.	
	B.1.2	Applicability. This appendix is a non-mandatory part of MIL-STD-188-110B; however, when the optional 39-tone parallel mode is used, it shall be implemented in accordance with this appendix.	
	B.2	Applicable documents. This section is not applicable to this appendix.	
	B.3	Definitions. See section 3.	
59	B.4	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 figure B-1) (1) accepts UNKNOWN serial binary data at its line side data input port, (2) performs forward error correction (FEC) encoding and interleaving, and (3) converts the resulting 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 (bps). A means is provided for synchronization of the signal element and interleaved data block timing. A 40th unmodulated tone is	7
59	B.4 (continued)	used for correcting frequency offsets introduced by Doppler shift or radio equipment instability. In a like manner, the receive direction (1) accepts QDPSK data tones at its input, (2) converts them into the transmitted serial bit stream, (3) performs deinterleaving and FEC decoding, and (4) makes the resulting data stream available at its line-side output port.	7
	B.5	Detailed requirements.	
	B.5.1	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.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
60	B.5.2	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: $g(x) = x^4 + a^{l3} x^3 + a^6x^2 + a^3x + a^{10}$; where "*a*" is a non-zero element of the Galois field (GF)(2^4) formed as the field of polynomials over GF(2) module $x^4 + x + 1$. For input signaling rates of 2400 bps, the code shall be shortened to (14,10). Otherwise, the code shall be shortened to (7,3).	7
61	B.5.3	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 are shown in table B-1 shall be provided. For a data signaling rate of 2400 bps, the selection shall consist of eight degrees. At data signaling rates below 2400 bps, four degrees for each bit rate shall be provided as shown in table B-1. The input data stream shall be loaded into the interleaver buffer as described by figures B-2 and B-3.	7
62	B.5.4	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 (msec). The transmit sequence of events is shown on figure B-4.	7

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
63	B.5.4.1	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 B-2.	7
64	B.5.4.2	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 non-extended 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).	7
65	B.5.4.3	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 pseudo-random 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 B-5.	7

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
65	B.5.4.3 (continued)	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 B-3 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 B-3. However, the final bit of the framing sequence shall always be the first space bit that 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).	7
66	B.5.5	Modulator output signal. The modulator output shall contain 39 QDPSK data tones (see table B-4). The 39 data tones shall be simultaneously keyed to produce a signal element interval of 22.5 milliseconds (msec) 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 bps. At input signaling rates less than 2400 bps, 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.	7
67	B.5.5	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 B-5.	7
68	B.5.6	In-band diversity. Two selectable methods of in-band diversity for data rates of 75 – 600 bps 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).	7

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
69	B.5.6.1	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 msec 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 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 B-6).	7
70	B.5.6.2	Frequency diversity. In-band diversity shall be characterized by transmitting a data word and its (d-1) copies in one signal element (e.g., 22.5 msec time interval). This characterization is according to the tone/bit assignments shown in table B-7.	7
71	B.5.7	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, and convert it to bit synchronous data prior to FEC encoding. Conversely, after FEC decoding, the demodulator shall convert bit synchronous data back into asynchronous format. Also, before FEC encoding, SPACE bits shall replace the start, stop, and parity bits. After FEC decoding, the start, stop, and parity bits shall be regenerated before placing the characters in the output data stream. Otherwise, the mode operates as specified in B.5.1 through B.5.6.2 above.	7
72	B.5.7.1	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 B-8.	7
73	B.5.7.2	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.	7
74	B.5.7.3	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.	7
75	B.5.7.3.1	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.	7

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
76	B.5.7.3.2	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.	7
77	B.5.7.4	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.	7
	B.5.7.5	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 B-9, B-10, and B-11, along with the corresponding framing sequence length.	
78	B.5.7.6	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 B-9, B-10, and B-11). 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.	7
79	B.6	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 B-12.	
	Appendix C	HF Data Modem Waveforms for Data Rates Above 2400 bps (optional)	
	C.1	General.	
	C.1.1	Scope. This appendix describes the HF data modem waveforms for data rates above 2400 bps.	
	C.1.2	Applicability. This appendix is a non-mandatory part of MIL-STD-188-110B; however, when using HF data modem waveforms for data rates above 2400 bps, they shall be implemented in accordance with this appendix.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	C.2	Applicable Documents. This section is not applicable to this appendix.	
	C.3	Definitions. See section 3.	
80	C.4	This appendix presents a modem waveform and coding specification for data rates of 3200, 4800, 6400, 8000 and 9600 bps. Uncoded operation at 12800 bps is a DO. The single-tone waveforms specified in this appendix use modulation techniques of greater complexity and data blocks larger than those found in section 5.3.2 of this standard in order to achieve the efficiencies necessary to obtain the required data rates. A block interleaver is used to obtain 6 interleaving lengths ranging from 0.12 s to 8.64 s. A single coding option, a constraint length 7, rate 1/2 convolutional code, punctured to rate 3/4, is used for all data rates. The full-tail-biting approach is used to produce block codes from this convolutional code that are the same length as the interleaver. Since the minimum interleaver length spans a single data frame, there is no option of zero interleaving, since the time delays would not be reduced.	8
81	C.4	Both the data rate and interleaver settings are explicitly transmitted as a part of the waveform, both as part of the initial preamble and then periodically as both a reinserted preamble and in the periodic known symbol blocks. This “auto baud” feature is critical in developing an efficient automatic repeat request (ARQ) protocol for high frequency (HF) channels. The receive modem is required to be able to deduce the data rate and interleaver setting from both the preamble or from the subsequent data portion of the waveform.	8
	C.5	Detailed Requirements.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
82	C.5.1	Modulation. The symbol rate for all symbols shall be 2400 symbols-per-second, which shall be accurate to a minimum of ±0.24 (10 ppm) symbols-per-second when the transmit data clock is generated by the modem and not provided by the data terminal equipment (DTE). Phase-Shift Keying (PSK) and quadrature amplitude modulation (QAM) modulation techniques shall be used. The sub-carrier (or pair of quadrature sub-carriers in the case of QAM) shall be centered at 1800 Hz accurate to a minimum of 0.018 Hz (10 ppm). The phase of the Quadrature sub-carrier relative to the In-phase carrier shall be 90 degrees. The correct relationship can be achieved by making the In-phase sub-carrier cos (1800 Hz) and the Quadrature sub-carrier–sin (1800 Hz). The power spectral density of the modulator output signal should be constrained to be at least 20 dB below the signal level measured at 1800 Hz, when tested outside of the band from 200 Hz to 3400 Hz. The filter employed shall result in a ripple of no more than ±2 dB in the range from 800 Hz to 2800 Hz.	8
83	C.5.1.1	Known symbols. For all known symbols, the modulation used shall be PSK, with the symbol mapping shown in table C-1 and figure C-1. No scrambling shall be applied to the known symbols.	8
84	C.5.1.2	Data symbols. For data symbols, the modulation used shall depend upon the data rate. Table C-21 specifies the modulation that shall be used with each data rate. The 3200-bps Quadrature Phase-Shift Keying (QPSK) constellation is scrambled to appear, on-air, as an 8-PSK constellation. Both the 16-QAM and 32-QAM constellations use multiple PSK rings to maintain good peak-to-average ratios, and the 64-QAM constellation is a variation of the standard square QAM constellation, which has been modified to improve the peak-to-average ratio.	8
85	C.5.1.2.1	PSK data symbols. For the PSK constellations, a distinction is made between the data bits and the symbol number for the purposes of scrambling the QPSK modulation to appear as 8-PSK, on-air. Scrambling is applied as a modulo 8 addition of a scrambling sequence to the 8-PSK symbol number. Trans-coding is an operation which links a symbol to be transmitted to a group of data bits.	8
86	C.5.1.2.1.1	QPSK symbol mapping. For the 3200 bps user data rate, trans-coding shall be achieved by linking one of the symbols specified in table C-1 to a set of two consecutive data bits (dibit) as shown in table C-3. In this table, the leftmost bit of the dibit shall be the older bit; i.e., fetched from the interleaver before the rightmost bit.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
87	C.5.1.2.1.2	8-PSK symbol mapping. For the 4800-bps user data rate, trans-coding shall be achieved by linking one symbol to a set of three consecutive data bits (tribit) as shown in table C-4. In this table, the leftmost bit of the tribit shall be the oldest bit; i.e., fetched from the interleaver before the other two, and the rightmost bit is the most recent bit.	8
88	C.5.1.2.2	QAM data symbols. For the QAM constellations, no distinction is made between the number formed directly from the data bits and the symbol number. Each set of 4 bits (16-QAM), 5 bits (32-QAM) or 6 bits (64-QAM) is mapped directly to a QAM symbol. For example, the four-bit grouping 0111 would map to symbol 7 in the 16-QAM constellation while the 6 bits 100011 would map to symbol 35 in the 64-QAM constellation. Again, in each case the leftmost bit shall be the oldest bit, i.e. fetched from the interleaver before the other bits, and the rightmost bit is the most recent bit. The mapping of bits to symbols for the QAM constellations has been selected to minimize the number of bit errors incurred when errors involve adjacent signaling points in the constellation.	8
89	C.5.1.2.2.1	The 16 QAM constellation. The constellation points that shall be used for 16-QAM, are shown in figure C-2 and specified in terms of their In-phase and Quadrature components in table C-5. As can be seen in the figure, the 16 QAM constellation is comprised of two PSK rings: 4-PSK inner and 12-PSK outer.	8
90	C.5.1.2.2.2	The 32 QAM constellation. The constellation points that shall be used for 32-QAM are shown in figure C-3 and specified in terms of their In-phase and Quadrature components in table C-6. This constellation contains an outer ring of 16 symbols and an inner square of 16 symbols.	8
91	C.5.1.2.2.3	The 64-QAM constellation. The constellation points that shall be used for the 64-QAM modulation are shown in figure C-4 and specified in terms of their In-phase and Quadrature components in table C-71. This constellation is a variation on the standard 8 x 8 square constellation, which achieves better peak-to-average without sacrificing the very good pseudo-Gray code properties of the square constellation.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
92	C.5.1.3	Data scrambling. Data symbols for the 8-PSK symbol constellation (3200 bps, 4800 bps) shall be scrambled by modulo 8 addition with a scrambling sequence. The data symbols for the 16-QAM, 32-QAM, and 64-QAM constellations shall be scrambled by using an Exclusive OR (XOR) operation. Sequentially, the data bits forming each symbol (4 for 16-QAM, 5 for 32-QAM, and 6 for 64-QAM) shall be XOR'd with an equal number of bits from the scrambling sequence. In all cases, the scrambling sequence generator polynomial shall be $x^9 + x^4 + 1$ and the generator shall be initialized to 1 at the start of each data frame. A block diagram of the scrambling sequence generator is shown in figure C-5. For 8-PSK symbols (3200 bps and 4800 bps), the scrambling shall be carried out taking the modulo 8 sum of the numerical value of the binary triplet consisting of the last (rightmost) three bits in the shift register, and the symbol number (trans-coded value). For example, if the last three bits in the scrambling sequence shift register were 010 which has a numerical value equal 2, and the symbol number before scrambling was 6, symbol 0 would be transmitted since: (6+2) Modulo 8 = 0. For 16-QAM symbols, scrambling shall be carried out by XORing the 4-bit number consisting of the last (rightmost) four bits in the shift register with the symbol number. For example, if the last 4 bits in the scrambling sequence shift register were 0101 and the 16-QAM symbol number before scrambling was 3 (i.e. 0011), symbol 6 (0110) would be transmitted. For 32-QAM symbols, scrambling shall be carried out by XORing the 5-bit number formed by the last (rightmost) five bits in the shift register with the symbol number. For 64-QAM symbols, scrambling shall be carried out by XORing the 6-bit number formed by the last (rightmost) six bits in the shift register with the symbol number.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
92	C.5.1.3 (continued)	After each data symbol is scrambled, the generator shall be iterated (shifted) the required number of times to produce all new bits for use in scrambling the next symbol (i.e., 3 iterations for 8-PSK, 4 iterations for 16-QAM, 5 iterations for 32-QAM and 6 iterations for 64-QAM). Since the generator is iterated after the bits are used, the first data symbol of every data frame shall, therefore, be scrambled by the appropriate number of bits from the initialization value of 00000001. The length of the scrambling sequence is 511 bits. For a 256-symbol data block with 6 bits per symbol, this means that the scrambling sequence will be repeated just slightly more than three times, although in terms of symbols, there will be no repetition.	8
93	C.5.2	Frame structure. The frame structure that shall be used for the waveforms specified in this appendix is shown in figure C-6. An initial 287-symbol preamble is followed by 72 frames of alternating data and known symbols. Each data frame shall consist of a data block consisting of 256 data symbols, followed by a mini-probe consisting of 31 symbols of known data. After 72 data frames, a 72 symbol subset of the initial preamble is reinserted to facilitate late acquisition, Doppler shift removal, and sync adjustment. It should be noted that the total length of known data in this segment is actually 103 symbols: the 72 reinserted preamble symbols plus the preceding 31 symbol mini-probe segment which follows the last 256-symbol data block.	8
	C.5.2.1	Synchronization and reinserted preambles. The synchronization preamble is used for rapid initial synchronization. The reinserted preamble is used to facilitate acquisition of an ongoing transmission (acquisition on data).	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
94	C.5.2.1.1	Synchronization preamble. The synchronization preamble shall consist of two parts. The first part shall consist of at least N blocks of 184 8-PSK symbols to be used exclusively for radio and modem AGC. The value of N shall be configurable to range from values of 0 to 7 (for N=0 this first section is not sent at all). These 184 symbols shall be formed by taking the complex conjugate of the first 184 symbols of the sequence specified below for the second section. The second section shall consist of 287 symbols. The first 184 symbols are intended exclusively for synchronization and Doppler offset removal purposes while the final 103 symbols, which are common with the reinserted preamble, also carry information regarding the data rate and interleaver settings. Expressed as a sequence of 8-PSK symbols, using the symbol numbers given in table C-1 the synchronization preamble shall be as shown in table C-8 where the data symbols D0, D1, and D2 take one of 30 sets of values chosen from table C-9 to indicate the data rate and interleaver settings. The Modulo operations are meant to signify that each of the D values are used to shift the phase of a length 13-bit Barker code (0101001100000) by performing modulo 8 addition of the D value with each of the Barker code 13 phase values (0 or 4). This operation can encode 6 bits of information using QPSK modulation of the 13-bit (chip) Barker codes. Since the three Barker code sequences only occupy 39 symbols, the 31 symbol mini-probes are lengthened to 32 symbols each to provide the additional 2 symbols required to pad the three 13 symbol Barker codes up to a total of 41 symbols.	8
94	C.5.2.1.1 (continued)	The mapping chosen to create table C-9 uses three-bits each to specify the data rate and interleaver length. The 3 data rate bits are the 3 most significant bits (MSB) of 3 dibit symbols and the interleaver length bits are the least significant bits (LSB). The phase of the Barker code is determined from the 3 resulting dibit words using table C-3, the dibit trans-coding table. The three-bit data rate and interleaver length mappings are shown in table C-10. Note that the trans-coding has the effect of placing the 3 interleaver length bits in quadrature with the 3 data rate bits. Because the Barker code is unbalanced in terms of the number of 0s and 1s, the 000 or 111 patterns exhibit a net imbalance in each quadrature component of the 39 symbols that is 12 to 27. These two patterns are reserved for future standardization of high data rate modes that employ constellations more dense than those specified in C.5.1. The other three-bit patterns are more balanced (17 to 22) and are used for the more robust constellations.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
95	C.5.2.1.2	Reinserted preamble. The reinserted preamble shall be identical to the final 72 symbols of the synchronization preamble. In fact, the final 103 symbols are common between the synchronization preamble and the contiguous block consisting of the reinserted preamble and the mini-probe that immediately precedes it. The 103 symbols of known data (including the 31 mini-probe symbols of the preceding data frame) are shown in table C-11 where the data symbols D0, D1, and D2 again take one of 30 sets of values chosen from table C-9 to indicate the data rate and interleaver settings as described in the Synchronization Preamble section above. The first 31 of these symbols are the immediately preceding mini-probe, which follows the last of the 72 data blocks. Note that the 3-Bit Mappings for Interleaver Length of 000 or 111 may result in an S_0 to S_8 pattern that could be confused with the fixed (- - - - - - - +) mini probe pattern. For this reason, these mappings are referred to as “illegal” in table C-10.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
96	C.5.2.2	Mini-probes. Mini-probes 31 symbols in length shall be inserted following every 256-symbol data block and at the end of each preamble (where they are considered to be part of the preamble). Using the 8-PSK symbol mapping, each mini-probe shall be based on the repeated Frank-Heimiller sequence. The sequence that shall be used, specified in terms of the 8-PSK symbol numbers, is given by: 0, 0, 0, 0, 0, 2, 4, 6, 0, 4, 0, 4, 0, 6, 4, 2, 0, 0, 0, 0, 0, 2, 4, 6, 0, 4, 0, 4, 0, 6, 4. This mini-probe will be designated '+'. The phase inverted version of this is: 4, 4, 4, 4, 4, 6, 0, 2, 4, 0, 4, 0, 4, 2, 0, 6, 4, 4, 4, 4, 4, 6, 0, 2, 4, 0, 4, 0, 4, 2, 0 and mini-probes using this sequence will be designated '-', as the phase of each symbol has been rotated 180 degrees from the '+'. There are a total of 73 mini-probes for each set of 72 data blocks. For convenience, each mini-probe will be sequentially numbered, with mini-probe 0 being defined as the last 31 symbols of the preceding (reinserted) preamble, mini-probe number 1 following the first data block after a (reinserted) preamble. Mini-probe 72 follows the 72nd data block, and is also the first 31 symbols of the next 103 symbol reinserted preamble. Mini-probes 0 and 72 have been defined as part of the reinsertion preamble to have the signs - and + respectively. The data rate and interleaver length information encoded into the synchronization and reinserted preambles shall also be encoded into mini-probes 1 through 72. These 72 mini-probes are grouped into four sets of 18 consecutive mini-probes (1 to 18, 19 to 36, 37 to 54, and 55 to 72). Note that the 256 symbol data block that immediately follows the 18th mini-probe, in each of the first three sets, is also the 1st data block of an interleaver block with frame lengths of 1, 3, 9, and 18. The length 36 interleaver block begins after the second set, and a reinserted preamble begins after the fourth set. This structure permits data to begin to be demodulated as soon as the interleaver boundary becomes known.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
96	C.5.2.2 (continued)	Each 18 mini-probe sequence shall consists of seven – signs, a + sign, followed by six sign values that are dependent on the data rate and interleaver length, three sign values that specify which of the four sets of 18 mini-probes it is, and then finally a + sign. For the fourth set, this final + sign (mini-probe 72) is also the initial mini-probe of the next reinserted preamble (which uses the + phase). Pictorially, this length 18 sequence is: - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 +, where the first six Si sign values are defined in table C-12. Note that these 6 bit patterns (+ is a 0) correspond to the concatenation of the three-bit mappings from table C-10 for the data rate (S0 S1 S2) and the interleaver length (S3 S4 S5). The final three Si sign values which specify the mini-probe set (count) are defined in table C-13. The 1st eight mini-probes in each set (- - - - - - - +) uniquely locate the starting point for the following nine Si values. This is possible since the Si sequences used contain at most runs of four + or - phases. This makes it impossible for a sequence of 7 mini-probes with the same phase followed by one with a phase reversal to occur anywhere else except at the beginning of one of the 18 mini-probe sequences. Once this fixed 8 mini-probe pattern is located, the 0 or 180 degree phase ambiguity is also resolved so that the following 9 mini-probes can be properly matched to the data rate, interleaver length, and mini-probe set count. The entire mini-probe sequence shall therefore be as follows: [rp] - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 + - - - - - - - + S0 S1 S2 S3 S4 S5 S6 S7 S8 [rp] where the [rp] represents the 103 reinserted preamble symbols (includes mini-probes 72 and 0).	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
97	C.5.3	Coding and interleaving. The interleaver used shall be a block interleaver. Each block of input data shall also be encoded using a block encoding technique with a code block size equal to the size of the block interleaver. Thus, the input data bits will be sent as successive blocks of bits that span the duration of the interleaver length selected. Table C-14 shows the number of input data bits per block as function of both data rate and interleaver length. Note that an "input data block" should not be confused with the 256-symbol data block that is part of a data frame in the waveform format. The bits from an input data block will be mapped through the coding and interleaving to the number of data frames, and thus 256 symbol data blocks, that define the interleaver length.	8
98	C.5.3.1	Block boundary alignment. Each code block shall be interleaved within a single interleaver block of the same size. The boundaries of these blocks shall be aligned such that the beginning of the first data frame following each reinserted preamble shall coincide with an interleaver boundary. Thus for an interleaver length of 3 frames, the first three data frames following a reinserted preamble will contain all of the encoded bits for a single input data block. The first data symbol from the first data frame in each interleaver set shall have as its MSB the first bit fetched from the interleaver. This is no different from what would normally be expected, but is a requirement.	8
99	C.5.3.2	Block encoding. The full-tail-biting and puncturing techniques shall be used with a rate 1/2 convolutional code to produce a rate 3/4-block code that is the same length as the interleaver.	8
100	C.5.3.2.1	Rate 1/2 convolutional code. A constraint length 7, rate 1/2 convolutional code shall be used prior to puncturing. This shall be the same code as is used in the single-tone waveform described in section 5.3.2 of this standard. Figure C-7 is a pictorial representation of the encoder. The two summing nodes in the figure represent modulo 2 addition. For each bit input to the encoder, two bits are taken from the encoder, with the upper output bit, T1(x), taken first.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
101	C.5.3.2.2	Full-tail-biting encoding. To begin encoding each block of input data, the encoder shall be preloaded by shifting in the first six input data bits without taking any output bits. These six input bits shall be temporarily saved so that they can be used to “flush” the encoder. The first two coded output bits shall be taken after the seventh bit has been shifted in, and shall be defined to be the first two bits of the resulting block code. After the last input data bit has been encoded, the first six “saved” data bits shall be encoded. Note that the encoder shift register should not be changed before encoding these saved bits; i.e., it should be filled with the last seven input data bits. The six “saved” data bits are encoded by shifting them into the encoder one at a time, beginning with the earliest of the six. The encoding thus continues by taking the two resulting coded output bits as each of the saved six bits is shifted in. These encoded bits shall be the final bits of the resulting (unpunctured) block code. Prior to puncturing, the resulting block code will have exactly twice as many bits as the input information bits. Puncturing of the rate 1/2 code to the required rate 3/4 shall be done prior to sending bits to the interleaver.	8
101	C.5.3.2.2 (continued)	Puncturing to rate 3/4. In order to obtain a rate 3/4 code from the rate 1/2 code used, the output of the encoder must be punctured by not transmitting 1 bit out of every 3. Puncturing shall be performed by using a puncturing mask of 1 1 1 0 0 1, applied to the bits output from the encoder. In this notation a 1 indicates that the bit is retained and a 0 indicates that the bit is not transmitted. For an encoder generated sequence of T1(k), T2(k), T1(k+1), T2(k+1), T1(k+2), T2(k+2) . . . the transmitted sequence shall be: T1(k), T2(k), T1(k+1), T2(k+2) . . . Defining T1(0), T2(0) to be the first two bits of the block code generated as defined in paragraph C.5.3.2, then the value of k in the above sequences shall be an integral multiple of 3. The block code shall be punctured in this manner before being input to the interleaver.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	C.5.3.3	Block interleaver structure. The block interleaver used is designed to separate neighboring bits in the punctured block code as far as possible over the span of the interleaver with the largest separations resulting for the bits that were originally closest to each other. Because of the 30 different combinations of data rates and interleaver lengths, a more flexible interleaver structure than used for the single-tone waveform described in section 5.3.2 of this standard is needed. The structure to be used is actually simpler than that used previously.	
	C.5.3.3.1	Interleaver size in bits. The interleaver shall consist of a single dimension array, numbered from 0 to its size in bits –1. The array size shall depend on both the data rate and interleaver length selected as shown in table C-15.	
102	C.5.3.3.2	Interleaver load. The punctured block code bits shall be loaded into the interleaver array beginning with location 0. The location for loading each successive bit shall be obtained from the previous location by incrementing by the "Interleaver Increment Value" specified in table C-16, modulo the "Interleaver Size in Bits." Defining the first punctured block code bit to be B(0), then the load location for B(n) is given by: Load Location = (n * Interleaver Increment Value) Modulo (Interleaver Size in Bits) Thus for 3200 bps, with a one frame interleaver (512 bit size with an increment of 97), the first 8 interleaver load locations are: 0, 97, 194, 291, 388, 485, 70, and 167.	8
102	C.5.3.3.2 (continued)	These increment values have been chosen to ensure that the combined cycles of puncturing and assignment of bit positions in each symbol for the specific constellation being used is the same as if there had been no interleaving. This is important, because each symbol of a constellation contains "strong" and "weak" bit positions, except for the lowest data rate. Bit position refers to the location of the bit, ranging from MSB to LSB, in the symbol mapping. A strong bit position is one that has a large average distance between all the constellation points where the bit is a 0 and the closest point where it is a 1. Typically, the MSB is a strong bit and the LSB a weak bit. An interleaving strategy that did not evenly distribute these bits in the way they occur without interleaving could degrade performance.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
103	C.5.3.3.3	Interleaver fetch. The fetching sequence for all data rates and interleaver lengths shall start location 0 of the interleaver array and increment the fetch location with by 1. This is a simple linear fetch from beginning to end of the interleaver array.	8
	C.5.4	Operational features and message protocols. The format of this high-rate waveform has been designed to permit it to work well with most of the protocols used and planned for use with HF. The reinserted preamble facilitates acquisition (or re-acquisition) of an ongoing broadcast transmission. The short length of the synchronization preamble, wide range of interleaving lengths, and the use of full-tail-biting coding is intended to provide efficient operation with ARQ protocols. To further enhance the operation with these protocols, the following operational features shall be included in the HF modem.	
	C.5.4.1	User interfaces.	
104	C.5.4.1.1	Conventional asynchronous interface. The modem shall be capable of interfacing with an asynchronous DTE. In this case the DTE provides (accepts) asynchronous Words consisting of a Start Bit, an N bit Character, and some minimum number of Stop Bits. Additional Stop Bits are provided (accepted) by the DTE between Words as necessary to accommodate gaps between their occurrences. Interoperability shall be provided for those cases where the value of N, the number of Bits in the Character, is 5, 6, 7, or 8 (including any parity bits), and the minimum number of Stop Bits is 1 or 2. Hence, interoperability is defined for those cases where the number of Bits in the Word is N+2 and N+3. In these cases the entire N+2 or N+3 bits of the Word shall be conveyed contiguously in the modulated signal. Additional Stop Bits shall be conveyed as necessary to accommodate gaps in data from the DTE; there shall be no modem-defined null character incorporated into the modulated signal.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
105	C.5.4.1.2	High-speed asynchronous user interface with flow control. Certain high-speed user interfaces provide data to (and accept data from) the modem in units of 8 bit bytes. Furthermore, the Input Data Blocks shown in table C-14 are all multiples of 8 bit bytes. An optional mode shall be provided to accommodate the special case of an 8-bit character (which includes any parity check bits) and a 1.0 unit interval Stop Bit. In this optional mode, the 8-bit character shall be aligned with the 256-symbol modem frame boundary, and no Start or Stop Bits shall be transmitted. In this mode of operation, it is assumed that the DTE data rate is greater than that which can be accommodated by the modem. Consequently, flow control shall be used to temporarily stop data flow from the DTE to the modem when the modem's input buffer becomes full. Conversely, when the modem's input buffer becomes empty, the modem shall assume that the DTE has finished its message, and the modem shall initiate its normal message-termination procedure. This method of operation obviates the need for the transmission of Null characters for the purpose of "rate padding." Consequently, no Null characters shall be transmitted for this purpose.	8
	C.5.4.1.3	Ethernet interface. The modem shall provide an Ethernet interface (see 0) for byte oriented user data transfers (see C.5.4.1.2), and these bytes shall be aligned with the Input Data Block boundaries.	
106	C.5.4.2	Onset of transmission. The modem shall begin a transmission no later than 100 msec after it has received an entire input data block (enough bits to fill a coded and interleaved block), or upon receipt of the last input data bit, whichever occurs first. The latter would only occur when the message is shorter than one interleaver block. A transmission shall be defined as beginning with the keying of the radio, followed by the output of the preamble waveform after the configured pre-key delay, if any. The delay between when the modem receives the first input data bit and the onset of transmission will be highly dependent on the means for delivery of the input data bits to the modem. A synchronous serial interface at the user data rate will have the greatest delay. For this reason it is recommended that a high-speed asynchronous interface (serial or Ethernet port) with flow-control be used if this delay is of concern for the deployed application.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
107	C.5.4.3	End-of-message. The use of an end-of-message (EOM) in the transmit waveform shall be a configurable option. When the use of an EOM has been selected, a 32-bit EOM pattern shall be appended after the last input data bit of the message. The EOM, expressed in hexadecimal notation is 4B65A5B2, where the left most bit is sent first. If the last bit of the EOM does not fill out an input data block, the remaining bits in the input data block shall be set to zero before encoding and interleaving the block. If the use of an EOM has been inhibited, and the last input data bit does not fill out an input data block, the remaining bits in the input data block shall be set to zero before encoding and interleaving the block. It is anticipated that the use of an EOM will only be inhibited when an ARQ data protocol uses ARQ blocks that completely fill (or nearly so) the selected input data block size (interleaver block). Without this feature, the use of an EOM would require the transmission of an additional interleaver block under these circumstances.	8
108	C.5.4.4	Termination of a transmission. Upon receipt of a radio silence (or equivalent) command, the modem shall immediately un-key the radio and terminate its transmit waveform. In normal operation, the modem shall terminate a transmission only after the transmission of the final data frame, including a mini-probe, associated with the final interleaver block. Note that a data frame consists of a 256-symbol data block followed by a mini-probe. Note that any signal processing and/or filter delays in the modem and the HF transmitter must be accounted for (as part of the key line control timing) to ensure that the entire final mini-probe is transmitted before the transmitter power is turned off.	8
	C.5.4.5	Termination of receive data processing. There are a number of events that shall cause the HF modem to cease processing the received signal to recover data, and return to the acquisition mode. These are necessary because a modem is not able to acquire a new transmission while it is attempting to demodulate and decode data.	
109	C.5.4.5.1	Detection of EOM. The HF modem shall always scan all of the decoded bits for the 32-bit EOM pattern defined in paragraph C.5.4.3. Upon detection of the EOM the modem shall return to the acquisition mode. The modem shall continue to deliver decoded bits to the user (DTE) until the final bit immediately preceding the EOM has been delivered.	8
110	C.5.4.5.2	Command to return to acquisition. Upon receipt of a command to terminate reception, the HF modem shall return to the acquisition mode and terminate the delivery of decoded bits to the user (DTE).	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	C.5.4.5.3	Receipt of a specified number of data blocks. The maximum message duration measured in number of Input Data Blocks (interleaver blocks) shall be a configurable parameter. One value of this parameter shall specify that an unlimited number may be received. Once the modem has decoded and delivered to the user (DTE), the number of bits corresponding to the configured maximum message duration, the HF modem shall return to the acquisition mode and terminate the delivery of decoded bits to the user (DTE). Note that for a given interleaver length, this parameter also specifies the maximum message duration in time, independent of the bit rate. Note that this parameter is the maximum duration and that the transmit end always has the option of using an EOM for shorter transmissions. Operation with a specified number of input data blocks may be used by an ARQ protocol where the size of the ARQ packet is fixed, or occasionally changed to accommodate changing propagation conditions. In this case, we anticipate that this parameter (maximum message duration) will be sent to the receiving end of the link as part of the ARQ protocol. It would then be sent to the receiving modem through the remote control interface (see C.5.4.6 below), since it is not embedded in the waveform itself as the data rate and interleaver length parameters are.	
111	C.5.4.5.4	Initiation of a transmission. If, and only if, the HF Modem is configured to operate in half-duplex mode with transmit override, the initiation of a transmission by the user (DTE) shall cause the HF modem to terminate the receive processing and the delivery of decoded bits to the user (DTE).	8
112	C.5.4.6	Remote control. The remote control interface (see section 5.3.1.5) shall provide the capability to specify the following parameters and commands: a. High-rate waveform parameters: The 5 data rates for the high-rate waveform The 6 interleaver lengths for the high-rate waveform b. A command to select the usage of the optional EOM in the transmit waveform. Note that the receiving modem must always scan for the EOM regardless of this setting. c. A command to specify the maximum message duration measured in number of Input Data Blocks (interleaver blocks). The value of 0 (zero) for this parameter shall specify that an unlimited number may be received. d. A command to cause the modem to terminate receive data processing and return to acquisition mode.	8

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	C.6	Performance.	
113	C.6.1	BER performance. The measured performance of the high data rate mode, using fixed-frequency operation and employing the maximum interleaving period (the 72-frame "Very Long" interleaver), shall achieve coded BER of no more than 1.0E-5 under each of the conditions listed in table C-17. Performance shall be tested using a baseband HF simulator patterned after the Watterson Model in accordance with ITU-R 520-2. The AWGN channel shall consist of a single, non-fading path. Each condition shall be measured for at least 60 minutes. The ITU-R Poor channel shall consist of two independent but equal average power Rayleigh fading paths, with a fixed 2-msec delay between paths, and with a fading (two sigma) bandwidth (BW) of 1 Hz. Each condition shall be measured for at least 5 hours. Both signal and noise power shall be measured in a 3-kHz bandwidth. Note that the average power of QAM symbols is different from that of the 8-PSK mini-probes and reinserted preambles; the measured signal power shall be the long-term average of user data, mini-probe, and reinserted preamble symbols.	8
114	C.6.3	Doppler shift test. The modem shall acquire and maintain synchronization for at least 5 minutes with a test signal having the following characteristics: 9600-bps/Very Long interleaver, 75-Hz frequency offset, 2-msec delay spread, a fading BW of 1 Hz, and an average SNR of 30 dB. The test shall be repeated with a –75-Hz frequency offset. No BER test is required.	8
115	C.6.4	Doppler sweep performance. The AWGN BER test at 9600 bps from table C-17 shall be repeated with a test signal having a frequency offset that continuously varies at a rate of 3.5 Hz/s between the limits of -75 and +75 Hz, such that a plot of frequency offset vs. time describes a periodic "triangle" waveform having a period of (300/3.5) seconds. Over a test duration of 1 hour, the modem shall achieve a BER of 1.0E-5 or less at an SNR of 24 dB.	8
	C.7	Associated Communications Equipment. The QAM constellations specified in this appendix are more sensitive to equipment variations than the PSK constellations specified in section 5.3.2 of this standard. Because of this sensitivity, radio filters will have a significant impact on the performance of modems implementing the waveforms in this appendix. In addition, because of the level sensitive nature of the QAM constellations, turn-on transients, AGC, and ALC can cause significant performance degradation.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	C.7	It is recommended that modems implementing the waveforms in this appendix should include a variable pre-key feature, by which the user can specify a delay between the time when the transmitter is keyed and the modem signal begins. This allows for turn-on transient settling, which is particularly important for legacy radio equipment. It is recommended that a slow AGC setting (e.g., the "non-data" mode in MIL-STD-188-141) be used when receiving the HDR waveforms in this appendix.	
	Appendix D	Subnetwork Interface (optional)	
	D.1	General.	
	D.1.1	Scope. This appendix describes the optional subnetwork interface to be provided by data modems.	
	D.1.2	Applicability. This appendix is a non-mandatory part of MIL-STD-188-110B; however, when the optional subnetwork interface is provided, it shall be implemented in accordance with this appendix.	
	D.2	Applicable documents. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents that are DOD adopted are those listed in the issues of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2).	
	D.3	Definitions. See section 3.	
	D.4	General Requirements.	
	D.4.1	Introduction. The subnetwork interface for MIL-STD-188-110B is an extended version of that specified in STANAG 5066, annex A.	
	D.4.2	Primitives. The primitives to be provided are listed in table D-1.	
	Appendix E	Data Link Protocol (optional).	
	E.1	General.	
	E.1.1	Scope. This appendix describes the optional data link protocol to be used with data modems.	
	E.1.2	Applicability. This appendix is a non-mandatory part of MIL-STD-188-110B; however, when the optional data link protocol is provided, it shall be implemented in accordance with this appendix.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	E.2	Applicable documents. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents that are DOD adopted are those listed in the issues of the DODISS cited in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS are the issues of the documents cited in the solicitation (see 6.2). North Atlantic Treaty Organization (NATO) Standardization Agreements (STANAG) 5066 - Profile for High Frequency (HF) Radio Data Communications.	
	E.3	Definitions. See section 3.	
	E.4	General requirements.	
	E.4.1	Introduction. The optional data link protocol is adapted from STANAG 5066.	
	E.4.2	Channel access protocol. The channel access protocol is specified in STANAG 5066, annex B.	
	E.4.3	Data transfer protocol. The data transfer protocol is specified in STANAG 5066, annex C.	
	Appendix F	HF Data Modems for Multiple Channel Systems (optional).	
	F.1	General.	
	F.1.1	Scope. This appendix describes HF data modem operation over multiple discrete channels (including independent sidebands of a single carrier), and specifies a waveform that supports data rates of 9600 to 19,200 bps over two-independent-sideband (2-ISB) radios using the waveforms from appendix C.	
	F.1.2	Applicability. This appendix is a nonmandatory part of MIL-STD-188-110B; however, systems using HF data modem waveforms on multiple discrete channels shall operate in accordance with this appendix.	
	F.2	Applicable documents. This section is not applicable to this appendix.	
	F.3	Definitions. See section 3.	
	F.4	General requirements. The use of multiple HF channels in parallel can provide data throughput greater than the use of a single sideband channel. Section F.4.1 describes a range of architectures for multiple channel operation that may be useful in specific applications. Section F.4.2 describes an independent sideband (ISB) modem waveform that may be used in any of these architectures.	
	F.4.1	Architecture for multiple channel operation.	

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
	F.4.1.1	Multiple channel operation with independent-sideband modem. When ISB radios and channel allocations are available, the channels provided by the radio inherently have similar channel characteristics, and can support similar data rates. A modem that spreads coded symbols over the available channels takes full advantage of this capability. Such a modem is shown in figure F-1 (with optional link-level encryption). The two-channel ISB (2-ISB) modem specified in section F.4.2 and F.5 is the mandatory portion of this appendix. The ISB capability is currently limited to two channels per modem. Four-channel radios support two such 2-ISB modems using either of the techniques described in the following sections.	
116	F.4.1.2	Multiple channel operation with multiple modems. (Optional) When ISB radios and channel allocations are available, but ISB modems with a matching number of audio channels are not available, multiple modems may be employed as shown in figure F-2. The upper diagram illustrates the case of unencrypted user data and link-level encryption (as in the previous section). The lower diagram depicts application-layer (end-to-end) encryption. The first bit of data to be sent shall be delivered to the modem associated with the highest over-the-air frequency, with succeeding bits delivered to modems with decreasing frequencies. When M modems are attached to a single ISB radio (M = 2 shown), all modems shall operate at a single data rate, and modem i (i = 0 .. M - 1) shall carry bits numbered $i + nM$ (n = 0, 1,…). This architecture also may be applied to multiple radios operating on unrelated frequencies. However, performance may not be satisfactory if the characteristics of the various channels are not sufficiently similar to support a common maximum data rate. Bit ordering shall be as specified above, with the identity of the modem associated with the highest over-the-air frequency determined when the link is initially established, regardless of subsequent frequency changes while linked.	9

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
116	F.4.1.2 (continued)	In the bit-synchronous approach described above, it is understood that the multiplexer and modems share a common clock. In addition, the multiplexer provides a short synchronization header in the bit stream to each modem prior to the payload data. Note that this header is transparent to the ARQ or other modem-user process. The header is used by the multiplexer at the receive end to establish bit-order integrity. This header is required since a bit-synchronous Tx modem interface does not generally guarantee that the first bit out of the receiving modem is the first bit out of the transmitting DTE following assertion of CTS. Alternatively, the High Speed Asynchronous Interface with Flow Control that is described in section C.5.4.1 may be used. In this case, data to successive modems from the multiplexer will be successive bytes rather than successive bits.	9
	F.4.1.3	Multiple channel operation with parallel ARQ channels. (Optional) The architecture shown in figure F-3 accommodates any combination of radios and modems for multiple-channel operation. As above, the upper diagram illustrates link-level encryption while the lower diagram depicts application-layer (end-to-end) encryption. A traffic manager process dynamically assigns packets to a separate ARQ protocol process associated with each modem. Each ARQ process adapts its modem's data rate to the channel conditions it encounters; the traffic manager likewise adapts the rate that it assigns packets to the ARQ processes based on their completion rates. Message reassembly relies on packet offset fields in the packet headers.	
117	F.4.2	HF data modem waveform for two-independent-sideband applications. This appendix presents a modem waveform and coding specification for data transmission over two HF sidebands for data rates from 9.6 up to 19.2 kbps. As in appendix C, a block interleaver is used to obtain 6 interleaving lengths ranging from 0.12 s to 8.64 s. The waveforms in this appendix have been designed to be compatible with the appendix C waveforms, and use identical preamble processing with the exception that these waveforms employ settings for specifying data rate and interleaver that are reserved in appendix C.	9

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
117	F.4.2	Data rate and interleaver settings are explicitly transmitted as a part of the waveform, both as part of the initial preamble and then periodically as a reinserted preamble and in the periodic known symbol blocks (“mini-probes”). This “auto baud” feature is critical in developing an efficient (ARQ) protocol for high frequency (HF) channels. The receive modem is required to be able to deduce the data rate and interleaver setting from either the preamble or the subsequent data portion of the waveform. A block diagram of the 2-ISB modem with 2-ISB radios is shown in figure F-4. In all applications of this modem, the quasi-analog signal designated Channel 0 shall be connected to the radio equipment so that the sideband that it produces is higher in frequency than the sideband produced by the quasi-analog signal designated Channel 1. In particular, with 2-ISB radios Channel 0 shall use the upper sideband and Channel 1 shall use the lower sideband.	9
	F.5	Detailed requirements.	
118	F.5.1	Modulation. Each of the channels shall be modulated independently. The modulation of each of the channels is identical, with a few specified exceptions, to that specified in appendix C for the high data rate single sideband option. The transmit data clock for both of the channels shall be synchronized so that there is no drift in the relative clocks for each of the channels. The power spectral density of each modulator output signal should be constrained to be at least 20 dB below the signal level measured at 1800 Hz, when tested outside of the band from 200 Hz to 3400 Hz. The filter employed shall result in a ripple of no more than ±2 dB in the range from 800 Hz to 2800 Hz.	9
119	F.5.1.1	Known symbols. For all known symbols, the modulation used shall be PSK, with the symbol mapping shown in table C-1 and figure C-1. No scrambling shall be applied to the known symbols.	9
	F.5.1.2	Data symbols. For data symbols, the modulation used depends upon the data rate as shown in table F-1.	
	F.5.1.2.1	PSK data symbols. For the PSK constellations, a distinction is made between the data bits and the symbol number. Trans-coding is an operation which links a symbol to be transmitted to a group of data bits.	
120	F.5.1.2.1.1	QPSK symbol mapping. For QPSK symbols, used in the preamble and reinserted preamble to specify data rate and interleaving, trans-coding shall be achieved by linking one of the symbols specified in table C-1 to a set of two consecutive data bits (dibit) as shown in table C-3. In this table, the leftmost bit of the dibit shall be the older bit; i.e., fetched from the interleaver before the rightmost bit.	9

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
121	F.5.1.2.1.2	8-PSK symbol mapping. For the 9600-bps user data rate, trans-coding shall be achieved by linking one symbol to a set of three consecutive data bits (tribit) as shown in table C-4. In this table, the leftmost bit of the tribit shall be the oldest bit; i.e., fetched from the interleaver before the other two, and the rightmost bit is the most recent bit.	9
122	F.5.1.2.2	QAM data symbols. For the QAM constellations, no distinction is made between the number formed directly from the data bits and the symbol number. Each set of 4 bits (16-QAM), 5 bits (32-QAM) or 6 bits (64-QAM) is mapped directly to a QAM symbol. For example, the four-bit grouping 0111 would map to symbol 7 in the 16-QAM constellation while the 6 bit grouping 100011 would map to symbol 35 in the 64-QAM constellation. Again, in each case the leftmost bit shall be the oldest bit, i.e. fetched from the interleaver before the other bits, and the rightmost bit is the most recent bit.	9
	F.5.1.2.2.1	The 16 QAM constellation. See figure C-2 and table C-5.	
	F.5.1.2.2.2	The 32 QAM constellation. See figure C-3 and table C-6.	
	F.5.1.2.2.3	The 64 QAM constellation. See figure C-4 and table C-7.	
123	F.5.1.3	Data scrambling. Data symbols for the 8-PSK symbol constellation shall be scrambled by modulo 8 addition with a scrambling sequence. The data symbols for the 16-QAM, 32-QAM, and 64-QAM constellations shall be scrambled by using an Exclusive OR (XOR) operation. Sequentially, the data bits forming each symbol (4 for 16-QAM, 5 for 32-QAM, and 6 for 64-QAM) shall be XOR'd with an equal number of bits from the scrambling sequence. In all cases, the scrambling sequence generator polynomial shall be $x^9 + x^4 + 1$ and the generator shall be initialized to 1 at the start of each data frame. A block diagram of the scrambling sequence generator is shown in figure C-5. Further details of the operation of the data scrambler may be found in C.5.1.3	9
124	F.5.2	Frame structure. The frame structure shall be as described in C.5.2 except that the data symbols D0, D1, and D2 (used in the preambles and encoded in the mini-probes) take on values distinct from those used for the appendix C SSB modes. For the two-sideband option, the three-bits used for data rate in SSB are fixed at 000. The bits normally used for interleaver setting in SSB are employed as specified in table F-2, using both channels, to select data rate and interleaver settings. Channel 0 carries the code for the combined data rate and Channel 1 carries the code for the common interleaver. Recall that channel 0 is always the lower of the two sidebands. Unused codings are reserved and shall not be used until standardized.	9

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
125	F.5.3	Coding and interleaving. The interleaver used shall be a block interleaver. Each block of input data shall be encoded using a block encoding technique with a code block size equal to the size of the block interleaver. Thus, the input data bits will be sent as successive blocks of bits on both channels that together span the duration of the interleaver length selected. Table F-3 shows the number of input data bits per block as function of both data rate and interleaver length. Note that an “input data block” should not be confused with the 256-symbol data block that is part of a data frame in the waveform format. The bits from an input data block will be mapped through the coding and interleaving to the number of data frames, and thus 256-symbol data blocks, that define the interleaver length.	9
126	F.5.3.1	Block boundary alignment. Each code block shall be interleaved within a single interleaver block of the same size. The boundaries of these blocks shall be aligned such that the beginning of the first data frame following each reinserted preamble shall coincide with an interleaver boundary. Thus for an interleaver length of 3 frames, the first three data frames following a reinserted preamble will contain all of the encoded bits for a single input data block. The first data symbol from the first data frame in each interleaver set shall have as its MSB the first bit fetched from the interleaver. This is no different from what would normally be expected, but is a requirement.	9
	F.5.3.2	Block encoding. See C.5.3.2.	
	F.5.3.3	Block interleaver structure. The block interleaver used is designed to separate neighboring bits in the punctured block code as far as possible over the span of the interleaver with the largest separations resulting for the bits that were originally closest to each other.	
127	F.5.3.3.1	Interleaver size in bits. The interleaver shall consist of a single dimension array, numbered from 0 to its size in bits – 1. The array size shall depend on both the data rate and interleaver length selected as shown in table F-4.	9
128	F.5.3.3.2	Interleaver load. The punctured block code bits shall be loaded into the interleaver array beginning with location 0. The location for loading each successive bit shall be obtained from the previous location by incrementing by the interleaver increment value “Inc” specified in table F-4, modulo the interleaver size in bits, “Size.” Defining the first punctured block code bit to be B(0), then the load location for B(n) is given by: Load Location = (n * Inc) modulo (Size)	9

Table B-1. MIL-STD-188-110B Requirements Matrix (continued)

Reference Number	MIL-STD Paragraph	Requirements	Subtest Number
129	F.5.3.3.3	Interleaver fetch. The fetching sequence for all data rates and interleaver lengths shall start with location 0 of the interleaver array and increment the fetch location by 1. The first bit fetched from the interleaver shall be sent to the symbol formation module for channel 0, the second bit fetched shall be sent to the symbol formation module for channel 1, and this pattern shall continue until all bits have been fetched from the interleaver. This is a linear fetch from beginning to end of the interleaver array with even numbered bits delivered to channel 0 and odd numbered bits to channel 1.	9
	F.5.4	Operational features and message protocols.	
	F.6	Performance. The performance requirements of the 2-ISB mode have not yet been established.	
	F.7	Associated communications equipment. See C.7.	

LEGEND:

ABCA – American, British, Canadian, Australian
AGC – Automatic Gain Control
ALE – Automatic Link Establishment
ANDVT – Advanced Narrowband Digital Voice Terminal
API – Application Programming Interface
ARQ – Automatic Repeat Request
AWGN – Additive White Gaussian Noise
Bd – baud
BER – Bit Error Rate
bps – bits per second
BW – Bandwidth
CTS – Clear-to-Send
dB – decibels
dBm – decibels referenced to 1 milliwatt
dBm0 – decibels referenced to zero transmission level point
DISAC – Defense Information Systems Agency Circular
DO – Design Objective
DODISS – Department of Defense Index of Specifications and Standards
DPSK – Differential Phase-Shift Keying
DSN – Digital Switched Network
DTE – Data Terminal Equipment
EIA – Electronic Industries Association
EOM – End-of-Message
FCC – Federal Communications Commission
FEC – Forward Error Correction; -
FED-STD – Federal Standard
FIPS PUB – Federal Information Processing Standard Publication
FSK – Frequency Shift Keying
GF – Galois Field
HDR – Header
HF – High Frequency
Hz – hertz
ISB – Independent Sideband
ITU – International Telecommunications Union
ITU-R – International Telecommunications Union Recommendation
kHz – kilohertz
LAN – Local Area Network
LF – Low Frequency
LSB – Least Significant Bits
MF – Medium Frequency
MGD – Modified-Gray Decoder
MIL-STD – Military Standard
MSB – Most Significant Bits

msec – milliseconds
NATO – North Atlantic Treaty Organization
PSK – Phase-Shift Keying
PSN – Public Switched Network
PTT – Push-to-Talk
PVC – Polyvinyl Chloride
QAM – Quadrature Amplitude Modulation
QDPSK – Quadrature Differential Phase-Shift Keying
QPSK – Quadrature Phase-Shift Keying
QSTAG – Quadripartite Standardization Agreement
RATT – Radio Teletypewriter System
rms – root-mean-square
RTS – Request-to-Send
s – second
SNR – Signal-to-Noise Ratio
SSB – Single Sideband
STANAG – Standardization Agreement
Sync – Synchronization
TIA – Telecommunications Industries Association
TLP – Transmission Level Point
UHF – Ultra High Frequency
VF – Voice Frequency
XOR – Exclusive OR

APPENDIX C

DATA COLLECTION FORMS

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MIL-STD-188-110B
CONFORMANCE TEST
Event Log Form

CONTROL NUMBER:

DATE:

(DD/MM/YY)

Form Number	Serial Number	Equipment Nomenclature	Call Sign	Remarks

DATA ENTRY TECHNICIAN:

TEST DIRECTOR:

SIGNATURE:

SIGNATURE:

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MIL-STD-188-110B
CONFORMANCE TEST
Equipment Configuration Diagram Form

CONTROL NUMBER:

DATE:
(DD/MM/YY)

TEST TECHNICIAN:	
DATA ENTRY TECHNICIAN:	TEST DIRECTOR:

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MIL-STD-188-110B
CONFORMANCE TEST
Event Log Form

CONTROL NUMBER:

DATE:
(DD/MM/YY)

Time (Local)	Initials	Event

TEST TECHNICIAN:	
DATA ENTRY TECHNICIAN:	TEST DIRECTOR:

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MIL-STD-188-110B **Waveform Conformance** **Test Plan Form**	CONTROL NUMBER:
	DATE: (DD/MM/YY)

Equipment:	Serial Number:

Description:

Remarks

TEST TECHNICIAN:	
DATA ENTRY TECHNICIAN:	TEST DIRECTOR:

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MIL-STD-188-110B CONFORMANCE TEST Additional Remarks Form	CONTROL NUMBER:
	DATE: (DD/MM/YY)

Remarks

TEST TECHNICIAN:	
DATA ENTRY TECHNICIAN:	TEST DIRECTOR:

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MIL-STD-188-110B CONFORMANCE TEST **Electrical Characteristics of Digital Interfaces**	**Control Number:**

DATE: __/__/__ TIME: _______
(MM / DD / YY) (LOCAL)

Data Collection Method: ☐ **Manual** ☐ **Automatic**

Unbalanced Interface

Binary State	V_o	V_t	I_s	I_x
ZERO				
ONE				

Balanced Interface

Binary State	$V_o \mid V_{os} \mid V_{ob}$	$V_t \mid V_{os}$	$I_{sa} \mid I_{sb}$	$I_{xa} \mid I_{xb}$
ZERO				
ONE				

Remarks

Authentication

Data Collector Name:	**Signature:**
Data Entry Name:	**Signature:**
Data Verification Name:	**Signature:**

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APPENDIX D

MATLAB CODE

D-1. 16-tone preamble.m

```
% This algorithm shows the (frequency domain) magnitude of an input .wav
% file sampled at 8 kHz.  It is used to observe the preamble for the 16-tone waveform.

Fs = 8000; % declare sample rate
[wave]=wavread('a:16-tone.wav'); % read 16-tone .wav file; sampled at 8 kHz

f=linspace(0,Fs*(1-1/32768),32768); % declare frequency vector

% The value of 'i' below corresponds to the duration of the preamble.
%  i = 1:5 implies that the preamble lasts for 5 data tone signal elements.

for i = 1:5

   symbol_number = i;
   wavex = wave((symbol_number.*106):(symbol_number.*106)+105);
   wavefft=abs(fft(wavex,65536));
   wavefft=wavefft(1:32768); % remove fft image

   plot(f,wavefft);
   hold on

end
hold off
```

D-2. 39-tone (preamble 1 and 2).m

```
% This algorithm shows the (frequency domain) magnitude of an input .wav
% file sampled at 8 kHz.  It is used to observe the first and second part
% of the preamble for the 39-tone waveform.  This algorithm cannot be used to
% view the third part of the preamble because of "frequency spill-over" between tones.


Fs = 8000; % declare sample rate
[wave]=wavread('a:wave.wav'); % read 39-tone .wav file; sampled at 8 kHz

f=linspace(0,Fs*(1-1/32768),32768); % declare frequency vector

% The value of 'i' below must be modified for each part of the preamble:
% Part 1:  set i = 1:14
% Part 2:  set i = 15:22
% Extended preamble part 1:  set i = 1:58
```

```
% Extended preamble part 2:  set i = 59:85

for i = 59:85

   symbol_number = i;
   wavex = wave((symbol_number.*180):(symbol_number.*180)+179);
   wavefft=abs(fft(wavex,65536));
   wavefft=wavefft(1:32768); % remove fft image

   plot(f,wavefft);
   hold on

end
hold off
```

D-3. 39-tone (preamble 3).m

```
% This algorithm shows the (frequency domain) magnitude of an input .wav
% file sampled at 8 kHz.  It is used to observe the first and second part
% of the preamble for the 39-tone waveform.  This algorithm cannot be used to
% view the third part of the preamble because of “frequency spill-over” between tones.


Fs = 8000; % declare sample rate
[wave]=wavread(‘a:wave.wav’); % read 39-tone .wav file; sampled at 8 kHz

f=linspace(0,Fs*(1-1/32768),32768); % declare frequency vector

% The value of ‘i’ below must be modified for each part of the preamble:
% Part 1:  set i = 1:14
% Part 2:  set i = 15:22
% Extended preamble part 1:  set i = 1:58
% Extended preamble part 2:  set i = 59:85

for i = 86:97

   symbol_number = i;
   wavex = wave((symbol_number.*180):(symbol_number.*180)+179);
   wavefft=angle(fft(wavex,65536));
   wavefft=wavefft(1:32768); % remove fft image

   plot(f,wavefft);
   hold on

end
hold off
```

D-4. 39-tone (phase-shift decode).m

```
% This algorithm measures the phase-shift between two adjacent symbols for
% all 39-tones.

[wave]=wavread(‘a:wave.wav’); % read 39-tone .wav file; sampled at 8 kHz
wavere = resample(wave,9,10); % downsample .wav file to 7200 Hz.
Fs = 7200; % declare sample rate

symbol_number = 102; % This is the first symbol number that will be decoded.

wavex = wavere((symbol_number.*162)+17:(symbol_number.*162)+144);
wavex2 = wavere((symbol_number.*162)+179:(symbol_number.*162)+306);

freq=Fs*(0:length(wavex)-1)/length(wavex); % declare frequency vector
wavefft = angle(fft(wavex)); % measure phase angle of fft for (symbol_number)
wavefft2 = angle(fft(wavex2)); % measure phase angle of fft for (symbol_number + 1)

wavefft = wavefft.*(180/pi) + 180; % convert phase angle from radians to degrees
wavefft2 = wavefft2.*(180/pi) + 180; % convert phase angle from radians to degrees

phaseshift = abs(wavefft - wavefft2); % measure phase-shift between two adjacent
symbols
result = phaseshift(13:51) % display phase-shifts for all 39-tones
```

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APPENDIX E

REFERENCES

MILITARY STANDARD (MIL-STD)

MIL-STD-188-110B, “Interoperability and Performance Standards for Data Modems,” 29 March 2000

MIL-STD-188-110A, “Interoperability and Performance Standards for Data Modems,” 30 September 1991

JOINT INTEROPERABILITY TEST COMMAND (JITC) DOCUMENTS

JITC Instruction 380-195-01B, “Test Manual for MIL-STD-188-110B,” June 1995

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