NATO STANDARD

AComP-5069

TECHNICAL STANDARDS FOR WIDEBAND WAVEFORMS FOR SINGLE NON-HOPPING, FLEXIBLE-BANDWIDTH HF CHANNELS

Edition A, Version 1

MARCH 2023

NORTH ATLANTIC TREATY ORGANIZATION

ALLIED COMMUNICATIONS PUBLICATION

Published by the
NATO STANDARDIZATION OFFICE (NSO)

INTENTIONALLY BLANK

NORTH ATLANTIC TREATY ORGANIZATION (NATO)

NATO STANDARDIZATION OFFICE (NSO)

NATO LETTER OF PROMULGATION

17 March 2023

1. The enclosed Allied Communications Publication AComP-5069, Edition A, Version 1, TECHNICAL STANDARDS FOR WIDEBAND WAVEFORMS FOR SINGLE NON-HOPPING, FLEXIBLE-BANDWIDTH HIGH FREQUENCY (HF) CHANNELS, which has been approved by the nations in the C3 Board, is promulgated herewith. The agreement of nations to use this publication is recorded in STANAG 5069.

2. AComP-5069, Edition A, Version 1, is effective upon receipt.

3. This NATO standardization document is issued by NATO. In case of reproduction, NATO is to be acknowledged. NATO does not charge any fee for its standardization documents at any stage, which are not intended to be sold. They can be retrieved from the NATO Standardization Document Database (https://nso.nato.int/nso/) or through your national standardization authorities.

4. This publication shall be handled in accordance with C-M(2002)60.

Dimitrios SIGOULAKIS
Lieutenant General, GRC (A)
Director, NATO Standardization Office

INTENTIONALLY BLANK

RESERVED FOR NATIONAL LETTER OF PROMULGATION

INTENTIONALLY BLANK

RECORD OF RESERVATIONS

CHAPTER	RECORD OF RESERVATION BY NATIONS
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

RECORD OF SPECIFIC RESERVATIONS

[nation]	[detail of reservation]
DEU	STANAG 5069 specifies a waveform that uses a frequency block of Nx3kHz or Mx6kHz for broadband modulation. As far as the german spokesman knows there is currently no frequency availability (operating permit) for such systems in DEU. As far as the german spokesman knows NARFA DEU must first be involved in the process before ratification / implementation can be proposed.
DNK	With the aim to ensure interoperability where required for HF radio modems in channel bandwidths greater than 3 kHz for single non-hopping, flexible-bandwidth HF channels Denmark can ratify future implementation with the reservation that a coordination and allocation of frequencies in the HF band with a bandwidth higher than 3KHz shall be performed prior to implementation
Note: The reservations listed on this page include only those that were recorded at time of promulgation and may not be complete. Refer to the NATO Standardization Document Database for the complete list of existing reservations.	

INTENTIONALLY BLANK

TABLE OF CONTENTS

INTENTIONALLY BLANK

ANNEX A FUNCTIONAL CHARACTERISTICS AND TECHNICAL OVERVIEW OF HF DIGITAL COMMUNICATIONS IN FLEXIBLE-BANDWIDTH CHANNELS

A.1 Introduction

A.1.1 Purpose

This Annex provides an introduction to modem waveforms to ensure interoperability within complying HF radio networks.

This document addresses NATO non-EPM requirements, as illustrated in Figure A.1-1. EPM requirements are addressed in STANAG 4444.

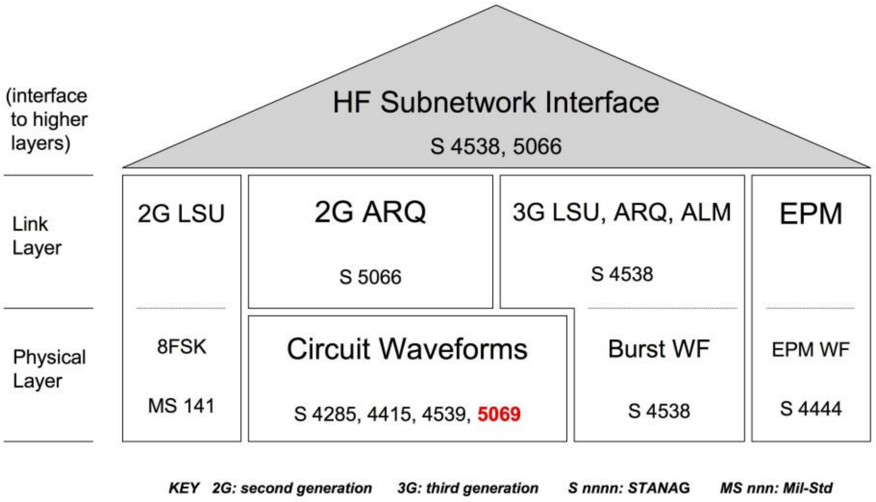

Figure A.1-1: Relationship of STANAG 5069 to the HF House

This document also supports interoperability between the HF House and the U.S. MIL-STD-188-110.

A.1.2 Approach and Structure of Annex A

The system described in STANAG 5069 is designed to satisfy NATO requirements.

This standard reflects the NATO emphasis on the International Standards Organization Open Systems Interconnect (ISO/OSI) model. The system attributes defined in STANAG 5069 are considered to lie within the physical layer of the OSI reference model. The structure of the Annex is as follows.

Section 1 is an introduction.

Section 2 presents an overview of the multi-waveform concept.

Section 3 addresses scalable single-channel waveforms.

Section 4 addresses use of multiple radio channels to carry the information of a single logical channel.

Section 5 addresses necessary characteristics of associated communications equipment.

A.2 Multi-Waveform Concept

The HF House system includes a flexible multi-waveform concept which not only permits the appropriate waveforms (WFs) to be used in a wide variety of propagation/interference conditions but also permits new WFs to be added as advances in communications technology permit.

There are 2 modes of operation, a non-EPM mode and an EPM mode. EPM mode waveforms are specified in STANAG 4444. Waveforms for the non-EPM mode are described in this and other STANAGs.

STANAG 4285 specifies a legacy waveform for data rates up to 3600 bps (without forward error-correction, or FEC, coding), and up to 2400 bps with FEC coding.

STANAG 4415 specifies a very robust 75 bps waveform for use in severely degraded HF channels.

STANAG 4539 Annexes A through C specify waveforms for use in 3-kHz channels that provide data rates ranging from 75 through 9600 bps (with FEC coding).

STANAG 4539 Annexes D through G specify non-hopping waveforms for use in Link 22 systems.

STANAG 4539 Annex H specifies waveforms for use in multiple 3-kHz channels (including non-contiguous channels) that provide data rates up to 153.600 bps (with FEC coding).

This STANAG specifies waveforms for channels of N x 3 kHz, where N ranges from 1 to 8, and M x 6 kHz, where M ranges from 5 to 8.

A.3 Scalable Single-Channel Waveforms

Wideband high-frequency radio (WBHF) modem waveforms and coding specifications for bandwidths of 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 42 and 48 kHz are specified in Annex B of this STANAG. Overall data rates of 75 through 240,000 bps are supported. A block interleaver is used to obtain 4 interleaving lengths ranging from approximately 0.12 s to 10.24 s. Various code rates are implemented based on a constraint length 7 or a constraint length 9 convolutional code.

The waveform data rate, encoder constraint length and interleaver settings are explicitly transmitted as a part of the initial preamble of the waveform. This “autobaud” 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 determine the data rate, encoder constraint length and interleaver setting during the reception of the preamble.

For broadcast applications, the receive modem is required to know the bandwidth, data rate, encoder constraint length and interleaver setting in order to acquire the waveform without the initial preamble.

Four levels of WBHF capability are defined in Annex B:

WBHF Block 1 offers 3-kHz operation only, but with somewhat improved performance over STANAG 4539 3-kHz modems.

WBHF Block 2 offers 3, 6, 9, and 12-kHz waveforms, with constraint length 7 convolutional coding.

WBHF Block 3 includes waveforms up to 24 kHz, with both constraint lengths (7 and 9).

WBHF Block 4 includes waveforms up to 48 kHz, with both constraint lengths (7 and 9).

A.4 Multiple-Channel Operation

Waveforms for operation in multiple contiguous sidebands related to a single suppressed carrier are specified in MIL-STD-188-110.

Waveforms for operation in multiple non-contiguous channels are specified in STANAG 4539 Annex H.

A.5 Associated Communications Equipment

The waveforms in this STANAG are designed to pass through wideband radio channels as specified in MIL-STD-188-141 or STANAG 4203 Annex D.

The Quadrature Amplitude Modulation (QAM) constellations specified in this STANAG are more sensitive to equipment variations than the PSK constellations employed in lower-data-rate modems. Because of this sensitivity, radio filters will have a significant impact on the performance of modems implementing such waveforms. In addition, because of the level sensitive nature of the QAM constellations, turn-on transients, Automatic Gain Control (AGC), and Automatic transmit Level Control (ALC) can cause significant performance degradation.

It is recommended that external modems (i.e., modems not integrated with the radio) implementing the waveforms in this STANAG should include a variable pre-key feature, by which a delay between the time when the transmitter is keyed and the modem signal begins may be specified. 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., “nondata”) be used when receiving the waveforms in this STANAG.

INTENTIONALLY BLANK

ANNEX B TECHNICAL SPECIFICATIONS TO ENSURE INTEROPERABILITY OF SERIAL WAVEFORMS FOR SINGLE NON-HOPPING, FLEXIBLE-BANDWIDTH HF CHANNELS (MANDATORY)

B.1 Introduction

B.1.1 Purpose

This Annex provides a detailed description of modem waveforms to ensure interoperability within complying wideband HF radio networks. A family of self-identifying waveforms is specified for operation single contiguous-bandwidth channels from 3 KHz to 48 KHz, with data rates ranging from 75 bps through 240 kbps.

This STANAG addresses NATO non-EPM requirements. EPM requirements are addressed in STANAG 4444.

This STANAG also supports interoperability between the HF House and the U.S. MIL-STD-188-110C Annex D wideband waveform.

B.1.2 Approach and Structure of Annex B

The system described in STANAG 5069 is designed to satisfy NATO requirements.

This Annex specifies waveforms for general applications, including broadcast and ARQ operation. The structure of the Annex is as follows.

Section 1 is an introduction.
Section 2 addresses standardized capability packages or “blocks.”
Section 3 addresses waveforms for operation in single contiguous channels from 3 to 48 KHz.
Section 4 addresses operational features and message protocols of modems complying with this STANAG.

Performance requirements for these waveforms are specified in Annex C.

B.2 Standardized Capability Packages Or “Blocks”

This Annex standardizes a family of wideband high-frequency radio (WBHF) modem waveforms and coding specifications for bandwidths of 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 42, and 48 kHz. Data rates of 75 through 240,000 bps are supported. A block interleaver is used to obtain 4 interleaving lengths ranging from approximately 0.12 s to 10.24 s. Various code rates are implemented based on a constraint length 7 or a constraint length 9 convolutional code. Various puncturing and repeat coding schemes are utilized to achieve a family of code rates from 1/16 up to 9/10. 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 approximately 120ms, there is no option of zero interleaving, since the time delays would not be reduced.

Four standardized subsets of the above capabilities are defined here, so that users not needing the full range of STANAG 5069 capabilities may procure suitable, interoperable systems. A statement that a systems complies with STANAG 5069 shall indicate which of these blocks of capabilities is provided.

B.2.1 WBHF Block 1 Requirements

A subset of the requirements of this Annex when implemented only for 3 kHz channels is termed the WBHF Block 1 capability. A Block 1 WBHF modem shall implement all of the following:

- Waveforms 0 through 13 for bandwidth of 3 kHz (see Table B.B.3.1.2-1).
- Constraint length 7 convolutional coding
- The operational features and message protocols in Section 4

and shall meet the Performance Requirements of Annex C for those waveforms.

B.2.2 WBHF Block 2 Requirements

The same subset of the requirements, but offered at 3, 6, 9, and 12 kHz, is termed the WBHF Block 2 capability. A Block 2 WBHF modem shall implement all of the following:

- Waveforms 0 through 12 for bandwidth of 3, 6, 9, and 12 kHz, and waveform 13 for 3 kHz only (see Table B.B.3.1.2-1).
- Constraint length 7 convolutional coding
- The operational features and message protocols in Section 4

and shall meet the Performance Requirements of Annex C for those waveforms.

B.2.3 WBHF Block 3 Requirements

A Block 3 WBHF modem shall implement all of the requirements in Sections 3 and 4 in this Annex, and the performance requirements of Annex C, for bandwidths up to 24 kHz.

B.2.4 WBHF Block 4 Requirements

A Block 4 WBHF modem shall implement all of the requirements in Sections 3 and 4 in this Annex and the performance requirements of Annex C.

B.3 Flexible-Bandwidth, Single-Channel Waveforms

B.3.1 Modulation

The symbol rate for all symbols is dependent on the bandwidth (BW). The symbol rate shall be accurate to within 10ppm. For example, at 2400 symbols per second, the symbol rate shall be accurate to a minimum of ±0.024 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 (300+(BW/2)) Hz accurate to within 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(Sub-Carrier) and the quadrature sub-carrier –sin(Sub-Carrier). Table B.3.1-1 specifies the symbol rates and sub-carrier frequencies for all bandwidths.

TABLE B.3.1-1. Symbol Rates and Sub Carrier

Bandwidth (kHz)	Symbol Rate (Sym/sec)	Sub-Carrier (Hz)
3	2400	1800
6	4800	3300
9	7200	4800
12	9600	6300
15	12,000	7800
18	14,400	9300
21	16,800	10,800
24	19,200	12,300
30	24,000	15,300
36	28,800	18,300
42	33,600	21,300
48	38,400	24,300

The output of the modulator shall have an occupied bandwidth no greater than the bandwidth of the waveform in Table B.3.1-1. This measurement can be performed at RF, IF or audio baseband.

B.3.1.1 Known symbols

For all known symbols, the modulation used shall be PSK. No scrambling shall be applied to the known symbols.

B.3.1.2 Data symbols

For data symbols, the modulation used shall depend upon the data rate. Table B.3.1.2-1 specifies the modulation that shall be used with each data rate. NOTE: throughout this document, the terms “Waveform Number” and “Waveform Identifier” (or WID) are used interchangeably.

TABLE B.3.1.2-1. Modulation used to obtain each data rate.

Waveform Number	**0 Walsh**	**1 BPSK**	**2 BPSK**	**3 BPSK**	**4 BPSK**	**5 BPSK**	**6 QPSK**	**7 8PSK**	**8 16QAM**	**9 32QAM**	**10 64QAM**	**11 64QAM**	**12 256QAM**	**13 QPSK**
Bandwidth (kHz)														
3	75	150	300	600	1200	1600	3200	4800	6400	8000	9600	12000	16000	2400
6	150	300	600	1200	2400	3200	6400	9600	12800	16000	19200	24000	32000	
9	300	600	1200	2400	-	4800	9600	14400	19200	24000	28800	36000	48000	
12	300	600	1200	2400	4800	6400	12800	19200	25600	32000	38400	48000	64000	
15	300	600	1200	2400	4800	8000	16000	24000	32000	40000	48000	57600	76800	
18	600	1200	2400	4800	-	9600	19200	28800	38400	48000	57600	72000	90000	
21	300	600	1200	2400	4800	9600	19200	28800	38400	48000	57600	76800	115200	
24	600	1200	2400	4800	9600	12800	25600	38400	51200	64000	76800	96000	120000	
30	600	1200	2400	4800	9600	16000	32000	48000	64000	80000	96000	120000	160000	
36	1200	2400	4800	9600	12800	19200	38400	57600	76800	96000	115200	144000	192000	
42	1200	2400	4800	9600	14400	19200	38400	57600	76800	96000	115200	160000	192000	
48	1200	2400	4800	9600	16000	24000	48000	72000	96000	120000	144000	192000	240000	

The waveforms utilizing binary phase-shift keying BPSK, quadrature phase-shift keying (QPSK), and eight-ary phase-shift keying (8PSK) constellations are scrambled to appear, on-air, as an 8PSK constellation. The scrambling serves a secondary purpose of randomizing the on air waveform in the presence of a fixed user data stream. The 16QAM and 32QAM constellations use multiple PSK rings to maintain good peak-to-average ratios, and the 64QAM constellation is a variation of the standard square QAM constellation, which has been modified to improve the peak-to-average ratio. The 256 QAM constellation is better than the standard 16 x 16 square constellation and achieves superior peak-to-average without sacrificing the very good pseudo-Gray code properties of the square constellation. An interesting feature of the constellation is the slight displacement of the 2 center-top and center-bottom constellation points to protect constellation points with larger Hamming distances by increasing the signal-space distance.

B.3.1.2.1 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 BPSK and QPSK modulations to appear as 8PSK, on-air. Scrambling is applied as a modulo 8 addition of a scrambling sequence to the 8PSK symbol number. Transcoding is an operation that links a symbol to be transmitted to a group of data bits.

B.3.1.2.1.1 BPSK symbol mapping

For the waveforms utilizing binary phase-shift keying BPSK, transcoding shall be achieved by linking one of the symbols specified in Table B.3.1.2.1.4-1 to a single data bits (bit) as shown in Table B.3.1.2.1.1-1.

TABLE B.3.1.2.1.1-1. Transcoding for BPSK.

bit	Symbol
0	0
1	4

B.3.1.2.1.2 QPSK symbol mapping

For the waveforms utilizing quadrature phase-shift keying QPSK, transcoding shall be achieved by linking one of the symbols specified in Table B.3.1.2.1.4-1 to a set of two consecutive data bits (dibit) as shown in Table B.3.1.2.1.2-1. In this Table, the leftmost bit of the dibit shall be the older bit; i.e., fetched from the interleaver before the rightmost bit.

TABLE B.3.1.2.1.2-1. Transcoding for QPSK.

Dibit	Symbol
00	0
01	2
10	6
11	4

B.3.1.2.1.3 8PSK symbol mapping

For the waveforms utilizing quadrature 8-ary phase-shift keying 8PSK, transcoding shall be achieved by linking one symbol to a set of three consecutive data bits (tribit) as shown in Table B.3.1.2.1.3-1. 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.

TABLE B.3.1.2.1.3-1. Transcoding for 8PSK.

Tribit	Symbol
000	1
001	0
010	2
011	3
100	6
101	7
110	5
111	4

B.3.1.2.1.4 The 8PSK constellation

The constellation points that shall be used for 8PSK are shown in Figure B.3.1.2.1.4-1 and specified in terms of their In-phase and Quadrature components in Table B.3.1.2.1.4-1.

TABLE B.3.1.2.1.4-1. 8PSK symbol mapping.

Symbol Number	Phase	In-Phase	Quadrature
0	0	1.000000	0.000000
1	$\pi/4$	0.707107	0.707107
2	$\pi/2$	0.000000	1.000000
3	$3\pi/4$	-0.707107	0.707107
4	π	-1.000000	0.000000
5	$5\pi/4$	-0.707107	-0.707107
6	$3\pi/2$	0.0000000	-1.000000
7	$7\pi/4$	0.707107	-0.707107

Note that the complex symbol values = $\exp[jn\pi/4]$ where n is the symbol number.

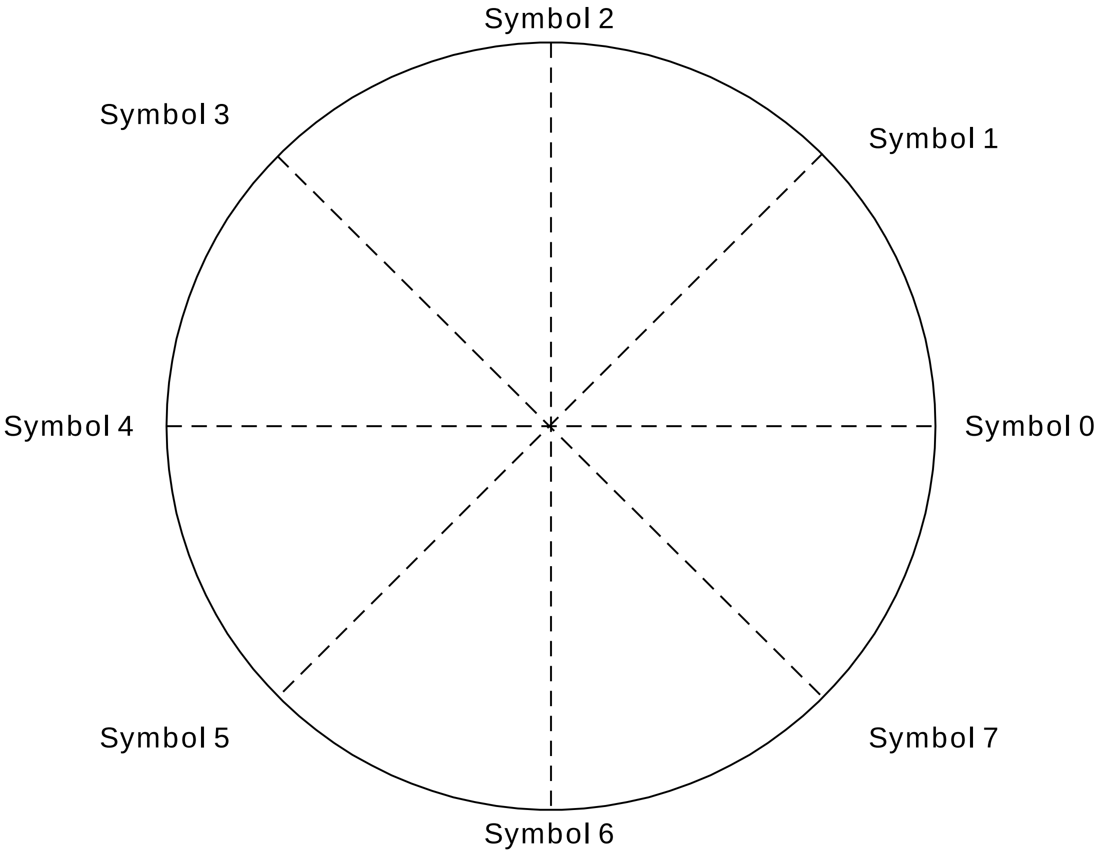

FIGURE B.3.1.2.1.4-1. 8PSK signal constellation and symbol mapping.

B.3.1.2.2 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 (16QAM), 5 bits (32QAM), 6 bits (64QAM), or 8 bits (256QAM) is mapped directly to a QAM symbol. For example, the four bit grouping 0111 would map to symbol 7 in the 16QAM constellation while the 6 bits 100011 would map to symbol 35 in the 64QAM 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.

B.3.1.2.2.1 The 16 QAM constellation

The constellation points which shall be used for 16QAM are shown in Figure B.3.1.2.2.1-1 and specified in terms of their In-phase and Quadrature components in Table B.3.1.2.2.1-1. As can be seen in the figure, the 16 QAM constellation is comprised of two PSK rings: a 4 PSK inner ring and a 12 PSK outer ring.

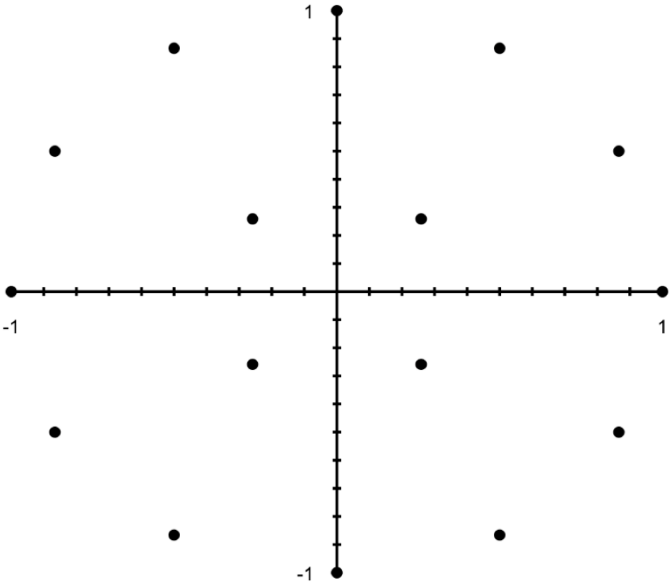

FIGURE B.3.1.2.2.1-1. 16QAM Signaling Constellation.

TABLE B.3.1.2.2.1-1. In-phase and Quadrature components of each 16QAM symbol.

Symbol Number	In-Phase	Quadrature
0	0.866025	0.500000
1	0.500000	0.866025
2	1.000000	0.000000
3	0.258819	0.258819
4	-0.500000	0.866025
5	0.000000	1.000000
6	-0.866025	0.500000
7	-0.258819	0.258819
8	0.500000	-0.866025
9	0.000000	-1.000000
10	0.866025	-0.500000
11	0.258819	-0.258819
12	-0.866025	-0.500000
13	-0.500000	-0.866025
14	-1.000000	0.000000
15	-0.258819	-0.258819

B.3.1.2.2.2 The 32 QAM constellation

The constellation points which shall be used for 32QAM are shown in Figure B.3.1.2.2.2-1 and specified in terms of their In-phase and Quadrature components in Table B.3.1.2.2.2-1. This constellation contains an outer ring of 16 symbols and an inner square of 16 symbols.

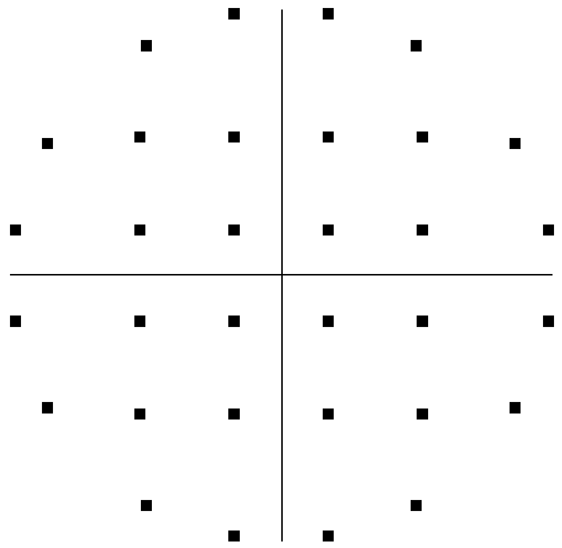

FIGURE B.3.1.2.2.2-1. 32QAM signaling constellation.

TABLE B.3.1.2.2.2-1. In-phase and Quadrature components of each 32QAM symbol.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	0.866380	0.499386	16	0.866380	-0.499386
1	0.984849	0.173415	17	0.984849	-0.173415
2	0.499386	0.866380	18	0.499386	-0.866380
3	0.173415	0.984849	19	0.173415	-0.984849
4	0.520246	0.520246	20	0.520246	-0.520246
5	0.520246	0.173415	21	0.520246	-0.173415
6	0.173415	0.520246	22	0.173415	-0.520246
7	0.173415	0.173415	23	0.173415	-0.173415
8	-0.866380	0.499386	24	-0.866380	-0.499386
9	-0.984849	0.173415	25	-0.984849	-0.173415
10	-0.499386	0.866380	26	-0.499386	-0.866380
11	-0.173415	0.984849	27	-0.173415	-0.984849
12	-0.520246	0.520246	28	-0.520246	-0.520246
13	-0.520246	0.173415	29	-0.520246	-0.173415
14	-0.173415	0.520246	30	-0.173415	-0.520246
15	-0.173415	0.173415	31	-0.173415	-0.173415

B.3.1.2.2.3 The 64QAM constellation

The constellation points which shall be used for the 64QAM modulation are shown in Figure B.3.1.2.2.3-1 and specified in terms of their In-phase and Quadrature components in Table B.3.1.2.2.2-1. 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.

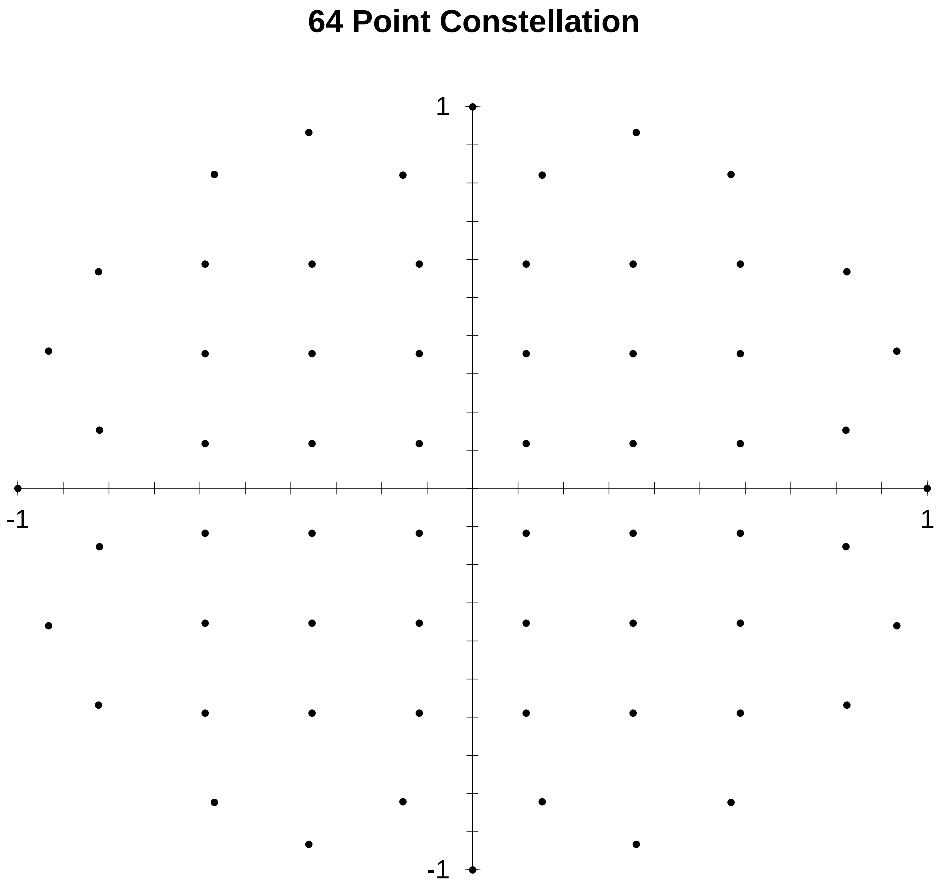

FIGURE B.3.1.2.2.3-1. 64QAM signaling constellation.

TABLE B.3.1.2.2.3-1. In-phase and Quadrature components of each 64QAM symbol.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	0.000000	1.000000
1	0.822878	0.568218	33	-0.822878	0.568218
2	0.821137	0.152996	34	-0.821137	0.152996
3	0.932897	0.360142	35	-0.932897	0.360142
4	0.000000	-1.000000	36	-1.000000	0.000000
5	0.822878	-0.568218	37	-0.822878	-0.568218
6	0.821137	-0.152996	38	-0.821137	-0.152996
7	0.932897	-0.360142	39	-0.932897	-0.360142
8	0.568218	0.822878	40	-0.568218	0.822878
9	0.588429	0.588429	41	-0.588429	0.588429
10	0.588429	0.117686	42	-0.588429	0.117686
11	0.588429	0.353057	43	-0.588429	0.353057
12	0.568218	-0.822878	44	-0.568218	-0.822878
13	0.588429	-0.588429	45	-0.588429	-0.588429
14	0.588429	-0.117686	46	-0.588429	-0.117686
15	0.588429	-0.353057	47	-0.588429	-0.353057
16	0.152996	0.821137	48	-0.152996	0.821137
17	0.117686	0.588429	49	-0.117686	0.588429
18	0.117686	0.117686	50	-0.117686	0.117686
19	0.117686	0.353057	51	-0.117686	0.353057
20	0.152996	-0.821137	52	-0.152996	-0.821137
21	0.117686	-0.588429	53	-0.117686	-0.588429
22	0.117686	-0.117686	54	-0.117686	-0.117686
23	0.117686	-0.353057	55	-0.117686	-0.353057
24	0.360142	0.932897	56	-0.360142	0.932897
25	0.353057	0.588429	57	-0.353057	0.588429
26	0.353057	0.117686	58	-0.353057	0.117686
27	0.353057	0.353057	59	-0.353057	0.353057
28	0.360142	-0.932897	60	-0.360142	-0.932897
29	0.353057	-0.588429	61	-0.353057	-0.588429
30	0.353057	-0.117686	62	-0.353057	-0.117686
31	0.353057	-0.353057	63	-0.353057	-0.353057

B.3.1.2.2.4 The 256QAM constellation

The constellation points that shall be used for the 256QAM modulation are shown in Figure B.3.1.2.2.4-1 and specified in terms of their In-phase and Quadrature components in Table B.3.1.2.2.4-1. This constellation is better than the standard 16 x 16 square constellation and achieves superior peak-to-average without sacrificing the very good pseudo-Gray code properties of the square constellation. An interesting feature of the constellation is the slight displacement of the 2 center-top and center-bottom constellation points to protect constellation points with larger Hamming distances by increasing the signal-space distance.

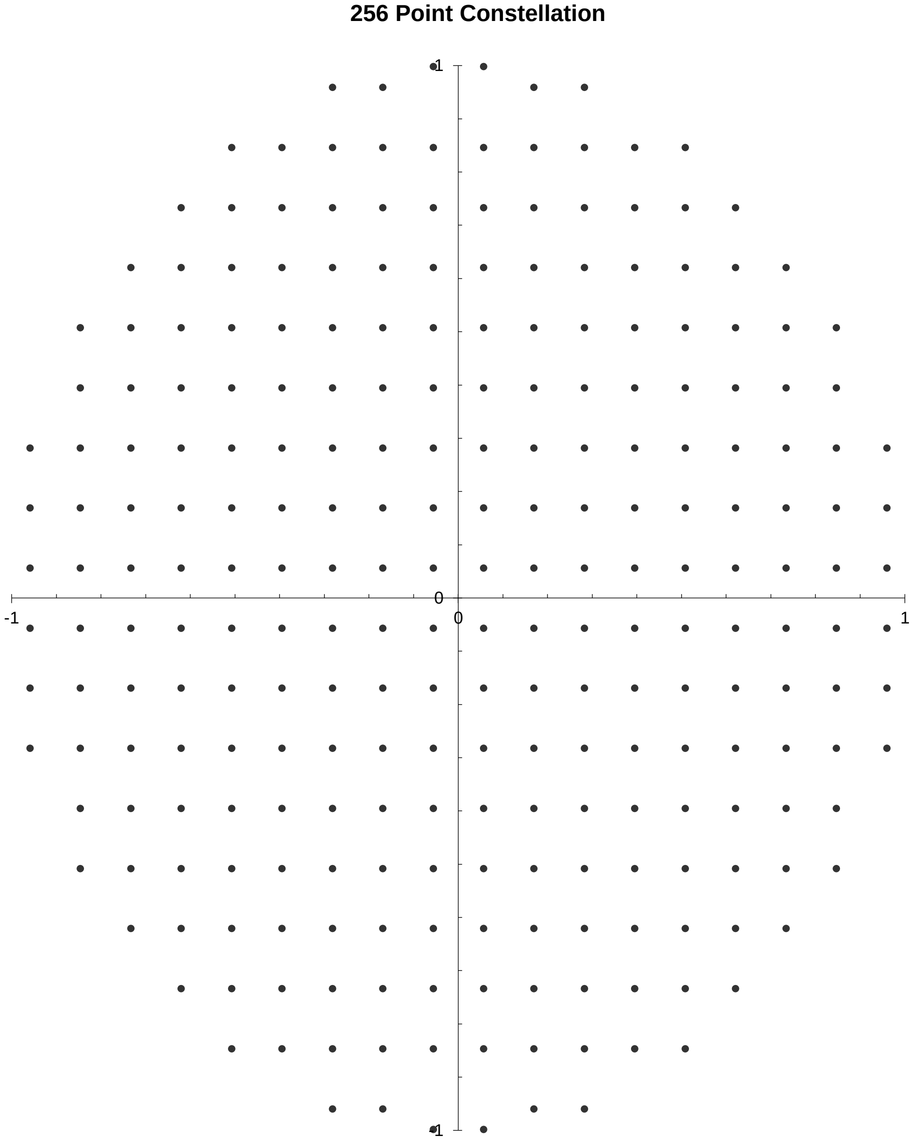

FIGURE B.3.1.2.2.4-1. 256QAM signaling constellation.

TABLE B.3.1.2.2.4-1. In-phase and Quadrature components of each 256QAM symbol.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	0.959366	0.056433	32	0.507899	0.846499
1	0.959366	0.169300	33	0.507899	0.733632
2	0.846499	0.507899	34	0.507899	0.507899
3	0.959366	0.282166	35	0.507899	0.620766
4	0.846499	0.056433	36	0.507899	0.056433
5	0.846499	0.169300	37	0.507899	0.169300
6	0.846499	0.395033	38	0.507899	0.395033
7	0.846499	0.282166	39	0.507899	0.282166
8	0.959366	-0.056433	40	0.507899	-0.846499
9	0.959366	-0.169300	41	0.507899	-0.733632
10	0.846499	-0.507899	42	0.507899	-0.507899
11	0.959366	-0.282166	43	0.507899	-0.620766
12	0.846499	-0.056433	44	0.507899	-0.056433
13	0.846499	-0.169300	45	0.507899	-0.169300
14	0.846499	-0.395033	46	0.507899	-0.395033
15	0.846499	-0.282166	47	0.507899	-0.282166
16	0.169300	0.959366	48	0.282166	0.959366
17	0.056433	0.998304	49	0.620766	0.733632
18	0.733632	0.507899	50	0.620766	0.507899
19	0.733632	0.620766	51	0.620766	0.620766
20	0.733632	0.056433	52	0.620766	0.056433
21	0.733632	0.169300	53	0.620766	0.169300
22	0.733632	0.395033	54	0.620766	0.395033
23	0.733632	0.282166	55	0.620766	0.282166
24	0.169300	-0.959366	56	0.282166	-0.959366
25	0.056433	-0.998304	57	0.620766	-0.733632
26	0.733632	-0.507899	58	0.620766	-0.507899
27	0.733632	-0.620766	59	0.620766	-0.620766
28	0.733632	-0.056433	60	0.620766	-0.056433
29	0.733632	-0.169300	61	0.620766	-0.169300
30	0.733632	-0.395033	62	0.620766	-0.395033
31	0.733632	-0.282166	63	0.620766	-0.282166

TABLE B.3.1.2.2.4-1 continued

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	0.056433	0.846499	96	0.395033	0.846499
65	0.056433	0.733632	97	0.395033	0.733632
66	0.056433	0.507899	98	0.395033	0.507899
67	0.056433	0.620766	99	0.395033	0.620766
68	0.056433	0.056433	100	0.395033	0.056433
69	0.056433	0.169300	101	0.395033	0.169300
70	0.056433	0.395033	102	0.395033	0.395033
71	0.056433	0.282166	103	0.395033	0.282166
72	0.056433	-0.846499	104	0.395033	-0.846499
73	0.056433	-0.733632	105	0.395033	-0.733632
74	0.056433	-0.507899	106	0.395033	-0.507899
75	0.056433	-0.620766	107	0.395033	-0.620766
76	0.056433	-0.056433	108	0.395033	-0.056433
77	0.056433	-0.169300	109	0.395033	-0.169300
78	0.056433	-0.395033	110	0.395033	-0.395033
79	0.056433	-0.282166	111	0.395033	-0.282166
80	0.169300	0.846499	112	0.282166	0.846499
81	0.169300	0.733632	113	0.282166	0.733632
82	0.169300	0.507899	114	0.282166	0.507899
83	0.169300	0.620766	115	0.282166	0.620766
84	0.169300	0.056433	116	0.282166	0.056433
85	0.169300	0.169300	117	0.282166	0.169300
86	0.169300	0.395033	118	0.282166	0.395033
87	0.169300	0.282166	119	0.282166	0.282166
88	0.169300	-0.846499	120	0.282166	-0.846499
89	0.169300	-0.733632	121	0.282166	-0.733632
90	0.169300	-0.507899	122	0.282166	-0.507899
91	0.169300	-0.620766	123	0.282166	-0.620766
92	0.169300	-0.056433	124	0.282166	-0.056433
93	0.169300	-0.169300	125	0.282166	-0.169300
94	0.169300	-0.395033	126	0.282166	-0.395033
95	0.169300	-0.282166	127	0.282166	-0.282166

TABLE B.3.1.2.2.4-1 continued

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
128	-0.959366	0.056433	160	-0.507899	0.846499
129	-0.959366	0.169300	161	-0.507899	0.733632
130	-0.846499	0.507899	162	-0.507899	0.507899
131	-0.959366	0.282166	163	-0.507899	0.620766
132	-0.846499	0.056433	164	-0.507899	0.056433
133	-0.846499	0.169300	165	-0.507899	0.169300
134	-0.846499	0.395033	166	-0.507899	0.395033
135	-0.846499	0.282166	167	-0.507899	0.282166
136	-0.959366	-0.056433	168	-0.507899	-0.846499
137	-0.959366	-0.169300	169	-0.507899	-0.733632
138	-0.846499	-0.507899	170	-0.507899	-0.507899
139	-0.959366	-0.282166	171	-0.507899	-0.620766
140	-0.846499	-0.056433	172	-0.507899	-0.056433
141	-0.846499	-0.169300	173	-0.507899	-0.169300
142	-0.846499	-0.395033	174	-0.507899	-0.395033
143	-0.846499	-0.282166	175	-0.507899	-0.282166
144	-0.169300	0.959366	176	-0.282166	0.959366
145	-0.056433	0.998304	177	-0.620766	0.733632
146	-0.733632	0.507899	178	-0.620766	0.507899
147	-0.733632	0.620766	179	-0.620766	0.620766
148	-0.733632	0.056433	180	-0.620766	0.056433
149	-0.733632	0.169300	181	-0.620766	0.169300
150	-0.733632	0.395033	182	-0.620766	0.395033
151	-0.733632	0.282166	183	-0.620766	0.282166
152	-0.169300	-0.959366	184	-0.282166	-0.959366
153	-0.056433	-0.998304	185	-0.620766	-0.733632
154	-0.733632	-0.507899	186	-0.620766	-0.507899
155	-0.733632	-0.620766	187	-0.620766	-0.620766
156	-0.733632	-0.056433	188	-0.620766	-0.056433
157	-0.733632	-0.169300	189	-0.620766	-0.169300
158	-0.733632	-0.395033	190	-0.620766	-0.395033
159	-0.733632	-0.282166	191	-0.620766	-0.282166

TABLE B.3.1.2.2.4-1 continued

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
192	-0.056433	0.846499	224	-0.395033	0.846499
193	-0.056433	0.733632	225	-0.395033	0.733632
194	-0.056433	0.507899	226	-0.395033	0.507899
195	-0.056433	0.620766	227	-0.395033	0.620766
196	-0.056433	0.056433	228	-0.395033	0.056433
197	-0.056433	0.169300	229	-0.395033	0.169300
198	-0.056433	0.395033	230	-0.395033	0.395033
199	-0.056433	0.282166	231	-0.395033	0.282166
200	-0.056433	-0.846499	232	-0.395033	-0.846499
201	-0.056433	-0.733632	233	-0.395033	-0.733632
202	-0.056433	-0.507899	234	-0.395033	-0.507899
203	-0.056433	-0.620766	235	-0.395033	-0.620766
204	-0.056433	-0.056433	236	-0.395033	-0.056433
205	-0.056433	-0.169300	237	-0.395033	-0.169300
206	-0.056433	-0.395033	238	-0.395033	-0.395033
207	-0.056433	-0.282166	239	-0.395033	-0.282166
208	-0.169300	0.846499	240	-0.282166	0.846499
209	-0.169300	0.733632	241	-0.282166	0.733632
210	-0.169300	0.507899	242	-0.282166	0.507899
211	-0.169300	0.620766	243	-0.282166	0.620766
212	-0.169300	0.056433	244	-0.282166	0.056433
213	-0.169300	0.169300	245	-0.282166	0.169300
214	-0.169300	0.395033	246	-0.282166	0.395033
215	-0.169300	0.282166	247	-0.282166	0.282166
216	-0.169300	-0.846499	248	-0.282166	-0.846499
217	-0.169300	-0.733632	249	-0.282166	-0.733632
218	-0.169300	-0.507899	250	-0.282166	-0.507899
219	-0.169300	-0.620766	251	-0.282166	-0.620766
220	-0.169300	-0.056433	252	-0.282166	-0.056433
221	-0.169300	-0.169300	253	-0.282166	-0.169300
222	-0.169300	-0.395033	254	-0.282166	-0.395033
223	-0.169300	-0.282166	255	-0.282166	-0.282166

B.3.1.2.3 Walsh Orthogonal Modulation

Waveform ID 0 utilizes a different modulation technique, Walsh Orthogonal Modulation. Slightly different methods are used for bandwidths from 3 to 24 kHz and bandwidths from 30 to 48 kHz, as specified in the following paragraphs.

B.3.1.2.3.1 Walsh Orthogonal Modulation for bandwidths from 3 to 24 kHz

In bandwidths from 3 to 24 kHz, for each pair of coded and interleaved data bits the method produces a 32 symbol repeated Walsh sequence. The Walsh Orthogonal Modulation is accomplished by taking each pair of bits, or di-bit, and selecting a corresponding Walsh Sequence listed in Table B.3.1.2.3.1-1.

TABLE B.3.1.2.3.1-1. WID 0 Normal Walsh Sequences (3 to 24 kHz Channels).

Di-bit	Walsh Sequence
00	0000
01	0404
10	0044
11	0440

The selected four element Walsh sequence is repeated 8 times to yield a 32-element Walsh sequence. For example, if the di-bit is 01, the sequence 0404 is repeated to generate

0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4

The last di-bit in any interleaver block shall be identified by use of an alternate set of Walsh sequences from Table B.3.1.2.3.1-2, which are repeated 4 times to achieve 32 symbols.

TABLE B.3.1.2.3.1-2. WID 0 Alternate Walsh Sequences (3 to 24 kHz Channels).

Di-bit	Alternate Walsh Sequence
00	00004444
01	04044040
10	00444400
11	04404004

The 32-symbol channel symbol shall be produced by an element by element modulo 8 addition of the repeated Walsh Sequence and the scrambling sequence (seeB.3.1.4).

B.3.1.2.3.2 Walsh Orthogonal Modulation for bandwidths from 30 to 48 kHz

In bandwidths from 30 to 48 kHz, for each four coded and interleaved data bits, the method produces a 64 symbol repeated Walsh sequence. The Walsh Orthogonal Modulation is accomplished by taking each set of four bits, or quad-bit, and selecting a corresponding Walsh Sequence listed in Table B.B.3.1.2.3.2-1.

TABLE B.3.1.2.3.2-1. WID 0 Walsh Sequences (30 to 48 kHz Channels).

Quad-bit	Walsh Sequence
0000	0000000000000000
0001	0404040404040404
0010	0044004400440044
0011	0440044004400440
0100	0000444400004444
0101	0404404004044040
0110	0044440000444400
0111	0440400404404004
1000	0000000044444444
1001	0404040440404040
1010	0044004444004400
1011	0440044040044004
1100	0000444444440000
1101	0404404040400404
1110	0044440044000044
1111	0440400440040440

The selected 16-element Walsh sequence is repeated 4 times to yield a 64-element Walsh sequence. For example, if the quad-bit is 0001, the sequence 0404040404040404 is repeated to generate

0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4

The last quad-bit in any interleaver block shall be identified by use of an alternate set of 32-symbol Walsh sequences from Table B.3.1.2.3.2-2. The selected sequence is repeated to yield a 64-element Walsh sequence.

TABLE B.3.1.2.3.2-2. WID 0 Alternate Walsh Sequences (30 to 48 kHz Channels).

Quad-bit	Alternate Walsh Sequence
0000	0000000000000000 4444444444444444
0001	0404040404040404 4040404040404040
0010	0044004400440044 4400440044004400
0011	0440044004400440 4004400440044004
0100	0000444400004444 4444000044440000
0101	0404404004044040 4040040440400404
0110	0044440000444400 4400004444000044
0111	0440400404404004 4004044040040440
1000	0000000044444444 4444444400000000
1001	0404040440404040 4040404004040404
1010	0044004444004400 4400440000440044
1011	0440044040044004 4004400404400440
1100	0000444444440000 4444000000004444
1101	0404404040400404 4040040404044040
1110	0044440044000044 4400004400444400
1111	0440400440040440 4004044004404004

The 64-symbol channel symbol shall be produced by an element by element modulo 8 addition of the repeated Walsh Sequence and the scrambling sequence (see B.3.1.4).

B.3.1.3 Data scrambling

Data symbols for Waveforms 1 through 7 and 13 (using BPSK, QPSK, or 8PSK modulation) shall be scrambled by modulo 8 addition with a scrambling sequence.

The data symbols for Waveforms 8 through 12(16QAM, 32QAM, 64QAM and 256QAM modulation) shall be scrambled by using an exclusive or (XOR) operation. Sequentially, the data bits forming each symbol (4 for 16QAM, 5 for 32QAM, 6 for 64QAM and 8 for 256 QAM) shall be XOR'd with an equal number of bits from the scrambling sequence.

For Waveforms 1 through 13, 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 B.B.3.1.3-1. In this illustration, three output bits are shown; this is the case for all PSK waveforms. For 2^N QAM waveforms, the rightmost N bits are used.

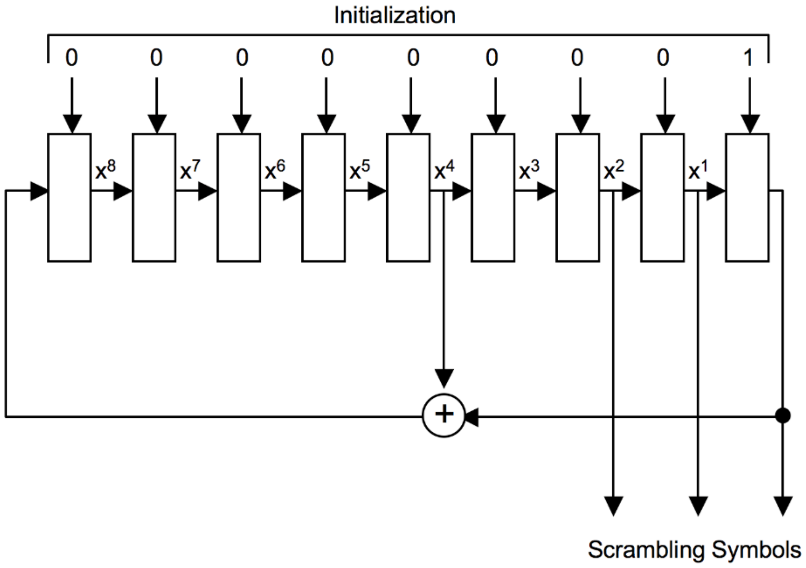

FIGURE B.3.1.3-1. Scrambling sequence generator illustrating scrambling generator for PSK symbols.

For PSK symbols (BPSK, QPSK, and 8PSK), 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 (transcoded 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 16QAM 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 16QAM symbol number before scrambling was 3 (i.e. 0011), symbol 6 (0110) would be transmitted. For 32QAM 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 64QAM 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. For 256QAM symbols, scrambling shall be carried out by XORing the 8 bit number formed by the last (rightmost) eight 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., 3 iterations for 8PSK, 4 iterations for 16QAM, 5 iterations for 32QAM and 6 iterations for 64QAM, and 8 iterations for 256QAM). 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 3 times, although in terms of symbols, there will be no repetition.

B.3.1.4 Waveform ID 0 Walsh Orthogonal Modulation Data scrambling

For the case of Waveform ID 0, an 8-PSK data scrambling sequence is utilized. This sequence is generated in a fashion similar to that described above but is based on a longer shift register of 159 bits with a single tap after bit 31. This is an implementation of a Trinomial (159, 31). The shift register is initialized to the following state:

```
int bitshift[159] =
{0, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 0, 0, 1, 0, 1,
 1, 1, 1, 1, 0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0,
 1, 0, 1, 1, 0, 0, 1, 1, 0, 0, 1, 0, 1, 1, 1, 0,
 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 0, 0, 0, 0,
 1, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 0, 1,
 0, 1, 1, 1, 1, 0, 1, 0, 1, 0, 0, 0, 1, 1, 1, 1,
 1, 1, 0, 0, 1, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0, 1,
 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0, 1, 1, 0, 1, 0,
 1, 1, 1, 0, 0, 1, 1, 1, 0, 0, 0, 1, 1, 0, 0, 0,
 1, 0, 0, 1, 0, 0, 0, 1, 1, 0, 1, 0, 0, 1, 1};
```

For Waveform ID 0 this implementation is used to generate 256*8 or 2048 values for bandwidths up to 24 kHz. For greater bandwidths, 4096 values are generated. The shift register is iterated 16 times between the generation of each 8-PSK symbol.

```
int tri( void)
{
   int bitout, bittap, bitin;
   int i,j;

   for(j=0;j<16;j++)
   {
      bitout = bitshift[158];
      bittap = bitshift[31];
      for(i=158;i>=1;i--) bitshift[i]=bitshift[i-1];
      bitin = bitout^bittap;
      bitshift[0]=bitin;
   }
   return (bitshift[2]<<2)+(bitshift[1]<<1)+bitshift[0];
}
```

Each channel symbol of the WID 0 waveforms is scrambled using 32 chips or symbols of the scramble sequence, generated as defined above.

> For example, the first 32 symbols of the scramble sequence are
>
> 5, 6, 2, 1, 7, 3, 1, 1, 6, 0, 5, 4, 0, 7, 7, 0, 5, 3, 1, 3, 3, 2, 2, 5, 5, 4, 7, 3, 5, 4, 3, 0,
>
> For this example, assume a 24 kHz channel, and the coded and interleaved data di-bit to be sent is 01; then the corresponding Walsh sequence 0 4 0 4 is repeated and combined with this scrambling sequence as shown below:
>
> 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4, 0, 4
> 5, 6, 2, 1, 7, 3, 1, 1, 6, 0, 5, 4, 0, 7, 7, 0, 5, 3, 1, 3, 3, 2, 2, 5, 5, 4, 7, 3, 5, 4, 3, 0,
> ==
> 5, 2, 2, 5, 7, 7, 1, 5, 6, 4, 5, 0, 0, 3, 7, 4, 5, 7, 1, 7, 3, 6, 2, 1, 5, 0, 7, 7, 5, 0, 3, 4

For the Walsh Orthogonal Modes the sequences are continuously wrapped around the 2048 or 4096 symbol boundary. The sequence is reset to the initialization value at the interleaver boundary.

B.3.1.5 Modulation filter

The role of the modulation filter is to spectrally constrain the transmit waveform to within the specified bandwidth. A square root of raised cosine filter is recommended with a roll off factor (excess bandwidth) of 35%. Utilizing this filter as both the modem modulation filter and demodulation filter will maximize the signal to noise ratio and minimize inter-symbol interference. The combined modulation and demodulation filters will have the following frequency response (symmetric around 0 Hz):

$H(f) = 1 \quad \text{for } |f| <= f_n – pf_n$

$H(f) = 0.5(1 – \sin(f-f_n * PI / 2pf_n) \quad \text{for } f_n – pf_n < |f| <= f_n + pf_n$

$H(f) = 0$ elsewhere

Where:

f_n is the Nyquist frequency ($f_n = 1 / (2T) = (1 / 2) * \text{SYMBOL RATE} = 1200$ Hz for 3kHz BW, 9600Hz for 24kHz BW)

p is the roll off factor or excess bandwidth.

The individual modulation and demodulation filters are realized by taking the square root of the above frequency response.

B.3.2 Frame structure

The frame structure that shall be used for the waveforms specified in this Annex is shown in Figure B.B.3.2-1. An initial synchronization preamble is followed by frames of alternating data (Unknown) and probe (Known) symbols. Each data frame shall consist of a data block consisting of U data symbols, followed by a mini-probe consisting of K known symbols.

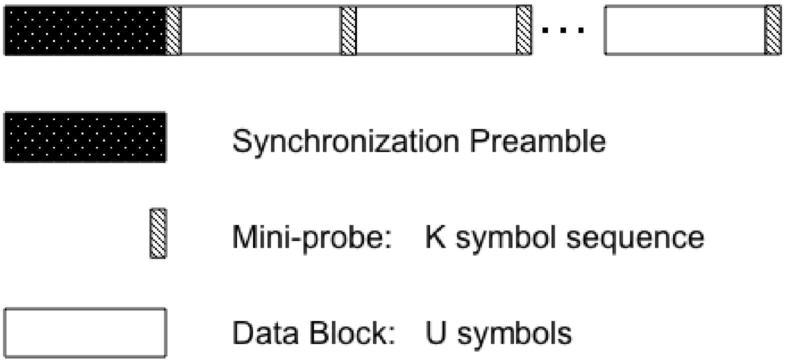

FIGURE B.3.2-1. Frame structure for waveforms 1-13.

Tables B.3.2-1 and B.3.2-2 provide the Unknown and Known frame structure for waveforms 1 through 12.

Waveform 0 uses a different structure after the Synchronization Preamble, in which data “frames” are 32-symbol Walsh sequences (channel symbols), each corresponding to a single unknown (data) bit (a di-bit or quad-bit after coding). Mini-probes are not sent in waveform 0, so Walsh-coded data symbols are sent continuously after the initial Synchronization Preamble.

TABLE B.3.2-1. Number of Unknown (Data) Symbols in Frame

WF Number	0	1	2	3	4	5	6	7	8	9	10	11	12	13
BW (kHz)														
3	N/A	48	48	96	96	256	256	256	256	256	256	360	360	256
6	N/A	96	96	204	204	544	544	544	544	544	544	540	540	
9	N/A	288	288	288	-	768	768	768	768	768	768	1080	1080	
12	N/A	192	192	384	384	1024	1024	1024	1024	1024	1024	1080	1080	
15	N/A	288	288	288	288	1280	1280	1280	1280	1280	1280	1152	1152	
18	N/A	448	448	448	-	1536	1536	1536	1536	1536	1536	1920	1920	
21	N/A	320	320	320	320	1344	1344	1344	1344	1344	1344	2560	2560	
24	N/A	272	272	816	816	2176	2176	2176	2176	2176	2176	1920	1920	
30	N/A	576	576	576	576	2560	2560	2560	2560	2560	2560	2700	2700	
36	N/A	1152	1152	1152	3072	3072	3072	3072	3072	3072	3072	3240	3240	
42	N/A	768	768	768	3456	3456	3456	3456	3456	3456	3456	3840	3840	
48	N/A	512	512	512	2560	2560	2560	2560	2560	2560	2560	2880	2880	

TABLE B.3.2-2. Number of Known Symbols (Mini-Probe) in Frame

WF Number	0	1	2	3	4	5	6	7	8	9	10	11	12	13
BW (kHz)														
3	N/A	48	48	32	32	32	32	32	32	32	32	24	24	32
6	N/A	96	96	68	68	68	68	68	68	68	68	36	36	
9	N/A	144	144	144	-	96	96	96	96	96	96	72	72	
12	N/A	192	192	128	128	128	128	128	128	128	128	72	72	
15	N/A	192	192	192	192	160	160	160	160	160	160	128	128	
18	N/A	224	224	224	-	192	192	192	192	192	192	128	128	
21	N/A	240	240	240	240	224	224	224	224	224	224	128	128	
24	N/A	272	272	272	272	272	272	272	272	272	272	128	128	
30	N/A	384	384	384	384	320	320	320	320	320	320	180	180	
36	N/A	576	576	576	384	384	384	384	384	384	384	216	216	
42	N/A	576	576	576	576	576	576	576	576	576	576	192	192	
48	N/A	512	512	512	512	512	512	512	512	512	512	192	192	

B.3.2.1 Synchronization preamble

The synchronization preamble is used for rapid initial synchronization and provides time and frequency alignment. The synchronization preamble shall consist of two main sections, a transmitter level control (TLC) settling time section, and a synchronization section containing a repeated preamble super-frame. The preamble super-frame consists of three distinct subsections, one with a fixed (known) modulation, one to convey a downcount, and one to convey waveform identification. The superframe shall be repeated M times. The Synchronization section shall be immediately followed by the modulated data (Figure B.3.2.1-1).

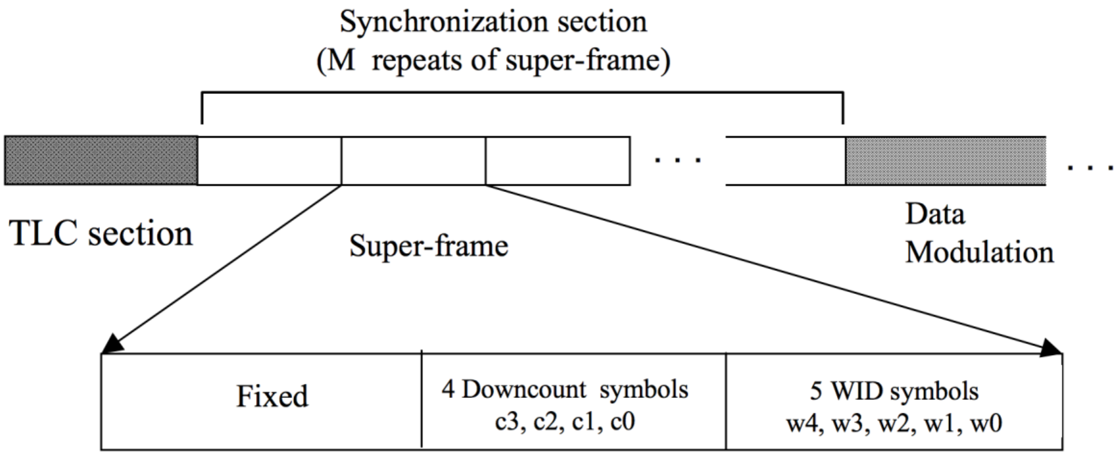

FIGURE B.3.2.1-1. Synchronization preamble structure.

B.3.2.1.1 4-ary Orthogonal Walsh Modulation in the preamble

4-ary orthogonal Walsh modulation shall be used in the synchronization section of the preamble (for all bandwidths). The length of each channel symbol, in chips or symbols, is dependent on the bandwidth of the modem waveform selected and shall be as given by Table B.3.2.1.1-1.

TABLE B.3.2.1.1-1. Length of Preamble Channel Symbols

Bandwidth (kHz)	Walsh Sequence Length in Preamble
3	32
6	64
9	96
12	128
15	160
18	192
21	224
24	256
30	320
36	384
42	448
48	512

The 4-ary orthogonal Walsh modulation shall use the Walsh sequences in Table B.B.3.2.1.1-2. The di-bit representing the 2 bits of information to convey is mapped into a 4 element Walsh sequence of 0 and 4 as defined in Table B.3.2.1.1-2. This 4-element sequence shall be repeated to satisfy the Walsh sequence length requirement in Table B.3.2.1.1-1 for the bandwidth in use.

TABLE B.3.2.1.1-2. Walsh Sequences for Synchronization Section of the Preamble

Di-bit	Walsh Sequence
00	0000
01	0404
10	0044
11	0440

Scrambling shall be performed by aligning the expanded Walsh sequence with the Fixed, Count, or the Waveform ID synchronization preambles defined in Tables B.3.2.1.4-1, B.3.2.1.4-2, and B.3.2.1.4-3 respectively, and performing a modulo 8 addition between the specified 8-PSK symbol from the table and the corresponding Walsh element.

B.3.2.1.2 TLC Section

The first section of the preamble, denoted TLC, is provided exclusively for radio and modem TGC and AGC. It shall consist of N blocks of 8-PSK. The length of each block in PSK symbols, based on the bandwidth used in the transmission to follow, shall be as shown in Table B.3.2.1.1-1. The value of N shall be configurable to range from 0 to 255 (for N=0 this first section is not transmitted). These symbols shall be formed by taking the complex conjugate of the symbols of the sequence specified below for the Fixed section in Table B.3.2.1.4-1.

B.3.2.1.3 Synchronization Section

The Fixed subsection of the super-frame shall consist of either 1 or 9 orthogonal Walsh modulated channel symbols. The length of each channel symbol, dependent on bandwidth, is given in Table B.3.2.1.1-1. For the case of the single Walsh symbol the di-bit shall be 3 (binary 11), and the super frame shall be transmitted only once (M=1). For the case of 9 Walsh symbols the di-bits shall be {0, 0, 2, 1, 2, 1, 0, 2, 3}, 3 being the last di-bit transmitted. The Fixed subsection is intended exclusively for synchronization and Doppler offset removal purposes.

The next subsection shall consists of four, orthogonal Walsh modulated di-bits, labeled as c3, c2, c1 and c0, each conveying two bits of information. This subsection represents a 5 bit downcount plus 3 parity bits. This count shall be initialized to a value of (M-1) and shall be decremented with each of the M preamble repetitions until it reaches zero in the final super-frame before data begins.

The final subsection of the preamble super-frame shall consist of five, orthogonal Walsh modulated channel symbols, each conveying two bits of information. These di-bits are labeled as w4, w3, w2, w1, and w0. These 10 bits represent a Waveform ID consisting of waveform number, interleaver option, convolutional code length and parity check.

B.3.2.1.3.1 Mapping of the downcount di-bits c3, c2, c1, and c0

The 5 bit super-frame down count is initialized to M-1 where M is the number of repeats of the super-frame and can be viewed as a binary number b4b3b2b1b0 where b4 is the MSB and b0 is the LSB. Bits b7, b6, and b5 shall contain a parity check computed over b4b3b2b1b0 as follows, where the ^ symbol indicates exclusive-or:

b7 = b1 ^ b2 ^ b3

b6 = b2 ^ b3 ^ b4

b5 = b0 ^ b1 ^ b2

C3 shall contain the two MSBs b7 and b6, b7 being the MSB. C2 shall contain the next two bits of the count b5 and b4, b5 being the MSB. C1 shall contain the next two bits of the count b3 and b2, b3 being the MSB. C0 shall contain the last two bits of the count b1 and b0, b1 being the MSB.

B.3.2.1.3.2 Mapping of the Waveform ID di-bits w4, w3, w2, w1, and w0

The 10 bit waveform ID field consists of 5 di-bits w4, w3, w2, w1, and w0. The 10 bits are labeled d9 down to d0. W4 contains d9 and d8, where d9 is the MSB, w3 contains d7 and d6, and so on down to w0 which contains d1 and d0.

The 3 LSBs, d2, d1, and d0, shall contain a 3 bit checksum calculated over d9d8d7d6d5d4d3 as follows, where the ^ symbol indicates exclusive-or:

d2 = d9 ^ d8 ^ d7

d1 = d7 ^ d6 ^ d5

d0 = d5 ^ d4 ^ d3

The four bit waveform number, defined in Table B.3.1.2-1 for all possible waveform options for a given bandwidth, shall be mapped into the w4 and w3 di-bits as defined in Table B.3.2.1.3.2-1. The reserved encodings shall not be sent.

TABLE B.3.2.1.3.2-1. Waveform number mapping.

Waveform Number	w4 d9 d8	w3 d7 d6
0	0 0	0 0
1	0 0	0 1
2	0 0	1 0
3	0 0	1 1
4	0 1	0 0
5	0 1	0 1
6	0 1	1 0
7	0 1	1 1
8	1 0	0 0
9	1 0	0 1
10	1 0	1 0
11	1 0	1 1
12	1 1	0 0
13	1 1	0 1
(reserved)	1 1	1 0
(reserved)	1 1	1 1

The Interleaver selection shall be mapped to w2 as defined in Table B.3.2.1.3.2-2.

TABLE B.3.2.1.3.2-2. Interleaver selection mapping.

Interleaver	w2 d5 d4
Ultra Short	0 0
Short	0 1
Medium	1 0
Long	1 1

The convolutional code constraint length shall be mapped into w1 as defined in Table B.3.2.1.3.2-3. The lsb of w1 shall be 0.

TABLE B.3.2.1.3.2-3. Constraint length and voice mode mapping.

Constraint Length	MSB of w1 d3
7	0
9	1

B.3.2.1.4 Preamble scrambling sequences

Expressed as a sequence of 8PSK symbols, using the symbol numbers given in Table B.3.1.2.1.4-1 the sections of the preamble shall be scrambled as described in B.3.2.1.1 using the respective sequences shown in Table B.3.2.1.4-1 through B.3.2.1.4-3:

TABLE B.3.2.1.4-1. TLC / Fixed Synchronization preamble

```
int fixedPN[512] =
{
    2,4,0,0,6,2,1,4,6,1,0,5,7,3,4,1,2,6,1,7,0,7,3,2,2,2,3,2,4,6,3,6,
    6,3,7,5,4,7,5,6,7,4,0,2,6,1,5,3,0,4,2,4,6,4,5,2,5,4,5,3,1,5,4,5,
    6,5,1,0,7,1,0,1,0,5,3,5,2,2,4,5,4,0,6,4,1,4,0,3,3,0,0,3,3,7,3,4,
    2,7,4,4,4,0,3,4,7,6,4,2,6,2,0,3,5,3,2,2,4,5,2,0,0,3,5,0,3,2,6,6,
    1,4,2,3,6,1,3,0,3,3,2,4,2,2,6,5,5,3,6,7,6,5,6,6,5,2,5,4,2,3,3,3,
    5,7,5,5,3,7,0,4,7,0,4,1,6,2,3,5,5,6,2,6,4,6,3,4,0,7,0,0,5,2,1,5,
    4,3,4,5,7,0,5,3,7,6,6,6,4,5,6,0,2,0,4,2,3,4,4,0,7,6,6,2,0,0,3,3,
    0,5,2,4,2,2,4,5,4,6,6,6,3,2,1,0,3,2,6,0,6,2,4,0,6,4,1,3,3,5,3,6,
    1,3,0,3,1,5,0,0,6,3,2,3,1,0,1,3,3,1,0,1,0,2,0,7,0,1,6,6,5,4,2,5,
    4,7,6,5,2,2,6,7,5,4,5,4,2,0,3,0,3,6,0,5,0,0,2,7,5,3,6,0,3,0,0,4,
    3,7,3,7,7,3,1,4,3,6,0,3,4,1,6,1,3,4,5,3,0,0,1,0,3,7,6,6,3,2,1,5,
    4,6,7,5,7,2,3,3,3,7,1,1,6,0,6,7,5,1,6,2,4,4,6,7,3,6,0,1,6,7,6,4,
    2,1,6,4,0,0,1,7,6,2,3,4,6,2,3,0,0,1,6,3,2,6,4,3,5,2,4,3,6,5,5,6,
    4,3,4,4,2,3,5,4,5,1,2,7,1,0,4,5,1,6,2,3,0,5,5,3,1,3,2,6,1,2,1,6,
    5,1,4,7,1,6,4,0,3,7,0,7,3,7,3,1,0,0,2,4,7,6,0,7,4,2,3,1,3,4,0,6,
    7,5,7,4,1,6,2,4,0,1,5,7,4,4,0,2,7,1,2,4,5,3,1,2,0,2,2,4,0,1,0,1};
```

TABLE B.3.2.1.4-2. Count Synchronization preamble.

```
int cntPN[512] =
{
    5,5,2,2,0,2,5,6,7,1,3,5,1,5,6,5,3,7,0,4,0,3,3,2,1,3,0,3,1,6,2,6,
    0,6,4,1,2,5,6,3,5,3,7,4,2,6,7,3,0,2,0,1,7,5,0,6,1,5,0,3,2,2,5,2,
    5,2,3,4,2,7,6,1,1,5,2,1,5,4,0,3,5,5,0,3,1,4,0,5,0,3,0,6,0,0,3,1,
    6,1,4,4,7,7,0,5,7,0,1,5,1,0,1,3,1,5,0,7,1,2,2,2,7,1,2,5,0,3,3,2,
    2,0,4,5,1,3,1,3,5,3,1,7,5,2,7,1,3,1,5,6,2,4,6,0,6,1,0,0,3,6,2,7,
    3,2,4,7,6,4,1,3,6,6,0,3,0,0,7,5,4,5,1,2,1,5,0,3,1,0,4,6,6,1,0,5,
    2,6,3,2,7,4,2,4,0,1,7,0,7,0,5,1,4,5,7,2,0,4,4,3,5,2,7,7,4,5,1,4,
    4,6,3,3,0,5,1,5,5,4,3,2,0,3,0,4,7,4,5,1,5,5,7,7,6,2,4,3,5,2,2,4,
    6,4,3,7,5,0,5,2,2,3,3,7,1,1,0,0,5,7,2,2,1,7,7,4,4,7,0,3,6,4,6,7,
    2,3,3,7,6,7,2,7,1,0,4,5,6,4,3,0,2,3,2,5,7,5,5,7,5,1,4,2,1,1,2,6,
    6,7,5,1,5,7,0,6,2,1,7,5,7,2,4,5,2,2,7,7,2,0,5,4,5,0,5,7,1,1,3,6,
    7,4,3,2,6,3,3,3,3,4,3,5,0,1,0,7,7,7,1,3,7,2,0,1,1,2,2,4,2,1,4,6,
    6,3,5,4,0,4,2,0,5,5,1,4,2,7,6,4,1,0,0,2,5,7,2,6,1,3,2,7,7,6,1,3,
    0,1,5,7,6,5,5,1,3,6,5,2,6,7,3,7,3,6,4,3,7,3,6,5,7,0,7,1,7,6,0,6,
    2,6,6,5,4,6,7,7,2,2,4,7,0,6,2,1,4,3,4,0,7,6,5,4,1,0,5,3,6,3,6,4,
    0,0,6,4,2,1,3,3,6,2,0,2,1,3,2,3,7,5,0,7,6,7,1,2,6,1,2,6,4,5,0,7};
```

TABLE B.3.2.1.4-3. Waveform Number Synchronization preamble.

```
int widPN[512] =
{
    2,3,0,3,7,3,3,0,1,4,4,6,5,5,4,5,6,2,0,5,6,6,5,3,5,5,2,2,1,2,3,6,
    1,1,4,3,1,0,5,1,0,3,3,0,3,0,4,4,6,2,5,6,1,7,2,6,2,0,0,4,7,2,3,5,
    2,7,1,6,5,0,4,1,6,2,1,5,4,3,5,0,3,4,1,3,2,1,6,1,5,7,0,4,7,6,6,0,
    4,7,6,6,6,6,2,3,5,0,7,0,3,1,5,1,2,0,5,3,2,4,5,6,6,7,7,3,5,1,6,0,
    1,4,4,5,6,0,6,7,2,4,4,0,3,7,2,0,0,1,4,0,7,1,7,4,5,4,5,5,5,3,3,2,
    0,5,1,3,1,5,3,4,1,5,4,1,4,4,2,2,4,3,0,7,4,1,5,7,1,4,7,2,5,5,6,6,
    1,6,5,6,3,0,2,5,7,7,4,4,3,4,4,6,0,7,2,2,0,0,2,1,0,0,3,6,6,4,0,2,
    4,3,4,5,2,6,3,7,7,5,7,3,0,7,0,0,7,2,6,2,2,6,1,4,3,7,6,5,0,6,5,4,
    1,7,5,7,2,7,0,2,4,2,5,6,4,3,3,3,1,5,3,3,5,1,4,2,6,1,4,3,2,3,6,4,
    2,6,7,2,4,4,4,2,3,0,7,6,6,2,2,5,5,4,1,4,1,7,5,4,6,4,0,7,5,3,4,5,
    4,6,4,7,0,7,3,4,5,2,6,6,4,6,3,3,7,7,5,5,2,1,2,4,2,3,5,1,7,4,5,1,
    3,6,6,2,1,3,0,2,0,1,4,4,6,3,2,4,6,4,7,2,1,2,5,3,6,4,6,6,4,0,4,2,
    0,6,6,4,1,2,6,0,7,4,5,6,4,2,6,1,5,1,0,1,7,6,0,1,5,5,5,2,3,6,1,0,
    3,1,7,5,5,3,2,5,1,5,1,7,7,5,2,3,6,5,0,7,6,2,4,2,3,2,6,1,5,7,1,0,
    7,1,7,2,4,1,7,1,3,3,3,0,6,6,4,1,1,6,2,0,0,4,7,2,6,4,1,6,6,2,7,2,
    1,4,6,4,0,0,6,7,2,1,2,7,4,0,7,3,6,5,1,7,6,3,1,4,7,5,0,0,1,2,6,7
};
```

B.2.2 Mini-probes

Mini-probes shall be inserted, following every data block and at the end of each preamble, for non-Walsh based modulations (i.e., all except Waveform ID 0). To support the wide range of bit rate and bandwidth options of this standard, 14 different mini-probe sequences are utilized. Each of the mini-probes consists of the base sequence cyclically extended to the required length.

The mini-probes are also utilized to identify the long interleaver block boundary. This is accomplished by transmitting a cyclically rotated version of the mini-probe following the second to last data block of the long interleaver frame. The position of this cyclically shifted mini-probe remains constant regardless of which interleaver has actually been selected. As all interleavers line up on the long interleaver block boundary, this feature can be used to synchronize to a broadcast transmission and provide a late entry feature when the Waveform ID fields are known in advance by the receiver. The cyclically rotated version of the mini-probe is obtained by first cyclically extending the base sequence, and then shifting by a predetermined number of symbols.

Table B.3.2.2-1 defines the mini-probe lengths and the base sequence used to generate the full mini-probe and also the cyclic shift utilized to signal the interleaver block boundary.

TABLE B.3.2.2-1. Mini-probe lengths and base sequences.

Mini-Probe Length	Base Sequence	Cyclic Shift for Interleaver Boundary
24	13	6
32	16	8
36	19	9
48	25	12
64	36	18
68	36	18
72	36	18
96	49	24
128	64	32
144	81	40
160	81	40
180	100	50
192	100	50
216	121	60
224	121	60
240	121	60
272	144	72
320	169	85
384	196	98
512	256	128
576	289	145

In the case of the cyclic shift applied to the mini-probe for use in marking the long interleaver block boundary, the first element of the sequence transmitted is the one corresponding to the specified cyclic shift.

The method of forming the mini-probe from the specified base sequence will be illustrated using the 24 symbol mini-probe and the cyclically shifted version of the 24 symbol mini-probe formed from the 13 symbol base sequence. The base sequence of length 13 is listed in Table B.3.2.2-2. This sequence is cyclically extended by repeating the first 11 symbols of the sequence as shown in Table B.3.2.2-3 to obtain the required mini-probe of length 24.

TABLE B.3.2.2-2. In-phase and Quadrature components of base sequence of length 13 used to form 24 symbol mini-probe.

Symbol Number	In-Phase	Quadrature
0	1.00000	0.0
1	1.00000	0.0
2	1.00000	0.0
3	1.00000	0.0
4	1.00000	0.0
5	-1.00000	0.0
6	-1.00000	0.0
7	1.00000	0.0
8	1.00000	0.0
9	-1.00000	0.0
10	1.00000	0.0
11	-1.00000	0.0
12	1.00000	0.0

TABLE B.3.2.2-3. In-phase and Quadrature components of Length 24 mini-probe

Symbol Number	In-Phase	Quadrature
0	1.00000	0.0
1	1.00000	0.0
2	1.00000	0.0
3	1.00000	0.0
4	1.00000	0.0
5	-1.00000	0.0
6	-1.00000	0.0
7	1.00000	0.0
8	1.00000	0.0
9	-1.00000	0.0
10	1.00000	0.0
11	-1.00000	0.0
12	1.00000	0.0
13	1.00000	0.0
14	1.00000	0.0
15	1.00000	0.0
16	1.00000	0.0
17	1.00000	0.0
18	-1.00000	0.0
19	-1.00000	0.0
20	1.00000	0.0
21	1.00000	0.0
22	-1.00000	0.0
23	1.00000	0.0

Table B.3.2.2-4 provides an example of the cyclic shift of the 24 symbol mini-probe. As specified in Table B.3.2.2-1, the shifted mini-probe sequence begins 6 symbols into the original 13 symbol base sequence. Thus, the shifted mini-probe contains the last 7 symbols of the length 13 base sequence, followed by a complete length 13 base sequence, followed by the first 4 symbols of the length 13 base sequence to complete the 24 symbol mini-probe.

TABLE B.3.2.2-4. In-phase and Quadrature components of Length 24 mini-probe cyclically shifted by 6 symbols

Symbol Number	In-Phase	Quadrature
0	-1.00000	0.0
1	1.00000	0.0
2	1.00000	0.0
3	-1.00000	0.0
4	1.00000	0.0
5	-1.00000	0.0
6	1.00000	0.0
7	1.00000	0.0
8	1.00000	0.0
9	1.00000	0.0
10	1.00000	0.0
11	1.00000	0.0
12	-1.00000	0.0
13	-1.00000	0.0
14	1.00000	0.0
15	1.00000	0.0
16	-1.00000	0.0
17	1.00000	0.0
18	-1.00000	0.0
19	1.00000	0.0
20	1.00000	0.0
21	1.00000	0.0
22	1.00000	0.0
23	1.00000	0.0

The tables which follow provide the In-phase and Quadrature components of each of the base sequences used to form the mini-probes identified in Table B.3.2.2-1. The method of construction of each of the mini-probe sequences and the cyclic shifted variant of the mini-probe sequence follows the methodology just illustrated for the length 13 base sequence.

TABLE B.3.2.2-5. In-phase and Quadrature components of 16 symbol Base Sequence used to form the 32 symbol mini-probe.

Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000
1	1.000000	0.000000
2	1.000000	0.000000
3	1.000000	0.000000
4	1.000000	0.000000
5	0.000000	-1.000000
6	-1.000000	0.000000
7	0.000000	1.000000
8	1.000000	0.000000
9	-1.000000	0.000000
10	1.000000	0.000000
11	-1.000000	0.000000
12	1.000000	0.000000
13	0.000000	1.000000
14	-1.000000	0.000000
15	0.000000	-1.000000

TABLE B.3.2.2-6. In-phase and Quadrature components of 19 symbol Base Sequence used to form the 36 symbol mini-probe

Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000
1	-1.000000	0.000000
2	1.000000	0.000000
3	1.000000	0.000000
4	-1.000000	0.000000
5	-1.000000	0.000000
6	-1.000000	0.000000
7	-1.000000	0.000000
8	1.000000	0.000000
9	-1.000000	0.000000
10	1.000000	0.000000
11	-1.000000	0.000000
12	1.000000	0.000000
13	1.000000	0.000000
14	1.000000	0.000000
15	1.000000	0.000000
16	-1.000000	0.000000
17	-1.000000	0.000000
18	1.000000	0.000000

TABLE B.3.2.2-7. In-phase and Quadrature components of 25 symbol Base Sequence used to form the 48 symbol mini-probe.

Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000
1	1.000000	0.000000
2	1.000000	0.000000
3	1.000000	0.000000
4	1.000000	0.000000
5	1.000000	0.000000
6	0.309017	-0.951057
7	-0.809017	-0.587785
8	-0.809017	0.587785
9	0.309017	0.951056
10	1.000000	0.000000
11	-0.809017	-0.587785
12	0.309017	0.951056
13	0.309017	-0.951057
14	-0.809017	0.587785
15	1.000000	0.000000
16	-0.809017	0.587785
17	0.309017	-0.951057
18	0.309017	0.951057
19	-0.809017	-0.587785
20	1.000000	0.000000
21	0.309017	0.951056
22	-0.809017	0.587785
23	-0.809017	-0.587785
24	0.309016	-0.951057

TABLE B.3.2.2-8. In-phase and Quadrature components of 36 symbol Base Sequence used to form the 64 and 72 symbol mini-probes.

Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000
1	1.000000	0.000000
2	1.000000	0.000000
3	1.000000	0.000000
4	1.000000	0.000000
5	1.000000	0.000000
6	1.000000	0.000000
7	0.500000	-0.866025
8	-0.500000	-0.866025
9	-1.000000	0.000000
10	-0.500000	0.866025
11	0.500000	0.866025
12	1.000000	0.000000
13	-0.500000	-0.866025
14	-0.500000	0.866025
15	1.000000	0.000000
16	-0.500000	-0.866025
17	-0.500000	0.866025
18	1.000000	0.000000
19	-1.000000	0.000000
20	1.000000	0.000000
21	-1.000000	0.000000
22	1.000000	0.000000
23	-1.000000	0.000000
24	1.000000	0.000000
25	-0.500000	0.866025
26	-0.500000	-0.866025
27	1.000000	0.000000
28	-0.500000	0.866026
29	-0.500000	-0.866026
30	1.000000	0.000000
31	0.500000	0.866025
32	-0.500000	0.866025
33	-1.000000	0.000000
34	-0.500000	-0.866026
35	0.500000	-0.866026

TABLE B.3.2.2-9. In-phase and Quadrature components of length 49 Base Sequence used to form the 96 symbol mini-probe.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	25	-0.222521	0.974928
1	1.000000	0.000000	26	0.623490	-0.781831
2	1.000000	0.000000	27	-0.900968	0.433885
3	1.000000	0.000000	28	1.000000	0.000000
4	1.000000	0.000000	29	-0.900969	0.433884
5	1.000000	0.000000	30	0.623490	-0.781832
6	1.000000	0.000000	31	-0.222521	0.974928
7	1.000000	0.000000	32	-0.222521	-0.974928
8	0.623490	-0.781832	33	0.623490	0.781832
9	-0.222521	-0.974928	34	-0.900969	-0.433884
10	-0.900969	-0.433884	35	1.000000	0.000000
11	-0.900969	0.433884	36	-0.222521	0.974928
12	-0.222521	0.974928	37	-0.900969	-0.433884
13	0.623490	0.781832	38	0.623490	-0.781831
14	1.000000	0.000000	39	0.623490	0.781832
15	-0.222521	-0.974928	40	-0.900969	0.433883
16	-0.900969	0.433884	41	-0.222520	-0.974928
17	0.623490	0.781832	42	1.000000	0.000000
18	0.623490	-0.781832	43	0.623490	0.781832
19	-0.900969	-0.433884	44	-0.222521	0.974928
20	-0.222521	0.974928	45	-0.900968	0.433885
21	1.000000	0.000000	46	-0.900969	-0.433884
22	-0.900969	-0.433884	47	-0.222520	-0.974928
23	0.623490	0.781832	48	0.623488	-0.781833
24	-0.222521	-0.974928			

TABLE B.3.2.2-10. In-phase and Quadrature components of length 64 Base Sequence used to form the 128 symbol mini-probe.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	1.000000	0.000000
1	1.000000	0.000000	33	-1.000000	0.000000
2	1.000000	0.000000	34	1.000000	0.000000
3	1.000000	0.000000	35	-1.000000	0.000000
4	1.000000	0.000000	36	1.000000	0.000000
5	1.000000	0.000000	37	-1.000000	0.000000
6	1.000000	0.000000	38	1.000000	0.000000
7	1.000000	0.000000	39	-1.000000	-0.000000
8	1.000000	0.000000	40	1.000000	0.000000
9	0.707107	-0.707107	41	-0.707107	0.707107
10	0.000000	-1.000000	42	0.000000	-1.000000
11	-0.707107	-0.707107	43	0.707107	0.707107
12	-1.000000	0.000000	44	-1.000000	0.000000
13	-0.707107	0.707107	45	0.707107	-0.707107
14	0.000000	1.000000	46	0.000000	1.000000
15	0.707107	0.707107	47	-0.707107	-0.707107
16	1.000000	0.000000	48	1.000000	0.000000
17	0.000000	-1.000000	49	0.000000	1.000000
18	-1.000000	0.000000	50	-1.000000	0.000000
19	0.000000	1.000000	51	0.000000	-1.000000
20	1.000000	0.000000	52	1.000000	0.000000
21	0.000000	-1.000000	53	0.000000	1.000000
22	-1.000000	0.000000	54	-1.000000	0.000000
23	0.000000	1.000000	55	0.000000	-1.000000
24	1.000000	0.000000	56	1.000000	0.000000
25	-0.707107	-0.707107	57	0.707107	0.707107
26	0.000000	1.000000	58	0.000000	1.000000
27	0.707107	-0.707107	59	-0.707107	0.707106
28	-1.000000	0.000000	60	-1.000000	-0.000001
29	0.707107	0.707107	61	-0.707107	-0.707107
30	0.000000	-1.000000	62	0.000000	-1.000000
31	-0.707107	0.707106	63	0.707108	-0.707106

TABLE B.3.2.2-11. In-phase and Quadrature components of 81 symbol Base Sequence used to form the 144 and 160 symbol mini-probes.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	-0.500000	0.866025
1	1.000000	0.000000	33	1.000000	0.000000
2	1.000000	0.000000	34	-0.500000	-0.866025
3	1.000000	0.000000	35	-0.500000	0.866026
4	1.000000	0.000000	36	1.000000	0.000000
5	1.000000	0.000000	37	-0.939693	-0.342020
6	1.000000	0.000000	38	0.766044	0.642788
7	1.000000	0.000000	39	-0.500000	-0.866025
8	1.000000	0.000000	40	0.173648	0.984808
9	1.000000	0.000000	41	0.173648	-0.984808
10	0.766044	-0.642788	42	-0.500000	0.866026
11	0.173648	-0.984808	43	0.766044	-0.642788
12	-0.500000	-0.866025	44	-0.939693	0.342020
13	-0.939693	-0.342020	45	1.000000	0.000000
14	-0.939693	0.342020	46	-0.939693	0.342020
15	-0.500000	0.866025	47	0.766044	-0.642788
16	0.173648	0.984808	48	-0.500000	0.866025
17	0.766044	0.642788	49	0.173648	-0.984808
18	1.000000	0.000000	50	0.173649	0.984808
19	0.173648	-0.984808	51	-0.500000	-0.866026
20	-0.939693	-0.342020	52	0.766045	0.642787
21	-0.500000	0.866025	53	-0.939693	-0.342020
22	0.766044	0.642788	54	1.000000	0.000000
23	0.766044	-0.642788	55	-0.500000	0.866025
24	-0.500000	-0.866025	56	-0.500000	-0.866025
25	-0.939693	0.342020	57	1.000000	0.000000
26	0.173648	0.984808	58	-0.500000	0.866026
27	1.000000	0.000000	59	-0.500000	-0.866026
28	-0.500000	-0.866025	60	1.000000	-0.000000
29	-0.500000	0.866025	61	-0.500000	0.866025
30	1.000000	0.000000	62	-0.500000	-0.866025
31	-0.500000	-0.866025	63	1.000000	0.000000
64	0.173648	0.984808	73	0.766044	0.642788
65	-0.939693	0.342020	74	0.173648	0.984808
66	-0.500000	-0.866025	75	-0.500000	0.866026
67	0.766044	-0.642788	76	-0.939693	0.342020
68	0.766045	0.642787	77	-0.939693	-0.342020
69	-0.500000	0.866025	78	-0.500001	-0.866025
70	-0.939693	-0.342019	79	0.173648	-0.984808
71	0.173648	-0.984808	80	0.766045	-0.642787
72	1.000000	0.000000			

TABLE B.3.2.2-12. In-phase and Quadrature components of 100 symbol Base Sequence used to form the 180 and 192 symbol mini-probes.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	-0.809017	0.587785
1	1.000000	0.000000	33	0.809017	0.587785
2	1.000000	0.000000	34	0.309017	-0.951057
3	1.000000	0.000000	35	-1.000000	0.000000
4	1.000000	0.000000	36	0.309017	0.951057
5	1.000000	0.000000	37	0.809017	-0.587785
6	1.000000	0.000000	38	-0.809017	-0.587785
7	1.000000	0.000000	39	-0.309018	0.951056
8	1.000000	0.000000	40	1.000000	0.000000
9	1.000000	0.000000	41	-0.809017	-0.587785
10	1.000000	0.000000	42	0.309017	0.951056
11	0.809017	-0.587785	43	0.309017	-0.951057
12	0.309017	-0.951057	44	-0.809017	0.587785
13	-0.309017	-0.951056	45	1.000000	0.000000
14	-0.809017	-0.587785	46	-0.809017	-0.587785
15	-1.000000	0.000000	47	0.309017	0.951057
16	-0.809017	0.587785	48	0.309016	-0.951057
17	-0.309017	0.951056	49	-0.809017	0.587785
18	0.309017	0.951056	50	1.000000	0.000000
19	0.809017	0.587785	51	-1.000000	0.000000
20	1.000000	0.000000	52	1.000000	0.000000
21	0.309017	-0.951057	53	-1.000000	0.000000
22	-0.809017	-0.587785	54	1.000000	0.000000
23	-0.809017	0.587785	55	-1.000000	0.000000
24	0.309017	0.951056	56	1.000000	0.000000
25	1.000000	0.000000	57	-1.000000	-0.000000
26	0.309017	-0.951057	58	1.000000	-0.000000
27	-0.809017	-0.587785	59	-1.000000	0.000000
28	-0.809017	0.587785	60	1.000000	0.000000
29	0.309017	0.951057	61	-0.809017	0.587785
30	1.000000	0.000000	62	0.309017	-0.951057
31	-0.309017	-0.951056	63	0.309017	0.951057

TABLE B.3.2.2-12. In-phase and Quadrature components of 100 symbol Base Sequence used to form the 180 and 192 symbol mini-probes (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	-0.809017	-0.587785	82	-0.809017	0.587785
65	1.000000	0.000000	83	-0.809017	-0.587785
66	-0.809017	0.587785	84	0.309016	-0.951057
67	0.309018	-0.951056	85	1.000000	-0.000000
68	0.309018	0.951056	86	0.309018	0.951056
69	-0.809016	-0.587786	87	-0.809018	0.587785
70	1.000000	0.000000	88	-0.809018	-0.587784
71	-0.309017	0.951056	89	0.309018	-0.951056
72	-0.809017	-0.587785	90	1.000000	0.000000
73	0.809017	-0.587785	91	0.809017	0.587785
74	0.309017	0.951057	92	0.309017	0.951057
75	-1.000000	-0.000000	93	-0.309018	0.951056
76	0.309018	-0.951056	94	-0.809017	0.587785
77	0.809017	0.587786	95	-1.000000	0.000000
78	-0.809018	0.587785	96	-0.809016	-0.587786
79	-0.309018	-0.951056	97	-0.309018	-0.951056
80	1.000000	0.000000	98	0.309018	-0.951056
81	0.309017	0.951056	99	0.809016	-0.587787

TABLE B.3.2.2-13. In-phase and Quadrature components of 121 symbol Base Sequence used to form the 216, 224 and 240 symbol mini-probes.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	0.415415	0.909632
1	1.000000	0.000000	33	1.000000	0.000000
2	1.000000	0.000000	34	-0.142315	-0.989821
3	1.000000	0.000000	35	-0.959493	0.281733
4	1.000000	0.000000	36	0.415415	0.909632
5	1.000000	0.000000	37	0.841254	-0.540641
6	1.000000	0.000000	38	-0.654861	-0.755750
7	1.000000	0.000000	39	-0.654861	0.755750
8	1.000000	0.000000	40	0.841253	0.540641
9	1.000000	0.000000	41	0.415415	-0.909632
10	1.000000	0.000000	42	-0.959493	-0.281732
11	1.000000	0.000000	43	-0.142315	0.989821
12	0.841254	-0.540641	44	1.000000	0.000000
13	0.415415	-0.909632	45	-0.654861	-0.755750
14	-0.142315	-0.989821	46	-0.142315	0.989821
15	-0.654861	-0.755750	47	0.841254	-0.540641
16	-0.959493	-0.281733	48	-0.959493	-0.281733
17	-0.959493	0.281733	49	0.415415	0.909632
18	-0.654861	0.755750	50	0.415415	-0.909632
19	-0.142315	0.989821	51	-0.959493	0.281733
20	0.415415	0.909632	52	0.841253	0.540641
21	0.841253	0.540641	53	-0.142315	-0.989821
22	1.000000	0.000000	54	-0.654861	0.755749
23	0.415415	-0.909632	55	1.000000	0.000000
24	-0.654861	-0.755750	56	-0.959493	-0.281733
25	-0.959493	0.281733	57	0.841253	0.540641
26	-0.142315	0.989821	58	-0.654861	-0.755750
27	0.841253	0.540641	59	0.415415	0.909632
28	0.841254	-0.540641	60	-0.142315	-0.989821
29	-0.142315	-0.989821	61	-0.142315	0.989821
30	-0.959493	-0.281733	62	0.415415	-0.909632
31	-0.654861	0.755750	63	-0.654861	0.755749

TABLE B.3.2.2-13. In-phase and Quadrature components of 121 symbol Base Sequence used to form the 216, 224 and 240 symbol mini-probes (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	0.841254	-0.540640	93	-0.654861	0.755749
65	-0.959493	0.281732	94	-0.654861	-0.755750
66	1.000000	0.000000	95	0.841253	-0.540641
67	-0.959493	0.281733	96	0.415414	0.909633
68	0.841254	-0.540641	97	-0.959493	0.281733
69	-0.654861	0.755750	98	-0.142314	-0.989822
70	0.415415	-0.909632	99	1.000000	0.000000
71	-0.142315	0.989821	100	0.415415	0.909632
72	-0.142315	-0.989821	101	-0.654861	0.755750
73	0.415414	0.909632	102	-0.959493	-0.281732
74	-0.654861	-0.755750	103	-0.142315	-0.989821
75	0.841254	0.540640	104	0.841254	-0.540640
76	-0.959493	-0.281733	105	0.841254	0.540640
77	1.000000	0.000000	106	-0.142315	0.989821
78	-0.654861	0.755750	107	-0.959493	0.281733
79	-0.142315	-0.989821	108	-0.654862	-0.755748
80	0.841253	0.540641	109	0.415416	-0.909632
81	-0.959493	0.281733	110	1.000000	0.000000
82	0.415415	-0.909632	111	0.841253	0.540641
83	0.415414	0.909632	112	0.415415	0.909632
84	-0.959493	-0.281732	113	-0.142315	0.989821
85	0.841253	-0.540641	114	-0.654861	0.755749
86	-0.142315	0.989821	115	-0.959493	0.281732
87	-0.654860	-0.755750	116	-0.959493	-0.281733
88	1.000000	0.000000	117	-0.654860	-0.755750
89	-0.142315	0.989821	118	-0.142314	-0.989822
90	-0.959493	-0.281733	119	0.415416	-0.909632
91	0.415415	-0.909632	120	0.841254	-0.540640
92	0.841253	0.540641			

TABLE B.3.2.2-14. In-phase and Quadrature components of 144 symbol Base Sequence used to form the 272 symbol mini-probe.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	-0.500000	-0.866025
1	1.000000	0.000000	33	-1.000000	0.000000
2	1.000000	0.000000	34	-0.500000	0.866025
3	1.000000	0.000000	35	0.500000	0.866026
4	1.000000	0.000000	36	1.000000	0.000000
5	1.000000	0.000000	37	0.000000	-1.000000
6	1.000000	0.000000	38	-1.000000	0.000000
7	1.000000	0.000000	39	0.000000	1.000000
8	1.000000	0.000000	40	1.000000	0.000000
9	1.000000	0.000000	41	0.000000	-1.000000
10	1.000000	0.000000	42	-1.000000	0.000000
11	1.000000	0.000000	43	0.000000	1.000000
12	1.000000	0.000000	44	1.000000	0.000000
13	0.866025	-0.500000	45	0.000000	-1.000000
14	0.500000	-0.866025	46	-1.000000	0.000000
15	0.000000	-1.000000	47	-0.000001	1.000000
16	-0.500000	-0.866025	48	1.000000	0.000000
17	-0.866025	-0.500000	49	-0.500000	-0.866025
18	-1.000000	0.000000	50	-0.500000	0.866025
19	-0.866025	0.500000	51	1.000000	0.000000
20	-0.500000	0.866025	52	-0.500000	-0.866025
21	0.000000	1.000000	53	-0.500000	0.866025
22	0.500000	0.866025	54	1.000000	0.000000
23	0.866025	0.500000	55	-0.500000	-0.866025
24	1.000000	0.000000	56	-0.500000	0.866026
25	0.500000	-0.866025	57	1.000000	0.000000
26	-0.500000	-0.866025	58	-0.500000	-0.866026
27	-1.000000	0.000000	59	-0.500001	0.866025
28	-0.500000	0.866025	60	1.000000	0.000000
29	0.500000	0.866025	61	-0.866025	-0.500000
30	1.000000	0.000000	62	0.500000	0.866025
31	0.500000	-0.866025	63	0.000000	-1.000000

TABLE B.3.2.2-14. In-phase and Quadrature components of 144 symbol Base Sequence used to form the 272 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	-0.500000	0.866025	96	1.000000	0.000000
65	0.866025	-0.500000	97	-0.500000	0.866025
66	-1.000000	0.000000	98	-0.500000	-0.866025
67	0.866025	0.500001	99	1.000000	0.000000
68	-0.500000	-0.866026	100	-0.500000	0.866026
69	0.000000	1.000000	101	-0.500000	-0.866026
70	0.500000	-0.866026	102	1.000000	-0.000001
71	-0.866025	0.500001	103	-0.500000	0.866025
72	1.000000	0.000000	104	-0.500001	-0.866025
73	-1.000000	0.000000	105	1.000000	0.000000
74	1.000000	0.000000	106	-0.500001	0.866025
75	-1.000000	0.000000	107	-0.499999	-0.866026
76	1.000000	0.000000	108	1.000000	0.000000
77	-1.000000	0.000000	109	0.000000	1.000000
78	1.000000	0.000000	110	-1.000000	0.000000
79	-1.000000	-0.000001	111	0.000000	-1.000000
80	1.000000	-0.000001	112	1.000000	0.000000
81	-1.000000	0.000000	113	0.000000	1.000000
82	1.000000	0.000001	114	-1.000000	0.000000
83	-1.000000	-0.000001	115	0.000002	-1.000000
84	1.000000	0.000000	116	1.000000	0.000000
85	-0.866025	0.500000	117	-0.000002	1.000000
86	0.500000	-0.866025	118	-1.000000	0.000000
87	0.000000	1.000000	119	0.000002	-1.000000
88	-0.500000	-0.866025	120	1.000000	0.000000
89	0.866025	0.500001	121	0.500000	0.866025
90	-1.000000	-0.000001	122	-0.500000	0.866025
91	0.866026	-0.500000	123	-1.000000	0.000000
92	-0.500000	0.866025	124	-0.500000	-0.866026
93	0.000002	-1.000000	125	0.500000	-0.866026
94	0.499999	0.866026	126	1.000000	0.000001
95	-0.866025	-0.500001	127	0.499999	0.866026

TABLE B.3.2.2-14. In-phase and Quadrature components of 144 symbol Base Sequence used to form the 272 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
128	-0.500001	0.866025	136	-0.500000	0.866025
129	-1.000000	0.000000	137	-0.866025	0.500000
130	-0.500001	-0.866025	138	-1.000000	-0.000000
131	0.499998	-0.866026	139	-0.866025	-0.500000
132	1.000000	0.000000	140	-0.499999	-0.866026
133	0.866025	0.500000	141	0.000000	-1.000000
134	0.500000	0.866026	142	0.500000	-0.866026
135	-0.000001	1.000000	143	0.866025	-0.500000

TABLE B.3.2.2-15. In-phase and Quadrature components of 169 symbol Base Sequence used to form the 320 symbol mini-probe

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	0.885456	-0.464723
1	1.000000	0.000000	33	0.885456	0.464723
2	1.000000	0.000000	34	0.120537	0.992709
3	1.000000	0.000000	35	-0.748511	0.663123
4	1.000000	0.000000	36	-0.970942	-0.239316
5	1.000000	0.000000	37	-0.354605	-0.935016
6	1.000000	0.000000	38	0.568065	-0.822984
7	1.000000	0.000000	39	1.000000	0.000000
8	1.000000	0.000000	40	0.120537	0.992709
9	1.000000	0.000000	41	-0.970942	0.239316
10	1.000000	0.000000	42	-0.354605	-0.935016
11	1.000000	0.000000	43	0.885456	-0.464723
12	1.000000	0.000000	44	0.568065	0.822984
13	1.000000	0.000000	45	-0.748511	0.663123
14	0.885456	0.464723	46	-0.748511	-0.663123
15	0.568065	0.822984	47	0.568065	-0.822984
16	0.120537	0.992709	48	0.885456	0.464723
17	-0.354605	0.935016	49	-0.354605	0.935016
18	-0.748511	0.663123	50	-0.970942	-0.239316
19	-0.970942	0.239316	51	0.120537	-0.992709
20	-0.970942	-0.239316	52	1.000000	0.000000
21	-0.748511	-0.663123	53	-0.354605	0.935016
22	-0.354605	-0.935016	54	-0.748511	-0.663123
23	0.120537	-0.992709	55	0.885456	-0.464723
24	0.568065	-0.822984	56	0.120537	0.992709
25	0.885456	-0.464723	57	-0.970942	-0.239316
26	1.000000	0.000000	58	0.568065	-0.822984
27	0.568065	0.822984	59	0.568065	0.822984
28	-0.354605	0.935016	60	-0.970942	0.239316
29	-0.970942	0.239316	61	0.120537	-0.992709
30	-0.748511	-0.663123	62	0.885456	0.464723
31	0.120537	-0.992709	63	-0.748511	0.663123

TABLE B.3.2.2-15. In-phase and Quadrature components of 169 symbol Base Sequence used to form the 320 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	-0.354605	-0.935016	96	-0.354605	-0.935016
65	1.000000	0.000000	97	0.120537	0.992709
66	-0.748511	0.663123	98	0.120537	-0.992709
67	0.120537	-0.992709	99	-0.354605	0.935016
68	0.568065	0.822984	100	0.568065	-0.822984
69	-0.970942	-0.239316	101	-0.748511	0.663123
70	0.885456	-0.464723	102	0.885456	-0.464723
71	-0.354605	0.935016	103	-0.970942	0.239316
72	-0.354605	-0.935016	104	1.000000	0.000000
73	0.885456	0.464723	105	-0.748511	-0.663123
74	-0.970942	0.239316	106	0.120537	0.992709
75	0.568065	-0.822984	107	0.568065	-0.822984
76	0.120537	0.992709	108	-0.970942	0.239316
77	-0.748511	-0.663123	109	0.885456	0.464723
78	1.000000	0.000000	110	-0.354605	-0.935016
79	-0.970942	0.239316	111	-0.354605	0.935016
80	0.885456	-0.464723	112	0.885456	-0.464723
81	-0.748511	0.663123	113	-0.970942	-0.239316
82	0.568065	-0.822984	114	0.568065	0.822984
83	-0.354605	0.935016	115	0.120537	-0.992709
84	0.120537	-0.992709	116	-0.748511	0.663123
85	0.120537	0.992709	117	1.000000	0.000000
86	-0.354605	-0.935016	118	-0.354605	-0.935016
87	0.568065	0.822984	119	-0.748511	0.663123
88	-0.748511	-0.663123	120	0.885456	0.464723
89	0.885456	0.464723	121	0.120537	-0.992709
90	-0.970942	-0.239316	122	-0.970942	0.239316
91	1.000000	0.000000	123	0.568065	0.822984
92	-0.970942	-0.239316	124	0.568065	-0.822984
93	0.885456	0.464723	125	-0.970942	-0.239316
94	-0.748511	-0.663123	126	0.120537	0.992709
95	0.568065	0.822984	127	0.885456	-0.464723

TABLE B.3.2.2-15. In-phase and Quadrature components of 169 symbol Base Sequence used to form the 320 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
128	-0.748511	-0.663123	149	0.885456	0.464723
129	-0.354605	0.935016	150	0.885456	-0.464723
130	1.000000	0.000000	151	0.120537	-0.992709
131	0.120537	-0.992709	152	-0.748511	-0.663123
132	-0.970942	-0.239316	153	-0.970942	0.239316
133	-0.354605	0.935016	154	-0.354605	0.935016
134	0.885456	0.464723	155	0.568065	0.822984
135	0.568065	-0.822984	156	1.000000	0.000000
136	-0.748511	-0.663123	157	0.885456	-0.464723
137	-0.748511	0.663123	158	0.568065	-0.822984
138	0.568065	0.822984	159	0.120537	-0.992709
139	0.885456	-0.464723	160	-0.354605	-0.935016
140	-0.354605	-0.935016	161	-0.748511	-0.663123
141	-0.970942	0.239316	162	-0.970942	-0.239316
142	0.120537	0.992709	163	-0.970942	0.239316
143	1.000000	0.000000	164	-0.748511	0.663123
144	0.568065	-0.822984	165	-0.354605	0.935016
145	-0.354605	-0.935016	166	0.120537	0.992709
146	-0.970942	-0.239316	167	0.568065	0.822984
147	-0.748511	0.663123	168	0.885456	0.464723
148	0.120537	0.992709			

TABLE B.3.2.2-16. In-phase and Quadrature components of 196 symbol Base Sequence used to form the 384 symbol mini-probe

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	-0.900969	-0.433884
1	1.000000	0.000000	33	-0.222521	-0.974928
2	1.000000	0.000000	34	0.623490	-0.781831
3	1.000000	0.000000	35	1.000000	0.000000
4	1.000000	0.000000	36	0.623490	0.781831
5	1.000000	0.000000	37	-0.222521	0.974928
6	1.000000	0.000000	38	-0.900969	0.433884
7	1.000000	0.000000	39	-0.900969	-0.433884
8	1.000000	0.000000	40	-0.222521	-0.974928
9	1.000000	0.000000	41	0.623490	-0.781831
10	1.000000	0.000000	42	1.000000	0.000000
11	1.000000	0.000000	43	0.222521	0.974928
12	1.000000	0.000000	44	-0.900969	0.433884
13	1.000000	0.000000	45	-0.623490	-0.781831
14	1.000000	0.000000	46	0.623490	-0.781831
15	0.900969	0.433884	47	0.900969	0.433884
16	0.623490	0.781831	48	-0.222521	0.974928
17	0.222521	0.974928	49	-1.000000	0.000000
18	-0.222521	0.974928	50	-0.222521	-0.974928
19	-0.623490	0.781831	51	0.900969	-0.433884
20	-0.900969	0.433884	52	0.623490	0.781831
21	-1.000000	0.000000	53	-0.623490	0.781831
22	-0.900969	-0.433884	54	-0.900969	-0.433884
23	-0.623490	-0.781831	55	0.222521	-0.974928
24	-0.222521	-0.974928	56	1.000000	0.000000
25	0.222521	-0.974928	57	-0.222521	0.974928
26	0.623490	-0.781831	58	-0.900969	-0.433884
27	0.900969	-0.433884	59	0.623490	-0.781831
28	1.000000	0.000000	60	0.623490	0.781831
29	0.623490	0.781831	61	-0.900969	0.433884
30	-0.222521	0.974928	62	-0.222521	-0.974928
31	-0.900969	0.433884	63	1.000000	0.000000

TABLE B.3.2.2-16. In-phase and Quadrature components of 196 symbol Base Sequence used to form the 384 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	-0.222521	0.974928	96	0.623490	0.781831
65	-0.900969	-0.433884	97	-0.900969	-0.433884
66	0.623490	-0.781831	98	1.000000	0.000000
67	0.623490	0.781831	99	-1.000000	0.000000
68	-0.900969	0.433884	100	1.000000	0.000000
69	-0.222521	-0.974928	101	-1.000000	0.000000
70	1.000000	0.000000	102	1.000000	0.000000
71	-0.623490	0.781831	103	-1.000000	0.000000
72	-0.222521	-0.974928	104	1.000000	0.000000
73	0.900969	0.433884	105	-1.000000	0.000000
74	-0.900969	0.433884	106	1.000000	0.000000
75	0.222521	-0.974928	107	-1.000000	0.000000
76	0.623490	0.781831	108	1.000000	0.000000
77	-1.000000	0.000000	109	-1.000000	0.000000
78	0.623490	-0.781831	110	1.000000	0.000000
79	0.222521	0.974928	111	-1.000000	0.000000
80	-0.900969	-0.433884	112	1.000000	0.000000
81	0.900969	-0.433884	113	-0.900969	-0.433884
82	-0.222521	0.974928	114	0.623490	0.781831
83	-0.623490	-0.781831	115	-0.222521	-0.974928
84	1.000000	0.000000	116	-0.222521	0.974928
85	-0.900969	0.433884	117	0.623490	-0.781831
86	0.623490	-0.781831	118	-0.900969	0.433884
87	-0.222521	0.974928	119	1.000000	0.000000
88	-0.222521	-0.974928	120	-0.900969	-0.433884
89	0.623490	0.781831	121	0.623490	0.781831
90	-0.900969	-0.433884	122	-0.222521	-0.974928
91	1.000000	0.000000	123	-0.222521	0.974928
92	-0.900969	0.433884	124	0.623490	-0.781831
93	0.623490	-0.781831	125	-0.900969	0.433884
94	-0.222521	0.974928	126	1.000000	0.000000
95	-0.222521	-0.974928	127	-0.623490	-0.781831

TABLE B.3.2.2-16. In-phase and Quadrature components of 196 symbol Base Sequence used to form the 384 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
128	-0.222521	0.974928	162	-0.222521	0.974928
129	0.900969	-0.433884	163	0.900969	0.433884
130	-0.900969	-0.433884	164	0.623490	-0.781831
131	0.222521	0.974928	165	-0.623490	-0.781831
132	0.623490	-0.781831	166	-0.900969	0.433884
133	-1.000000	0.000000	167	0.222521	0.974928
134	0.623490	0.781831	168	1.000000	0.000000
135	0.222521	-0.974928	169	0.623490	-0.781831
136	-0.900969	0.433884	170	-0.222521	-0.974928
137	0.900969	0.433884	171	-0.900969	-0.433884
138	-0.222521	-0.974928	172	-0.900969	0.433884
139	-0.623490	0.781831	173	-0.222521	0.974928
140	1.000000	0.000000	174	0.623490	0.781831
141	-0.222521	-0.974928	175	1.000000	0.000000
142	-0.900969	0.433884	176	0.623490	-0.781831
143	0.623490	0.781831	177	-0.222521	-0.974928
144	0.623490	-0.781831	178	-0.900969	-0.433884
145	-0.900969	-0.433884	179	-0.900969	0.433884
146	-0.222521	0.974928	180	-0.222521	0.974928
147	1.000000	0.000000	181	0.623490	0.781831
148	-0.222521	-0.974928	182	1.000000	0.000000
149	-0.900969	0.433884	183	0.900969	-0.433884
150	0.623490	0.781831	184	0.623490	-0.781831
151	0.623490	-0.781831	185	0.222521	-0.974928
152	-0.900969	-0.433884	186	-0.222521	-0.974928
153	-0.222521	0.974928	187	-0.623490	-0.781831
154	1.000000	0.000000	188	-0.900969	-0.433884
155	0.222521	-0.974928	189	-1.000000	0.000000
156	-0.900969	-0.433884	190	-0.900969	0.433884
157	-0.623490	0.781831	191	-0.623490	0.781831
158	0.623490	0.781831	192	-0.222521	0.974928
159	0.900969	-0.433884	193	0.222521	0.974928
160	-0.222521	0.974928	194	0.623490	0.781831
161	-1.000000	0.974928	195	0.900969	0.433884

TABLE B.3.2.2-17. In-phase and Quadrature components of 256 symbol Base Sequence used to form the 512 symbol mini-probe

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	1.000000	0.000000
1	1.000000	0.000000	33	0.707107	0.707107
2	1.000000	0.000000	34	0.000000	1.000000
3	1.000000	0.000000	35	-0.707107	0.707107
4	1.000000	0.000000	36	-1.000000	0.000000
5	1.000000	0.000000	37	-0.707107	-0.707107
6	1.000000	0.000000	38	0.000000	-1.000000
7	1.000000	0.000000	39	0.707107	-0.707107
8	1.000000	0.000000	40	1.000000	0.000000
9	1.000000	0.000000	41	0.707107	0.707107
10	1.000000	0.000000	42	0.000000	1.000000
11	1.000000	0.000000	43	-0.707107	0.707107
12	1.000000	0.000000	44	-1.000000	0.000000
13	1.000000	0.000000	45	-0.707107	-0.707107
14	1.000000	0.000000	46	0.000000	-1.000000
15	1.000000	0.000000	47	0.707107	-0.707107
16	1.000000	0.000000	48	1.000000	0.000000
17	0.923880	0.382683	49	0.382683	0.923880
18	0.707107	0.707107	50	-0.707107	0.707107
19	0.382683	0.923880	51	-0.923880	-0.382683
20	0.000000	1.000000	52	0.000000	-1.000000
21	-0.382683	0.923880	53	0.923880	-0.382683
22	-0.707107	0.707107	54	0.707107	0.707107
23	-0.923880	0.382683	55	-0.382683	0.923880
24	-1.000000	0.000000	56	-1.000000	0.000000
25	-0.923880	-0.382683	57	-0.382683	-0.923880
26	-0.707107	-0.707107	58	0.707107	-0.707107
27	-0.382683	-0.923880	59	0.923880	0.382683
28	0.000000	-1.000000	60	0.000000	1.000000
29	0.382683	-0.923880	61	-0.923880	0.382683
30	0.707107	-0.707107	62	-0.707107	-0.707107
31	0.923880	-0.382683	63	0.382683	-0.923880

TABLE B.3.2.2-17. In-phase and Quadrature components of 256 symbol Base Sequence used to form the 512 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	1.000000	0.000000	96	1.000000	0.000000
65	0.000000	1.000000	97	-0.707107	0.707107
66	-1.000000	0.000000	98	0.000000	-1.000000
67	0.000000	-1.000000	99	0.707107	0.707107
68	1.000000	0.000000	100	-1.000000	0.000000
69	0.000000	1.000000	101	0.707107	-0.707107
70	-1.000000	0.000000	102	0.000000	1.000000
71	0.000000	-1.000000	103	-0.707107	-0.707107
72	1.000000	0.000000	104	1.000000	0.000000
73	0.000000	1.000000	105	-0.707107	0.707107
74	-1.000000	0.000000	106	0.000000	-1.000000
75	0.000000	-1.000000	107	0.707107	0.707107
76	1.000000	0.000000	108	-1.000000	0.000000
77	0.000000	1.000000	109	0.707107	-0.707107
78	-1.000000	0.000000	110	0.000000	1.000000
79	0.000000	-1.000000	111	-0.707107	-0.707107
80	1.000000	0.000000	112	1.000000	0.000000
81	-0.382683	0.923880	113	-0.923880	0.382683
82	-0.707107	-0.707107	114	0.707107	-0.707107
83	0.923880	-0.382683	115	-0.382683	0.923880
84	0.000000	1.000000	116	0.000000	-1.000000
85	-0.923880	-0.382683	117	0.382683	0.923880
86	0.707107	-0.707107	118	-0.707107	-0.707107
87	0.382683	0.923880	119	0.923880	0.382683
88	-1.000000	0.000000	120	-1.000000	0.000000
89	0.382683	-0.923880	121	0.923880	-0.382683
90	0.707107	0.707107	122	-0.707107	0.707107
91	-0.923880	0.382683	123	0.382683	-0.923880
92	0.000000	-1.000000	124	0.000000	1.000000
93	0.923880	0.382683	125	-0.382683	-0.923880
94	-0.707107	0.707107	126	0.707107	0.707107
95	-0.382683	-0.923880	127	-0.923880	-0.382683

TABLE B.3.2.2-17. In-phase and Quadrature components of 256 symbol Base Sequence used to form the 512 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
128	1.000000	0.000000	160	1.000000	0.000000
129	-1.000000	0.000000	161	-0.707107	-0.707107
130	1.000000	0.000000	162	0.000000	1.000000
131	-1.000000	0.000000	163	0.707107	-0.707107
132	1.000000	0.000000	164	-1.000000	0.000000
133	-1.000000	0.000000	165	0.707107	0.707107
134	1.000000	0.000000	166	0.000000	-1.000000
135	-1.000000	0.000000	167	-0.707107	0.707107
136	1.000000	0.000000	168	1.000000	0.000000
137	-1.000000	0.000000	169	-0.707107	-0.707107
138	1.000000	0.000000	170	0.000000	1.000000
139	-1.000000	0.000000	171	0.707107	-0.707107
140	1.000000	0.000000	172	-1.000000	0.000000
141	-1.000000	0.000000	173	0.707107	0.707107
142	1.000000	0.000000	174	0.000000	-1.000000
143	-1.000000	0.000000	175	-0.707107	0.707107
144	1.000000	0.000000	176	1.000000	0.000000
145	-0.923880	-0.382683	177	-0.382683	-0.923880
146	0.707107	0.707107	178	-0.707107	0.707107
147	-0.382683	-0.923880	179	0.923880	0.382683
148	0.000000	1.000000	180	0.000000	-1.000000
149	0.382683	-0.923880	181	-0.923880	0.382683
150	-0.707107	0.707107	182	0.707107	0.707107
151	0.923880	-0.382683	183	0.382683	-0.923880
152	-1.000000	0.000000	184	-1.000000	0.000000
153	0.923880	0.382683	185	0.382683	0.923880
154	-0.707107	-0.707107	186	0.707107	-0.707107
155	0.382683	0.923880	187	-0.923880	-0.382683
156	0.000000	-1.000000	188	0.000000	1.000000
157	-0.382683	0.923880	189	0.923880	-0.382683
158	0.707107	-0.707107	190	-0.707107	-0.707107
159	-0.923880	0.382683	191	-0.382683	0.923880

TABLE B.3.2.2-17. In-phase and Quadrature components of 256 symbol Base Sequence used to form the 512 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
192	1.000000	0.000000	224	1.000000	0.000000
193	0.000000	-1.000000	225	0.707107	-0.707107
194	-1.000000	0.000000	226	0.000000	-1.000000
195	0.000000	1.000000	227	-0.707107	-0.707107
196	1.000000	0.000000	228	-1.000000	0.000000
197	0.000000	-1.000000	229	-0.707107	0.707107
198	-1.000000	0.000000	230	0.000000	1.000000
199	0.000000	1.000000	231	0.707107	0.707107
200	1.000000	0.000000	232	1.000000	0.000000
201	0.000000	-1.000000	233	0.707107	-0.707107
202	-1.000000	0.000000	234	0.000000	-1.000000
203	0.000000	1.000000	235	-0.707107	-0.707107
204	1.000000	0.000000	236	-1.000000	0.000000
205	0.000000	-1.000000	237	-0.707107	0.707107
206	-1.000000	0.000000	238	0.000000	1.000000
207	0.000000	1.000000	239	0.707107	0.707107
208	1.000000	0.000000	240	1.000000	0.000000
209	0.382683	-0.923880	241	0.923880	-0.382683
210	-0.707107	-0.707107	242	0.707107	-0.707107
211	-0.923880	0.382683	243	0.382683	-0.923880
212	0.000000	1.000000	244	0.000000	-1.000000
213	0.923880	0.382683	245	-0.382683	-0.923880
214	0.707107	-0.707107	246	-0.707107	-0.707107
215	-0.382683	-0.923880	247	-0.923880	-0.382683
216	-1.000000	0.000000	248	-1.000000	0.000000
217	-0.382683	0.923880	249	-0.923880	0.382683
218	0.707107	0.707107	250	-0.707107	0.707107
219	0.923880	-0.382683	251	-0.382683	0.923880
220	0.000000	-1.000000	252	0.000000	1.000000
221	-0.923880	-0.382683	253	0.382683	0.923880
222	-0.707107	0.707107	254	0.707107	0.707107
223	0.382683	0.923880	255	0.923880	0.382683

TABLE B.3.2.2-18. In-phase and Quadrature components of 289 symbol Base Sequence used to form the 576 symbol mini-probe

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.000000	0.000000	32	0.739009	-0.673696
1	1.000000	0.000000	33	0.932472	-0.361242
2	1.000000	0.000000	34	1.000000	0.000000
3	1.000000	0.000000	35	0.739009	0.673696
4	1.000000	0.000000	36	0.092268	0.995734
5	1.000000	0.000000	37	-0.602635	0.798017
6	1.000000	0.000000	38	-0.982973	0.183750
7	1.000000	0.000000	39	-0.850217	-0.526432
8	1.000000	0.000000	40	-0.273663	-0.961826
9	1.000000	0.000000	41	0.445738	-0.895163
10	1.000000	0.000000	42	0.932472	-0.361242
11	1.000000	0.000000	43	0.932472	0.361242
12	1.000000	0.000000	44	0.445738	0.895163
13	1.000000	0.000000	45	-0.273663	0.961826
14	1.000000	0.000000	46	-0.850217	0.526432
15	1.000000	0.000000	47	-0.982973	-0.183750
16	1.000000	0.000000	48	-0.602635	-0.798017
17	1.000000	0.000000	49	0.092268	-0.995734
18	0.932472	0.361242	50	0.739009	-0.673696
19	0.739009	0.673696	51	1.000000	0.000000
20	0.445738	0.895163	52	0.445738	0.895163
21	0.092268	0.995734	53	-0.602635	0.798017
22	-0.273663	0.961826	54	-0.982973	-0.183750
23	-0.602635	0.798017	55	-0.273663	-0.961826
24	-0.850217	0.526432	56	0.739009	-0.673696
25	-0.982973	0.183750	57	0.932472	0.361242
26	-0.982973	-0.183750	58	0.092268	0.995734
27	-0.850217	-0.526432	59	-0.850217	0.526432
28	-0.602635	-0.798017	60	-0.850217	-0.526432
29	-0.273663	-0.961826	61	0.092268	-0.995734
30	0.092268	-0.995734	62	0.932472	-0.361242
31	0.445738	-0.895163	63	0.739009	0.673696

TABLE B.3.2.2-18. In-phase and Quadrature components of 289 symbol Base Sequence used to form the 576 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
64	-0.273663	0.961826	96	0.092268	0.995734
65	-0.982973	0.183750	97	-0.982973	-0.183750
66	-0.602635	-0.798017	98	0.445738	-0.895163
67	0.445738	-0.895163	99	0.739009	0.673696
68	1.000000	0.000000	100	-0.850217	0.526432
69	0.092268	0.995734	101	-0.273663	-0.961826
70	-0.982973	0.183750	102	1.000000	0.000000
71	-0.273663	-0.961826	103	-0.602635	0.798017
72	0.932472	-0.361242	104	-0.273663	-0.961826
73	0.445738	0.895163	105	0.932472	0.361242
74	-0.850217	0.526432	106	-0.850217	0.526432
75	-0.602635	-0.798017	107	0.092268	-0.995734
76	0.739009	-0.673696	108	0.739009	0.673696
77	0.739009	0.673696	109	-0.982973	0.183750
78	-0.602635	0.798017	110	0.445738	-0.895163
79	-0.850217	-0.526432	111	0.445738	0.895163
80	0.445738	-0.895163	112	-0.982973	-0.183750
81	0.932472	0.361242	113	0.739009	-0.673696
82	-0.273663	0.961826	114	0.092268	0.995734
83	-0.982973	-0.183750	115	-0.850217	-0.526432
84	0.092268	-0.995734	116	0.932472	-0.361242
85	1.000000	0.000000	117	-0.273663	0.961826
86	-0.273663	0.961826	118	-0.602635	-0.798017
87	-0.850217	-0.526432	119	1.000000	0.000000
88	0.739009	-0.673696	120	-0.850217	0.526432
89	0.445738	0.895163	121	0.445738	-0.895163
90	-0.982973	0.183750	122	0.092268	0.995734
91	0.092268	-0.995734	123	-0.602635	-0.798017
92	0.932472	0.361242	124	0.932472	0.361242
93	-0.602635	0.798017	125	-0.982973	0.183750
94	-0.602635	-0.798017	126	0.739009	-0.673696
95	0.932472	-0.361242	127	-0.273663	0.961826

TABLE B.3.2.2-18. In-phase and Quadrature components of 289 symbol Base Sequence used to form the 576 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
128	-0.273663	-0.961826	160	-0.273663	-0.961826
129	0.739009	0.673696	161	0.092268	0.995734
130	-0.982973	-0.183750	162	0.092268	-0.995734
131	0.932472	-0.361242	163	-0.273663	0.961826
132	-0.602635	0.798017	164	0.445738	-0.895163
133	0.092268	-0.995734	165	-0.602635	0.798017
134	0.445738	0.895163	166	0.739009	-0.673696
135	-0.850217	-0.526432	167	-0.850217	0.526432
136	1.000000	0.000000	168	0.932472	-0.361242
137	-0.982973	0.183750	169	-0.982973	0.183750
138	0.932472	-0.361242	170	1.000000	0.000000
139	-0.850217	0.526432	171	-0.850217	-0.526432
140	0.739009	-0.673696	172	0.445738	0.895163
141	-0.602635	0.798017	173	0.092268	-0.995734
142	0.445738	-0.895163	174	-0.602635	0.798017
143	-0.273663	0.961826	175	0.932472	-0.361242
144	0.092268	-0.995734	176	-0.982973	-0.183750
145	0.092268	0.995734	177	0.739009	0.673696
146	-0.273663	-0.961826	178	-0.273663	-0.961826
147	0.445738	0.895163	179	-0.273663	0.961826
148	-0.602635	-0.798017	180	0.739009	-0.673696
149	0.739009	0.673696	181	-0.982973	0.183750
150	-0.850217	-0.526432	182	0.932472	0.361242
151	0.932472	0.361242	183	-0.602635	-0.798017
152	-0.982973	-0.183750	184	0.092268	0.995734
153	1.000000	0.000000	185	0.445738	-0.895163
154	-0.982973	-0.183750	186	-0.850217	0.526432
155	0.932472	0.361242	187	1.000000	0.000000
156	-0.850217	-0.526432	188	-0.602635	-0.798017
157	0.739009	0.673696	189	-0.273663	0.961826
158	-0.602635	-0.798017	190	0.932472	-0.361242
159	0.445738	0.895163	191	-0.850217	-0.526432

TABLE B.3.2.2-18. In-phase and Quadrature components of 289 symbol Base Sequence used to form the 576 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
192	0.092268	0.995734	224	-0.273663	0.961826
193	0.739009	-0.673696	225	0.932472	0.361242
194	-0.982973	-0.183750	226	0.445738	-0.895163
195	0.445738	0.895163	227	-0.850217	-0.526432
196	0.445738	-0.895163	228	-0.602635	0.798017
197	-0.982973	0.183750	229	0.739009	0.673696
198	0.739009	0.673696	230	0.739009	-0.673696
199	0.092268	-0.995734	231	-0.602635	-0.798017
200	-0.850217	0.526432	232	-0.850217	0.526432
201	0.932472	0.361242	233	0.445738	0.895163
202	-0.273663	-0.961826	234	0.932472	-0.361242
203	-0.602635	0.798017	235	-0.273663	-0.961826
204	1.000000	0.000000	236	-0.982973	0.183750
205	-0.273663	-0.961826	237	0.092268	0.995734
206	-0.850217	0.526432	238	1.000000	0.000000
207	0.739009	0.673696	239	0.445738	-0.895163
208	0.445738	-0.895163	240	-0.602635	-0.798017
209	-0.982973	-0.183750	241	-0.982973	0.183750
210	0.092268	0.995734	242	-0.273663	0.961826
211	0.932472	-0.361242	243	0.739009	0.673696
212	-0.602635	-0.798017	244	0.932472	-0.361242
213	-0.602635	0.798017	245	0.092268	-0.995734
214	0.932472	0.361242	246	-0.850217	-0.526432
215	0.092268	-0.995734	247	-0.850217	0.526432
216	-0.982973	0.183750	248	0.092268	0.995734
217	0.445738	0.895163	249	0.932472	0.361242
218	0.739009	-0.673696	250	0.739009	-0.673696
219	-0.850217	-0.526432	251	-0.273663	-0.961826
220	-0.273663	0.961826	252	-0.982973	-0.183750
221	1.000000	0.000000	253	-0.602635	0.798017
222	0.092268	-0.995734	254	0.445738	0.895163
223	-0.982973	-0.183750	255	1.000000	0.000000

TABLE B.3.2.2-18. In-phase and Quadrature components of 289 symbol Base Sequence used to form the 576 symbol mini-probe (continued)

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
256	0.739009	-0.673696	273	0.932472	-0.361242
257	0.092268	-0.995734	274	0.739009	-0.673696
258	-0.602635	-0.798017	275	0.445738	-0.895163
259	-0.982973	-0.183750	276	0.092268	-0.995734
260	-0.850217	0.526432	277	-0.273663	-0.961826
261	-0.273663	0.961826	278	-0.602635	-0.798017
262	0.445738	0.895163	279	-0.850217	-0.526432
263	0.932472	0.361242	280	-0.982973	-0.183750
264	0.932472	-0.361242	281	-0.982973	0.183750
265	0.445738	-0.895163	282	-0.850217	0.526432
266	-0.273663	-0.961826	283	-0.602635	0.798017
267	-0.850217	-0.526432	284	-0.273663	0.961826
268	-0.982973	0.183750	285	0.092268	0.995734
269	-0.602635	0.798017	286	0.445738	0.895163
270	0.092268	0.995734	287	0.739009	0.673696
271	0.739009	0.673696	288	0.932472	0.361242
272	1.000000	0.000000			

B.3.3 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. Tables B.3.3-1 through B.3.3-12 show the number of input data bits per block as function of both data rate and interleaver length, one table for each bandwidth. Note that the “Number of Input Bits” should not be confused with the “Number of Bits,” which is the interleaver size. The bits from an input data block will be mapped through the coding and interleaving into a number of data frames and it is the number of bits per frame times the number of data frames that defines the interleaver length.

TABLE B.3.3-1. Interleaver Parameters for 3kHz Bandwidth

Waveform Number	UltraShort			Short			Medium			Long		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	40	80	40	144	288	144	576	1152	576
1	4	192	24	16	768	96	64	3072	384	256	12288	1536
2	4	192	48	16	768	192	64	3072	768	256	12288	3072
3	2	192	64	8	768	256	32	3072	1024	128	12288	4096
4	2	192	128	8	768	512	32	3072	2048	128	12288	8192
5	1	256	192	4	1024	768	16	4096	3072	64	16384	12288
6	1	512	384	4	2048	1536	16	8192	6144	64	32768	24576
7	1	768	576	4	3072	2304	16	12288	9216	64	49152	36864
8	1	1024	768	4	4096	3072	16	16384	12288	64	65536	49152
9	1	1280	960	4	5120	3840	16	20480	15360	64	81920	61440
10	1	1536	1152	4	6144	4608	16	24576	18432	64	98304	73728
11	1	2160	1920	4	8640	7680	16	34560	30720	64	138240	122880
12	1	2880	2560	4	11520	10240	16	46080	40960	64	184320	163840
13	1	512	288	4	2048	1152	16	8192	4608	64	32768	18432

TABLE B.3.3-2. Interleaver Parameters for 6kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	80	160	80	288	576	288	1152	2304	1152
1	4	384	48	16	1536	192	64	6144	768	256	24576	3072
2	4	384	96	16	1536	384	64	6144	1536	256	24576	6144
3	2	408	136	8	1632	544	32	6528	2176	128	26112	8704
4	2	408	272	8	1632	1088	32	6528	4352	128	26112	17408
5	1	544	408	4	2176	1632	16	8704	6528	64	34816	26112
6	1	1088	816	4	4352	3264	16	17408	13056	64	69632	52224
7	1	1632	1224	4	6528	4896	16	26112	19584	64	104448	78336
8	1	2176	1632	4	8704	6528	16	34816	26112	64	139264	104448
9	1	2720	2040	4	10880	8160	16	43520	32640	64	174080	130560
10	1	3264	2448	4	13056	9792	16	52224	39168	64	208896	156672
11	1	3240	2880	4	12960	11520	16	51840	46080	64	207360	184320
12	1	4320	3840	4	17280	15360	16	69120	61440	64	276480	245760

TABLE B.3.3-3. Interleaver Parameters for 9kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	120	240	160	432	864	576	1728	3456	2304
1	2	576	72	8	2304	288	32	9216	1152	128	36864	4608
2	2	576	144	8	2304	576	32	9216	2304	128	36864	9216
3	2	576	288	8	2304	1152	32	9216	4608	128	36864	18432
4	-	-	-	-	-	-	-	-	-	-	-	-
5	1	768	576	4	3072	2304	16	12288	9216	64	49152	36864
6	1	1536	1152	4	6144	4608	16	24576	18432	64	98304	73728
7	1	2304	1728	4	9216	6912	16	36864	27648	64	147456	110592
8	1	3072	2304	4	12288	9216	16	49152	36864	64	196608	147456
9	1	3840	2880	4	15360	11520	16	61440	46080	64	245760	184320
10	1	4608	3456	4	18432	13824	16	73728	55296	64	294912	221184
11	1	6480	5760	4	25920	23040	16	103680	92160	64	414720	368640
12	1	8640	7680	4	34560	30720	16	138240	122880	64	552960	491520

TABLE B.3.3-4. Interleaver Parameters for 12kHz Bandwidth

Waveform Number	UltraShort			Short			Medium			Long		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	160	320	160	576	1152	576	2304	4608	2304
1	3	576	72	12	2304	288	48	9216	1152	192	36864	4608
2	3	576	144	12	2304	576	48	9216	2304	192	36864	9216
3	2	768	256	8	3072	1024	32	12288	4096	128	49152	16384
4	2	768	512	8	3072	2048	32	12288	8192	128	49152	32768
5	1	1024	768	4	4096	3072	16	16384	12288	64	65536	49152
6	1	2048	1536	4	8192	6144	16	32768	24576	64	131072	98304
7	1	3072	2304	4	12288	9216	16	49152	36864	64	196608	147456
8	1	4096	3072	4	16384	12288	16	65536	49152	64	262144	196608
9	1	5120	3840	4	20480	15360	16	81920	61440	64	327680	245760
10	1	6144	4608	4	24576	18432	16	98304	73728	64	393216	294912
11	1	6480	5760	4	25920	23040	16	103680	92160	64	414720	368640
12	1	8640	7680	4	34560	30720	16	138240	122880	64	552960	491520

TABLE B.3.3-5. Interleaver Parameters for 15kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	200	400	160	720	1440	576	2880	5760	2304
1	3	864	72	12	3456	288	48	13824	1152	192	55296	4608
2	3	864	144	12	3456	576	48	13824	2304	192	55296	9216
3	3	864	288	12	3456	1152	48	13824	4608	192	55296	18432
4	3	864	576	12	3456	2304	48	13824	9216	192	55296	36864
5	1	1280	960	4	5120	3840	16	20480	15360	64	81920	61440
6	1	2560	1920	4	10240	7680	16	40960	30720	64	163840	122880
7	1	3840	2880	4	15360	11520	16	61440	46080	64	245760	184320
8	1	5120	3840	4	20480	15360	16	81920	61440	64	327680	245760
9	1	6400	4800	4	25600	19200	16	102400	76800	64	409600	307200
10	1	7680	5760	4	30720	23040	16	122880	92160	64	491520	368640
11	1	6912	6144	4	27648	24576	16	110592	98304	64	442368	393216
12	1	9216	8192	4	36864	32768	16	147456	131072	64	589824	524288

TABLE B.3.3-6. Interleaver Parameters for 18kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	240	480	320	864	1728	1152	3456	6912	4608
1	3	1344	168	12	5376	672	48	21504	2688	192	86016	10752
2	3	1344	336	12	5376	1344	48	21504	5376	192	86016	21504
3	3	1344	672	12	5376	2688	48	21504	10752	192	86016	43008
4	-	-	-	-	-	-	-	-	-	-	-	-
5	1	1536	1152	4	6144	4608	16	24576	18432	64	98304	73728
6	1	3072	2304	4	12288	9216	16	49152	36864	64	196608	147456
7	1	4608	3456	4	18432	13824	16	73728	55296	64	294912	221184
8	1	6144	4608	4	24576	18432	16	98304	73728	64	393216	294912
9	1	7680	5760	4	30720	23040	16	122880	92160	64	491520	368640
10	1	9216	6912	4	36864	27648	16	147456	110592	64	589824	442368
11	1	11520	10240	4	46080	40960	16	184320	163840	64	737280	655360
12	1	15360	12800	4	61440	51200	16	245760	204800	64	983040	819200

TABLE B.3.3-7. Interleaver Parameters for 21kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	280	560	160	1008	2016	576	4032	8064	2304
1	4	1280	80	16	5120	320	64	20480	1280	256	81920	5120
2	4	1280	160	16	5120	640	64	20480	2560	256	81920	10240
3	4	1280	320	16	5120	1280	64	20480	5120	256	81920	20480
4	4	1280	640	16	5120	2560	64	20480	10240	256	81920	40960
5	1	1344	896	4	5376	3584	16	21504	14336	64	86016	57344
6	1	2688	1792	4	10752	7168	16	43008	28672	64	172032	114688
7	1	4032	2688	4	16128	10752	16	64512	43008	64	258048	172032
8	1	5376	3584	4	21504	14336	16	86016	57344	64	344064	229376
9	1	6720	4480	4	26880	17920	16	107520	71680	64	430080	286720
10	1	8064	5376	4	32256	21504	16	129024	86016	64	516096	344064
11	1	15360	12288	4	61440	49152	16	245760	196608	64	983040	786432
12	1	20480	18432	4	81920	73728	16	327680	294912	64	1310720	1179648

TABLE B.3.3-8. Interleaver Parameters for 24kHz Bandwidth

Waveform Number	UltraShort			Short			Medium			Long		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	320	640	320	1152	2304	1152	4608	9216	4608
1	4	1088	136	16	4352	544	64	17408	2176	256	69632	8704
2	4	1088	272	16	4352	1088	64	17408	4352	256	69632	17408
3	2	1632	544	8	6528	2176	32	26112	8704	128	104448	34816
4	2	1632	1088	8	6528	4352	32	26112	17408	128	104448	69632
5	1	2176	1632	4	8704	6528	16	34816	26112	64	139264	104448
6	1	4352	3264	4	17408	13056	16	69632	52224	64	278528	208896
7	1	6528	4896	4	26112	19584	16	104448	78336	64	417792	313344
8	1	8704	6528	4	34816	26112	16	139264	104448	64	557056	417792
9	1	10880	8160	4	43520	32640	16	174080	130560	64	696320	522240
10	1	13056	9792	4	52224	39168	16	208896	156672	64	835584	626688
11	1	11520	10240	4	46080	40960	16	184320	163840	64	737280	655360
12	1	15360	12800	4	61440	51200	16	245760	204800	64	983040	819200

TABLE B.3.3-9. Interleaver Parameters for 30 kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	200	800	320	720	2880	1152	2880	11520	4608
1	3	1728	144	12	6912	576	48	27,648	2304	192	110,592	9216
2	3	1728	288	12	6912	1152	48	27,648	4608	192	110,592	18,432
3	3	1728	576	12	6912	2304	48	27,648	9216	192	110,592	36,864
4	3	1728	1152	12	6912	4608	48	27,648	18,432	192	110,592	73,728
5	1	2560	1920	4	10,240	7680	16	40,960	30,720	64	163,840	122,880
6	1	5120	3840	4	20,480	15,360	16	81,920	61,440	64	327,680	245,760
7	1	7680	5760	4	30,720	23,040	16	122,880	92,160	64	491,520	368,640
8	1	10,240	7680	4	40,960	30,720	16	163,840	122,880	64	655,360	491,520
9	1	12,800	9600	4	51,200	38,400	16	204,800	153,600	64	819,200	614,400
10	1	15,360	11,520	4	61,440	46,080	16	245,760	184,320	64	983,040	737,280
11	1	16,200	14,400	4	64,800	57,600	16	259,200	230,400	64	1,036,800	921,600
12	1	21,600	19,200	4	86,400	76,800	16	345,600	307,200	64	1,382,400	1,228,800

TABLE B.3.3-10. Interleaver Parameters for 36 kHz Bandwidth

Waveform Number	UltraShort			Short			Medium			Long		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	240	960	640	864	3456	2304	3856	13824	9216
1	2	2304	288	8	9216	1152	32	36,864	4608	128	147,456	18,432
2	2	2304	576	8	9216	2304	32	36,864	9216	128	147,456	36,864
3	2	2304	1152	8	9216	4608	32	36,864	18,432	128	147,456	73,728
4	1	3072	1536	4	12,288	6144	16	49,152	24,576	64	196,608	98,304
5	1	3072	2304	4	12,288	9216	16	49,152	36,864	64	196,608	147,456
6	1	6144	4608	4	24,576	18,432	16	98,304	73,728	64	393,216	294,912
7	1	9216	6912	4	36,864	27,648	16	147,456	110,592	64	589,824	442,368
8	1	12,288	9216	4	49,152	36,864	16	196,608	147,456	64	786,432	589,824
9	1	15,360	11,520	4	61,440	46,080	16	245,760	184,320	64	983,040	737,280
10	1	18,432	13,824	4	73,728	55,296	16	294,912	221,184	64	1,179,648	884,736
11	1	19,440	17,280	4	77,760	69,120	16	311,040	276,480	64	1,244,160	1,105,920
12	1	25,920	23,040	4	103,680	92,160	16	414,720	368,640	64	1,658,880	1,474,560

TABLE B.3.3-11. Interleaver Parameters for 42 kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	280	1120	640	1008	4032	2304	7032	16128	9216
1	3	2304	288	12	9216	1152	48	36,864	4608	192	147,456	18,432
2	3	2304	576	12	9216	2304	48	36,864	9216	192	147,456	36,864
3	3	2304	1152	12	9216	4608	48	36,864	18,432	192	147,456	73,728
4	1	3456	1728	4	13,824	6912	16	55,296	27,648	64	221,184	110,592
5	1	3456	2304	4	13,824	9216	16	55,296	36,864	64	221,184	147,456
6	1	6912	4608	4	27,648	18,432	16	110,592	73,728	64	442,368	294,912
7	1	10,368	6912	4	41,472	27,648	16	165,888	110,592	64	663,552	442,368
8	1	13,824	9216	4	55,296	36,864	16	221,184	147,456	64	884,736	589,824
9	1	17,280	11,520	4	69,120	46,080	16	276,480	184,320	64	1,105,920	737,280
10	1	20,736	13,824	4	82,944	55,296	16	331,776	221,184	64	1,327,104	884,736
11	1	23,040	19,200	4	92,160	76,800	16	368,640	307,200	64	1,474,560	1,228,800
12	1	30,720	23,040	4	122,880	92,160	16	491,520	368,640	64	1,966,080	1,474,560

TABLE B.3.3-12. Interleaver Parameters for 48 kHz Bandwidth

Waveform Number	**UltraShort**			**Short**			**Medium**			**Long**		
	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits	Number of Frames	Number of bits	Number of Input Bits
0	-	-	-	320	1280	640	1152	4608	2304	4608	18432	9216
1	3	1536	192	18	9216	1152	72	36,864	4608	288	147,456	18,432
2	3	1536	384	18	9216	2304	72	36,864	9216	288	147,456	36,864
3	3	1536	768	18	9216	4608	72	36,864	18,432	288	147,456	73,728
4	1	2560	1280	6	15,360	7680	24	61,440	30,720	96	245,760	122,880
5	1	2560	1920	6	15,360	11,520	24	61,440	46,080	96	245,760	184,320
6	1	5120	3840	6	30,720	23,040	24	122,880	92,160	96	491,520	368,640
7	1	7680	5760	6	46,080	34,560	24	184,320	138,240	96	737,280	552,960
8	1	10,240	7680	6	61,440	46,080	24	245,760	184,320	96	983,040	737,280
9	1	12,800	9600	6	76,800	57,600	24	307,200	230,400	96	1,228,800	921,600
10	1	15,360	11,520	6	92,160	69,120	24	368,640	276,480	96	1,474,560	1,105,920
11	1	17,280	15,360	6	103,680	92,160	24	414,720	368,640	96	1,658,880	1,474,560
12	1	23,040	19,200	6	138,240	115,200	24	552,960	460,800	96	2,211,840	1,843,200

B.3.3.1 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 shall coincide with an interleaver boundary. 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.

B.3.3.2 Block encoding

The full-tail-biting and puncturing techniques shall be used with either a rate 1/2 k=7 convolutional code or a rate 1/2 k=9 convolutional code to produce a block code that is the same length as the interleaver. For those data rates where the code is punctured to rate 9/10, 8/9, 5/6, 4/5, 3/4, 2/3, 9/16, 1/2, 2/5, 1/3, 2/7, 1/4, 1/6, 1/8, 1/12 and 1/16 the punctured block shall still fit exactly within the interleaver. Table B.B.3.3.2-1 indicates which code rates and modulations are used by the different waveform and bandwidths supported by this standard.

TABLE B.3.3.2-1. Code Rate and Modulation.

Waveform Number	**0** Walsh	**1** BPSK	**2** BPSK	**3** BPSK	**4** BPSK	**5** BPSK	**6** QPSK	**7** 8PSK	**8** 16QAM	**9** 32QAM	**10** 64QAM	**11** 64QAM	**12** 256QAM	**13** QPSK
Bandwidth (kHz)														
3	1/2	1/8	1/4	1/3	2/3	3/4	3/4	3/4	3/4	3/4	3/4	8/9	8/9	9/16
6	1/2	1/8	1/4	1/3	2/3	3/4	3/4	3/4	3/4	3/4	3/4	8/9	8/9	
9	2/3	1/8	1/4	1/2	-	3/4	3/4	3/4	3/4	3/4	3/4	8/9	8/9	
12	1/2	1/8	1/4	1/3	2/3	3/4	3/4	3/4	3/4	3/4	3/4	8/9	8/9	
15	2/5	1/12	1/6	1/3	2/3	3/4	3/4	3/4	3/4	3/4	3/4	8/9	8/9	
18	2/3	1/8	1/4	1/2	-	3/4	3/4	3/4	3/4	3/4	3/4	8/9	5/6	
21	2/7	1/16	1/8	1/4	1/2	2/3	2/3	2/3	2/3	2/3	2/3	4/5	9/10	
24	1/2	1/8	1/4	1/3	2/3	3/4	3/4	3/4	3/4	3/4	3/4	8/9	5/6	
30	2/5	1/12	1/6	1/3	2/3	3/4	3/4	3/4	3/4	3/4	3/4	8/9	8/9	
36	2/3	1/8	1/4	1/2	1/2	3/4	3/4	3/4	3/4	3/4	3/4	8/9	8/9	
42	4/7	1/8	1/4	1/2	1/2	2/3	2/3	2/3	2/3	2/3	2/3	5/6	3/4	
48	1/2	1/8	1/4	1/2	1/2	3/4	3/4	3/4	3/4	3/4	3/4	8/9	5/6	

B.3.3.2.1 Constraint length 7, rate 1/2 convolutional code

A constraint length 7, rate 1/2 convolutional code shall be used prior to puncturing. Figure B.B.3.3.2.1-1 is a pictorial representation of the encoder.

Polynomials:

(b0) $T_1 = x^6 + x^4 + x^3 + x^1 + 1$

(b1) $T_2 = x^6 + x^5 + x^4 + x^3 + 1$

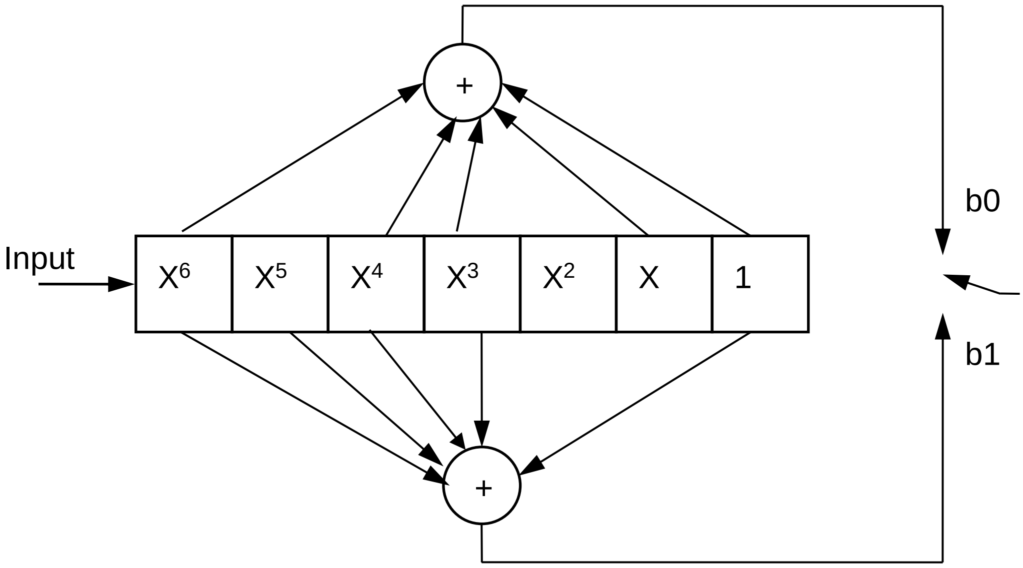

FIGURE B.3.3.2.1-1. Constraint length 7, rate 1/2 convolutional encoder.

The two summing nodes in the figure represent modulo 2 additions. For each bit input to the encoder, two bits are taken from the encoder, with the upper output bit b0, generated by polynomial $T_1(x)$, taken first.

B.3.3.2.2 Constraint length 9, rate 1/2 convolutional code

A constraint length 9, rate 1/2 convolutional code shall be used prior to puncturing. Figure B.B.3.3.2.2-1 is a pictorial representation of the encoder.

Polynomials:

(b0) T1 = $x^8+x^6 + x^5 + x^4 + 1$

(b1) T2 = $x^8+x^7 + x^6 + x^5 + x^3 + x^1+1$

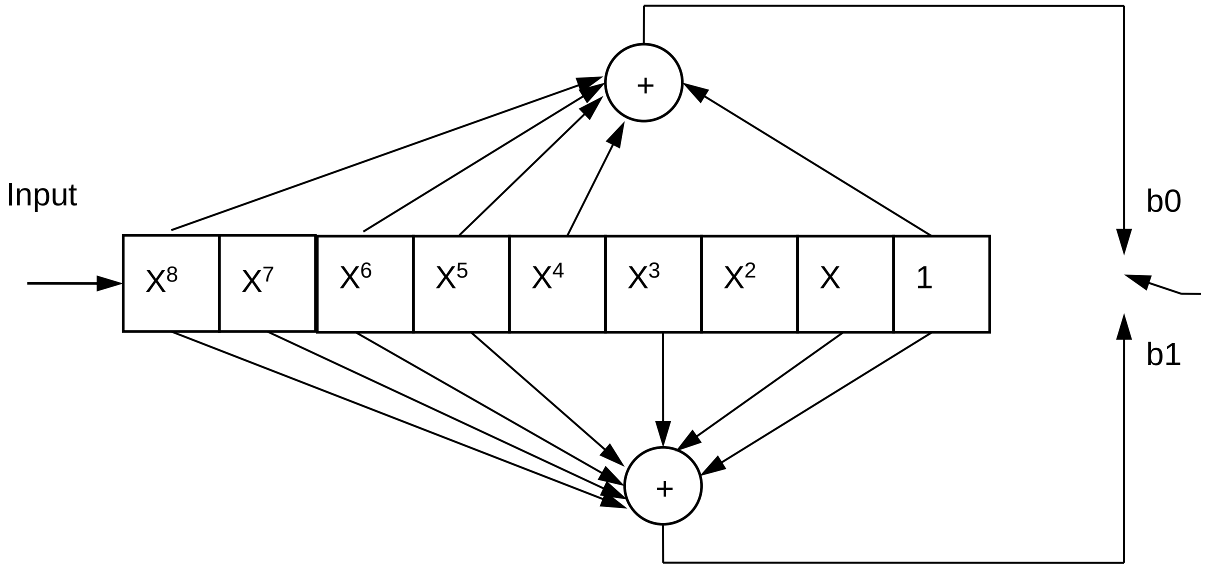

FIGURE B.3.3.2.2-1. Constraint length 9, rate 1/2 convolutional encoder.

The two summing nodes in the figure represent modulo 2 additions. For each bit input to the encoder, two bits are taken from the encoder, with the upper output bit b0, generated by polynomial $T_1(x)$, taken first.

B.3.3.2.3 Full-tail-biting encoding

To begin encoding each block of input data, the encoder shall be preloaded by shifting in the first (k-1) input data bits without taking any output bits. These (k-1) 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 (kth) 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 (k-1) “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 (k-1) “saved” data bits are encoded by shifting them into the encoder one at a time, beginning with the earliest of the (k-1). The encoding thus continues by taking the two resulting coded output bits as each of the saved (k-1) 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 other required rates shall be done prior to sending bits to the interleaver.

B.3.3.2.4 Puncturing and Repetition

In order to obtain a higher-rate code from a lower-rate code, the output of the encoder must be punctured by not transmitting all of the encoder's output bits. Which bits are transmitted are defined by a puncturing mask. For example, when puncturing a rate ½ code to rate ¾ code one out of every 3 bits must not be transmitted. In this case puncturing shall be performed by using a puncturing mask of

110
101

In this notation the first row indicates the bits retained by the T1 branch, the second row indicates the bits retained by the T2 branch. A 1 indicates that the bit is transmitted and a 0 indicates that the bit is not transmitted. For an encoder generated sequence of

$T_1(k), T_2(k), T_1(k+1), T_2(k+1), T_1(k+2), T_2(k+2) \ldots$

the transmitted sequence shall be

$T_1(k), T_2(k), T_1(k+1), P, P, T_2(k+2) \ldots$

Defining $T_1(0)$, $T_2(0)$ to be the first two bits of the block code generated as defined in paragraph B.3.3.2, 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.

In order to obtain a lower code rate from a higher code rate, repetition can be used. For example, to generate a rate ¼ code from a rate ½ code the two output bits

$T_1(k), T_2(k), T_1(k+1), T_2(k+1),$

Are repeated to yield four output bits for each input bit, giving

$T_1(k), T_2(k), T_1(k), T_2(k), T_1(k+1), T_2(k+1), T_1(k+1), T_2(k+1)$

For the cases that require a combination of repitition and puncturing the code words are first repeated and then the puncturing is applied. For example to generate a rate 1/3 code from a rate ½ code the two output, T1(k),T2(k) bits are repeated twice

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

The Puncturing pattern from the Rate 2/3 code is now applied twice resulting in

T1(k), T2(k), T1(k), P, T1(k+1), T2(k+1), T1(k+1), P

The code rates in Table B.3.3.2-1 shall be obtained using the puncture patterns in Table B.3.3.2.4-1.

TABLE B.3.3.2.4-1. Puncture patterns.

Code Rate	K=7 Puncture Pattern	K=9 Puncture Pattern	Number of Repeats
9 / 10	111101110 100010001	111000101 100111010	n/a
8 / 9	11110100 10001011	11100000 10011111	n/a
5 / 6	11010 10101	10110 11001	n/a
4 / 5	1111 1000	1101 1010	n/a
3 / 4	110 101	111 100	n/a
2 / 3	11 10	11 10	n/a
4/7	1111 0111	1111 0111	n/a
9/16	111101111 111111011	111101111 111111011	n/a
1 / 2	n/a	n/a	n/a
2 / 5	1110 1010	1110 1010	½ Repeated 2x
1 / 3	n/a	n/a	2/3 Repeated 2x
2 / 7	1111 0111	1111 0111	½ Repeated 2x
1 / 4	n/a	n/a	1/2 repeated 2x
1 / 6	n/a	n/a	1/2 repeated 3x
1 / 8	n/a	n/a	1/2 repeated 4x
1 / 12	n/a	n/a	1/2 repeated 6x
1 / 16	n/a	n/a	1/2 repeated 8x

B.3.3.3 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.

B.3.3.3.1 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 the Tables B.3.3-1 through B.3.3-8, one for each bandwidth.

B.3.3.3.2 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 Tables B.3.3.3.2-1 through B.3.3.3.2-8, 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 Waveform 1 in Table B.B.3.3-1, using ultrashort interleaver (192 bit size with an increment of 25), the first 9 interleaver load locations are: 0, 25, 50, 75, 100, 125, 150, 175 and 8.

TABLE B.3.3.3.2-1. Interleaver increment value for 3 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	11	37	145
1	25	97	385	1543
2	25	97	385	1543
3	25	97	385	1549
4	25	97	385	1549
5	33	129	513	2081
6	65	257	1025	4161
7	97	385	1537	6241
8	129	513	2049	8321
9	161	641	2561	10403
10	193	769	3073	12481
11	271	1081	4321	17551
12	361	1441	5761	23401
13	65	257	1025	4161

TABLE B.3.3.3.2-2. Interleaver increment value for 6 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	21	73	289
1	49	193	769	3085
2	49	193	769	3085
3	53	205	817	3293
4	53	205	817	3293
5	69	273	1089	4421
6	137	545	2177	8841
7	205	817	3265	13261
8	273	1089	4353	17681
9	341	1361	5441	22103
10	409	1633	6529	26521
11	409	1621	6481	26329
12	553	2161	8641	35113

TABLE B.3.3.3.2-3. Interleaver increment value for 9 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	31	109	433
1	73	289	1153	4645
2	73	289	1153	4645
3	73	289	1153	4645
4	-	-	-	-
5	97	385	1537	6241
6	193	769	3073	12481
7	289	1153	4609	18721
8	385	1537	6145	24961
9	481	1921	7681	31207
10	577	2305	9217	37441
11	811	3241	13771	52651
12	1081	4321	18361	70201

TABLE B.3.3.3.2-4. Interleaver increment value for 12 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	41	145	577
1	73	289	1153	4633
2	73	289	1153	4633
3	97	385	1537	6193
4	97	385	1537	6193
5	129	513	2049	8321
6	257	1025	4097	16641
7	385	1537	6145	24961
8	513	2049	8193	33281
9	641	2561	10241	41603
10	769	3073	13057	49921
11	811	3241	13771	52651
12	1081	4321	18361	70201

TABLE B.3.3.3.2-5. Interleaver increment value for 15 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	–	51	181	721
1	109	433	1729	6949
2	109	433	1729	6949
3	109	433	1729	6949
4	109	433	1729	6949
5	161	641	2561	10401
6	321	1281	5121	20801
7	481	1921	7681	31201
8	641	2561	10241	41601
9	801	3201	13603	52003
10	961	3841	16321	62401
11	865	3457	14689	56161
12	1153	4609	19585	74881

TABLE B.3.3.3.2-6. Interleaver increment value for 18 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	61	217	865
1	169	673	2689	10811
2	169	673	2689	10811
3	169	673	2689	10811
4	-	-	-	-
5	193	769	3073	12481
6	385	1537	6145	24961
7	577	2305	9217	37441
8	769	3073	13057	49921
9	961	3841	16327	62407
10	1153	4609	19585	74881
11	1441	5761	24481	93601
12	1921	7681	32641	124801

TABLE B.3.3.3.2-7. Interleaver increment value for 21 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	71	253	1009
1	161	641	2561	10281
2	161	641	2561	10281
3	161	641	2561	10281
4	161	641	2561	10281
5	169	673	2689	10921
6	337	1345	5377	21841
7	505	2017	8065	32761
8	673	2689	11425	43681
9	841	3361	14293	54613
10	1009	4033	17137	65521
11	1921	7681	32641	124801
12	2561	10241	43521	166401

TABLE B.3.3.3.2-8. Interleaver increment value for 24 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	81	289	1153
1	137	545	2177	8739
2	137	545	2177	8739
3	205	817	3265	13159
4	205	817	3265	13159
5	273	1089	4353	17681
6	545	2177	8705	35361
7	817	3265	13873	53041
8	1089	4353	18497	70721
9	1361	5441	23123	88403
10	1633	6529	27745	106081
11	1441	5761	24481	93601
12	1921	7681	32641	124801

TABLE B.3.3.3.2-8. Interleaver increment value for 30 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	119	431	1673
1	275	1259	4207	15445
2	275	1259	4207	15445
3	275	1259	4207	15445
4	275	1259	4207	15445
5	381	2951	8729	24989
6	781	5893	29161	49991
7	1207	8821	26221	71341
8	1529	11837	43733	142017
9	1941	14711	54541	221051
10	2257	17623	65557	288127
11	2473	18643	55669	281233
12	3281	25097	74329	374993

TABLE B.3.3.3.2-8. Interleaver increment value for 36 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	143	511	2011
1	901	1577	11843	22595
2	901	1577	11843	22595
3	901	1577	11843	22595
4	455	3557	17575	26663
5	455	3557	17575	26663
6	911	7027	35179	69763
7	1633	10867	52741	90013
8	1913	14245	70337	119977
9	2411	17831	87931	133351
10	2719	22267	105163	174025
11	2851	22381	110509	197491
12	4049	29977	148361	281057

TABLE B.3.3.3.2-8. Interleaver increment value for 40 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	167	601	2371
1	1001	1687	5867	30619
2	1001	1687	5867	30619
3	1001	1687	5867	30619
4	593	4007	11789	33757
5	593	4007	11789	33757
6	1019	7993	23641	67505
7	1531	11995	35335	101203
8	2029	15965	47137	134965
9	2581	19901	58871	168701
10	3079	23995	70669	202411
11	3499	26539	78571	249943
12	4673	35281	104857	333113

TABLE B.3.3.3.2-8. Interleaver increment value for 48 kHz waveform

WID	Interleaver Size			
	Ultrashort	Short	Medium	Long
0	-	191	697	2693
1	943	1735	6805	14425
2	943	1735	6805	14425
3	943	1735	6805	14425
4	397	2941	8393	39551
5	397	2941	8393	39551
6	797	5881	16739	72607
7	1231	8827	25099	104197
8	1509	11729	46729	137413
9	1911	14701	41981	181541
10	2281	17623	70183	217873
11	2569	19831	56599	247963
12	3401	26449	105209	326729

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. For waveforms 7-12, this is important, because each symbol of a constellation contains “strong” and “weak” bit positions. 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 does not evenly distribute these bits in the way they occur without interleaving could degrade performance.

B.3.3.3.3 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. This is a simple linear fetch from beginning to end of the interleaver array.

B.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.

B.4.1 User interfaces

B.4.1.1 Conventional synchronous interface

A synchronous serial interface shall be provided.

B.4.1.2 Conventional asynchronous interface

In addition to the standard synchronous serial interface, the modem shall also 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 occurrence. 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 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.

B.4.1.3 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 Tables B.3.3-1 through B.3.3-12 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.

B.4.1.4 Ethernet interface (optional)

The modem may provide an Ethernet interface for byte oriented user data transfers, and these bytes shall be aligned with the Input Data Block boundaries.

B.4.2 Onset of transmission

The modem shall begin a transmission no later than 100 ms 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.

B.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 which 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.

B.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.

An optional feature can be added to the end of each transmission. The transmitter can insert an end-of-transmission (EOT) marker following the last mini-probe sequence. The purpose of this EOT marker is to allow receiver implementations to detect the end of a transmission immediately, without having to wait for the EOM marker embedded within the data. The EOT will not be as robust an indicator of the end of a transmission as the embedded EOM. However, in relatively benign channels, this feature will reduce the time before the receiver is able to return to acquisition mode, with the result that in a TDMA system, back-to-back receptions can be scheduled with a significantly smaller guard time between them. The EOT shall consist of a cyclic extension of the last mini-probe, where the mini-probe sequence has been defined in Table B.3.2.2-1. The length of the cyclic extension shall be 13.333 ms (an integer multiple of 32 symbols for each symbol rate). Furthermore, it will be optional for the receiver to search for this EOT marker, so that operation on challenging multipath fading channels is not affected by the need to search for EOT marker.

For example, for the length 13 base sequence used with the 3 kHz bandwidth, the last mini-probe shall consist of the 24 symbols of the last mini-probe, plus 32 additional symbols formed by the cyclic extension of the 13 symbol Base Sequence. Thus, the final mini-probe will be 56 symbols in length and consist of 4 complete 13 symbol Base sequences plus the first 4 symbols of a fifth base sequence. This specific example is illustrated in Table B.4.4-1.

TABLE B.4.4-1. In-phase and Quadrature components of 13 symbol Base Sequence used to form 24 symbol mini-probe and cyclically extended by 32 symbols to mark the EOT.

Symbol Number	In-Phase	Quadrature	Symbol Number	In-Phase	Quadrature
0	1.00000	0.0	28	1.00000	0.0
1	1.00000	0.0	29	1.00000	0.0
2	1.00000	0.0	30	1.00000	0.0
3	1.00000	0.0	31	-1.00000	0.0
4	1.00000	0.0	32	-1.00000	0.0
5	-1.00000	0.0	33	1.00000	0.0
6	-1.00000	0.0	34	1.00000	0.0
7	1.00000	0.0	35	-1.00000	0.0
8	1.00000	0.0	36	1.00000	0.0
9	-1.00000	0.0	37	-1.00000	0.0
10	1.00000	0.0	38	1.00000	0.0
11	-1.00000	0.0	39	1.00000	0.0
12	1.00000	0.0	40	1.00000	0.0
13	1.00000	0.0	41	1.00000	0.0
14	1.00000	0.0	42	1.00000	0.0
15	1.00000	0.0	43	1.00000	0.0
16	1.00000	0.0	44	-1.00000	0.0
17	1.00000	0.0	45	-1.00000	0.0
18	-1.00000	0.0	46	1.00000	0.0
19	-1.00000	0.0	47	1.00000	0.0
20	1.00000	0.0	48	-1.00000	0.0
21	1.00000	0.0	49	1.00000	0.0
22	-1.00000	0.0	50	-1.00000	0.0
23	1.00000	0.0	51	1.00000	0.0
24	-1.00000	0.0	52	1.00000	0.0
25	1.00000	0.0	53	1.00000	0.0
26	1.00000	0.0	54	1.00000	0.0
27	1.00000	0.0	55	1.00000	0.0

B.4.5 Termination of receive data processing

There are a number of events which 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.

B.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 B.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.

B.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).

B.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 B.4.6 below), since it is not embedded in the waveform itself as the data rate and interleaver length parameters are.

B.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).

B.4.6 Remote control

A remote control interface shall be provided that includes the capability to specify the following parameters and commands:

a. Waveform parameters:
   1) The bandwidth (from 3 kHz through 24 kHz, in multiples of 3 kHz, and from 30 kHz through 48 kHz in multiples of 6 kHz)
   2) The waveform ID (0 through 13)
   3) The Interleaver length (UltraShort, Short, Medium, or Long)

    4) The convolutional code constraint length (7 or 9)

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.

INTENTIONALLY BLANK

ANNEX C PERFORMANCE REQUIREMENTS OF SERIAL WAVEFORMS FOR SINGLE NON-HOPPING, FLEXIBLE-BANDWIDTH HF CHANNELS

C.1 Introduction

C.1.1 Purpose

This Annex specifies the performance requirements of the STANAG 5069 wideband high-frequency radio (WBHF) modem waveforms.

This STANAG addresses NATO non-EPM requirements. EPM requirements are addressed in STANAG 4444.

This STANAG also supports interoperability between the HF House and the U.S. MIL-STD-188-110C Annex D wideband waveform.

C.1.2 Approach and Structure of Annex C

This Annex specifies performance requirements for STANAG 5069 waveforms. The structure of the Annex is as follows.

Section 1 is an introduction.

Section 2 addresses performance requirements for the waveforms in Annex B.

C.2 Performance Requirements

All STANAG 5069 modem functionality testing should be performed at baseband. In the case of testing a modem embedded in an HF Radio, a baseband interface should be utilized if available. If no baseband interface is provided, care must be taken in the test set up to ensure that two radios, when connected back to back, deliver a signal to noise ratio (SNR) significantly higher than the condition under test so as to not compromise the measurement.

When testing a modem embedded in a radio with no baseband audio interface, the RF signals must be downconverted to baseband for processing by the channel simulator, and the result upconverted to RF for the receiver. In this case, transmit gain control (TGC), built-in analog and digital radio filters and automatic gain control (AGC) will affect the performance of the modems. Therefore, when testing embedded modems, the SNR values specified in Table C.2.1-1 shall be increased by 3 dB after verifying that the SNR condition mentioned in previous paragraph is met. Note that the SNR requirement mentioned in previous paragraph must also be met by the up/down conversion chain with the channel simulator set to non-fading path with 99 dB SNR.

C.2.1 BER performance on AWGN and Multipath Fading Channels

The measured performance of the wideband waveform modes, using fixed-frequency operation and employing the maximum interleaving period (“Long” interleaver) and a 20-superframe preamble, shall achieve coded bit error rate (BER) of no more than 1.0E-5 under each of the conditions listed in Table C.2.1-1. The channel conditions denoted “Poor Channel” in the tables shall comply with the ITU-R F.1487 Mid-Latitude-Disturbed Channel.

TABLE C.2.1-1. Data performance requirements, All Bandwidths.

Waveform Identifier (WID)	Average SNR (dB) for BER ≤ 1.0E-5		Exceptions
	AWGN Channel	“Poor” Channel	(for specific bandwidths)
0	-6	-1	9 kHz Poor channel only: allow +1 dB
1	-3	3	
2	0	5	
3	3	7	9 kHz: allow extra 1 dB (both channels)
4	5	10	this waveform not available in 9 or 18 kHz
5	6	11	
6	9	14	
7	13	19	
8	16	23	
9	19	27	
10	21	31	24–48 kHz Poor channel only: test for BER ≤ 1.0E-4 and allow 33 dB
11	24	-	
12	30	-	
13	6	11	this waveform available in 3 kHz only

Performance shall be tested using a baseband HF simulator patterned after the Watterson Model.

- The AWGN channel shall consist of a single, non-fading path. Each condition shall be measured for at least 60 minutes.
- The “Poor” channel shall consist of two independent but equal average power Rayleigh fading paths, with a fixed 2 ms delay between paths, and with a fading (two sigma) bandwidth (BW) of 1 Hz. Each condition shall be measured for at least 5 hours.
- To compute SNR, both signal and noise power shall be measured *in the specified bandwidth*.

When testing a modem embedded with a radio, so that only radio frequency (RF) signals are available for testing, the RF signals must be downconverted to baseband for processing by the channel simulator, and the result upconverted to RF for the receiver. In this case, the built-in radio filters will affect the performance of the modems. Therefore, when testing embedded modems, the SNR values specified in Table C.2.1-1 shall be increased by 2 dB (3 dB for WID 10–12).

When the sending and receiving modems used in this test are not identical make and model, an extra dB of SNR shall be allowed due to potential degradation in mismatched filters.

C.2.2 BER performance on static multipath channels

The measured performance of the wideband waveform modes, using fixed-frequency operation and employing the maximum interleaving period (“Long” interleaver), shall achieve coded BER of no more than 1.0E-5 for an SNR of 50 dB under the static multipath channel conditions shown in Table C.2.2-1. For all the static channels defined in table, all paths have equal power (except the second path in 48 kHz for WID 12). The test period for each test should be 10 minutes. Due to possible alignment issues when acquiring channels with large delay spread, up to 3 opportunities are allowed per test to achieve a BER < 1.0E-5. Table C.2.2-1 shows the delay in milliseconds (ms) between the equal-power paths. For example, for WID 2 in 3 kHz, the second path is delayed 3.0 ms from the first path, and the third is delayed 9.0 ms from the first path.

TABLE C.2.2-1. Static Channel Tests

Bandwidth	WID	Multipath Channel Delays (ms)
3 KHz	2	3-Path (0.0, 3.0, 9.0)
	10	3-Path (0.0, 2.0, 4.5)
	12	2-Path (0.0, 1.5)
6 KHz	2	3-Path (0.0, 2.0, 9.0)
	10	4-Path (0.0, 1.5, 3.0, 5.0)
	12	2-Path (0.0, 1.5)
9 KHz	3	3-Path (0.0, 3.0, 8.0)
	10	3-Path (0.0, 2.0, 4.5)
	12	2-Path (0.0, 1.5)
12 KHz	2	3-Path (0.0, 2.5, 8.5)
	10	4-Path (0.0, 1.5, 3.0, 5.0)
	12	2-Path (0.0, 1.5)
24 KHz	5	3-Path (0.0, 2.5, 5.5)
	10	4-Path (0.0, 1.5, 3.0, 5.0)
	12	2-Path (0.0, 1.5)
48 KHz	5	3-Path (0.0, 2.5, 4.0)
	10	4-Path (0.0, 1.5, 3.0, 4.0)
	12	2-Path (0.0, 1.5) Second path 2 dB down

C.2.3 Acquisition performance

Not yet standardized.

C.2.4 Doppler shift test

The modem shall acquire and maintain synchronization in 3, 6, 9, 12, 24, and 48 kHz channels for at least 5 minutes with a test signal having the following characteristics**:** WID 10, Long interleaver, +75 Hz frequency offset, 2 ms 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.

C.2.5 Doppler sweep performance

The AWGN BER test for WID 10 shall be repeated in 3, 6, 9, 12, 24, and 48 kHz channels 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.

AComP-5069(A)(1)