IRIG STANDARD 106-86

TELEMETRY STANDARDS

TELEMETRY GROUP
RANGE COMMANDERS COUNCIL

WHITE SANDS MISSILE RANGE
KWAJALEIN MISSILE RANGE
YUMA PROVING GROUND

PACIFIC MISSILE TEST CENTER
NAVAL WEAPONS CENTER
ATLANTIC FLEET WEAPONS TRAINING FACILITY
NAVAL AIR TEST CENTER

EASTERN SPACE AND MISSILE CENTER
ARMAMENT DIVISION
WESTERN SPACE AND MISSILE CENTER
AIR FORCE SATELLITE CONTROL FACILITY
AIR FORCE FLIGHT TEST CENTER
AIR FORCE TACTICAL FIGHTER WEAPONS CENTER

IRIG STANDARD 106-86

TELEMETRY STANDARDS

TELEMETRY GROUP
RANGE COMMANDERS COUNCIL

MAY 1986

Published by

Secretariat
Range Commanders Council
U.S. Army White Sands Missile Range
New Mexico 88002

TABLE OF CONTENTS

Page

Page

Page

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 General

The Telemetry Group (TG) of the Range Commanders Council (RCC) has prepared this document to foster the compatibility of telemetry transmitting, receiving, and signal processing equipment at all of the Test and Evaluation (T&E) ranges under the cognizance of the RCC. The Range Commanders highly recommend that telemetry equipment operated at the T&E ranges and telemetry equipment used by the range personnel in programs that require test range support, conform to these standards.

1.2 Scope

These standards do not necessarily define the existing capability of any test range, but constitute a guide for the orderly implementation and application of telemetry systems for both the ranges and range users. The scope of capabilities attainable with the utilization of these standards requires a careful consideration of trade-offs. Guidance concerning these trade-offs is provided in the text.

1.3 Purpose

These standards provide the necessary criteria on which to base equipment design and modification. The ultimate purpose is to ensure an efficient spectrum and an interference-free operation of the radio link for telemetry systems at the RCC member ranges.

1.3.1 A five volume companion series, IRIG Document 118, Test Methods for Telemetry Systems and Subsystems, has been published in conjunction with this standard.

1.3.2 The policy of the Telemetry Group is to update the telemetry standards and test methods as required to be consistent with advances in the state of the art. As a result, IRIG Standard 106-80 superseded IRIG Standard 106-77 and IRIG Document 118-79 (volumes I, II, III, and IV) superseded IRIG Document 118-73 (revised July 1975). However, a new revision of IRIG Standard 106-80 has not been issued since September 1980.

1.3.3 Metric units are included in this edition and are shown preceding the Unites States units.

1.4 Reference Documents

Reference documents are identified at the point of reference.

1.5 Definitions

Commonly-used terms are defined in any standard reference glossary or dictionary unless otherwise indicated. Definitions of terms with special applications are included when the term first appears.

1.6 General Statements or Requirements

The general statements or requirements are contained in each chapter of this document.

CHAPTER 2

TRANSMITTER AND RECEIVER SYSTEMS

2.1 Radio Frequency Standards for Telemetry

These standards provide the criteria on which to base equipment requirements and capabilities. The intent is to ensure efficient usage of equipment, interchange of operations and data for radio-link telemetry systems at the member ranges. Throughout this section, when specifying radio-frequency (RF) bandwidths, the transmitter and receiver shall be considered as a system. Information efficiency of systems not adhering to these standards will be subjected to a critical review by the cognizant government agency to justify the use of frequency spectrum or nonstandard data formatting. These standards are designed for use on the RCC ranges and recommended for all telemetry service.

2.2 225 to 260 MHz Very High Frequency (VHF) Band

This frequency band is allocated to fixed mobile services. Telemetry operations in this band should be transferred to the 1435 to 1535 MHz and 2200 to 2290 MHz bands. This continued use of telemetry in the 225 to 260 MHz band will be on a nonprotected and noninterference basis to current and future operations conducted in accordance with the National Table of Frequency Allocations. No further waivers will be given by the Military Communications-Electronics Board (MCEB) for the use of telemetry in the 225 to 260 MHz band. See paragraph 3, appendix A for this band's standards.

NOTE

Because of the continued growth of military tactical communications in the 225 to 400 MHz band and increased incidence of interference from co-channel and adjacent channel operations, it is the MCEB policy that telemetry operations be reaccommodated from the band 225 to 260 MHz.

2.3 Ultra High Frequency (UHF) Telemetry Frequency Bands

Narrowband channel spacing of these bands is in increments of 1 MHz beginning with the frequency of 1435.5 MHz in the 1435 to 1535 MHz band, 2200.5 MHz in the 2200 to 2290 MHz band, and 2310.5 in the 2310 to 2390 MHz band. Wideband channels are also permitted and center on the center frequency of narrowband channels. Refer to appendix A for guidance on specific radio frequencies available for satisfying various channel bandwidth requirements.

2.3.1 Allocation of 1435 to 1535 MHz Band. This band is nationally allocated to government and nongovernment aeronautical telemetry use on a shared basis. Telemetry assignments are made for flight testing[1] of manned or unmanned aircraft, missiles, space vehicles, or their major components. They are described below.

2.3.1.1 1435 to 1535 MHz Channels. The frequencies between 1435 and 1535 MHz will be assigned for aeronautical telemetry and associated-telecommand operations for flight testing of manned or unmanned aircraft, missiles, or their major components. Permissible usage includes telemetry associated with lauching and reentry into the Earth's atmosphere as well as any incidental orbiting prior to reentry of manned or unmanned objects undergoing flight tests. The following frequencies are shared with flight telemetering mobile stations: 1444.5, 1453.5, 1501.5, 1515.5, 1524.5, and 1525.5 MHz.

2.3.1.2 1530 to 1535 MHz Channels. In the band 1530 to 1535 MHz, the Maritime Mobile-Satellite Service will be the only primary service after 1 Januray 1990.

2.3.2 Allocation of 2200 to 2290 MHz Band. Telemetering other than flight testing of manned aircraft is described below. Refer to appendix A for guidance on specific radio frequencies available for satisfying various channel bandwidth requirements.

2.3.2.1 2200 to 2290 MHz Channels. These channels are shared equally with the government's fixed, mobile and space research services. These channels include telemetry associated with launch vehicles, missiles, upper atmosphere research rockets, and space vehicles, regardless of their trajectories.

2.3.2.2 2290 to 2300 MHz Channels. Channels in this band are for deep space research telemetry on a shared basis with fixed and mobile service. Aeronautical mobile telemetry should not be used from 2290 to 2300 MHz.

2.3.2.3 Allocation of 2310 to 2390 MHz Band. This band is nationally allocated to government and nongovernment telemetry use on a co-equal shared basis with radio location service.

2.3.2.3.1 Flight Testing. Telemetry assignments are made for flight testing of manned or unmanned aircraft, missiles, space vehicles, or their major components.

2.3.2.3.2 Orbital Testing. Permissible use of this band includes telemetry associated with lauching and reentry into the Earth's atmospherre of manned or unmanned objects undergoing flight tests.

---

[1] **Flight testing telemetry is defined as telemetry used in support of research, development, test and evaluation, and which is not integral to the operational function of the system.**

2.4 UHF Telemetry Transmitter Systems

Air and space-ground telemetering must be accommodated in the appropriate allocated UHF bands, 1435 to 1535 MHz, 2200 to 2290 MHz, and 2310 to 2390 MHz, to enhance unrestricted use of 225 to 400 MHz communications band for communications. The following subparagraphs describe the characteristics of these transmitter systems.

2.4.1 Frequency Tolerance. The frequency tolerance for transmitters built before 1 January 1986 shall be ±0.003 percent of the assigned radio frequency under all operating conditions and environments. For transmitters built after 1 January 1987, the tolerance shall be ±0.002 percent.

2.4.2 Channel Spacing. Narrowband telemetry channel spacing is in increments of 1 MHz beginning with the frequencies 1435.5, 2200.5, and 2310.5 MHz. These numbers will be used as the base from which all frequency assignments are to be made. Wideband channels are permitted and will be centered on the center frequency of the narrowband channels. Accordingly, all telemetry equipment, whether for narrow, medium, or wideband channel application, must be capable of operating on any 1 MHz increment in the respective UHF band without infringing on adjacent bands.

NOTE

Between 1 and 5 seconds after initial turn on, the transmitter radio frequency shall remain within twice the specified limits for the assigned radio frequency. After 5 seconds, the specified frequency tolerance is applicable for any and all operations in which the conducted power level is greater than -25 dBm for a duration of 1 or more seconds. If radiated measurements become necessary for the determination of frequency, the specified frequency tolerance shall apply when a field intensity of greater than 500 microvolts per meter is experienced at any radial angle at a distance of 30.48 meters (100 feet) from the transmitter system.

2.4.3 Output Power. The output power is as directed by the intended use and never more than absolutely necessary for reliable telemetry reception.

2.4.4 Modulation Polarity. A positive increase in voltage at the transmitter modulation input will cause an increase in RF carrier frequency.

2.4.5 Spurious Emission and Interference Requirements. The antenna-conducted and antenna-radiated spurious emissions (0.150 to 10,000 MHz) shall be measured using the test methods and equipment outlined in MIL-STD 461 and MIL-STD 462 or other applicable military standards and specifications.

2.4.5.1 Transmitter-Antenna System Emissions. Emissions from the transmitter-antenna system are of primary importance. Spurious and harmonic outputs, antenna-conducted (those measured in the antenna transmission line) or antenna-radiated (those measured in free space) shall be limited to -25 dBm. Free space measurements may be made at a distance of 30.48 m (100 ft). The maximum field strength shall not exceed 320 microvolts per meter.

NOTE

Radiated tests will be used only when the transmission line is inaccessible for conducted measurements. Conducted or radiated spurious emissions are checked under unmodulated conditions.

2.4.5.2 Conducted and Radiated Interference. All interference voltages (0.150 to 25 MHz) conducted by the power leads and interference fields (0.150 to 10,000 MHz) radiated directly from equipment, units or cables shall be within the limits specified by the applicable military standard or specification.

2.4.6 Operation Flexibility. The transmitter shall be capable of operating throughout the entire frequency band from 1435 to 1535 MHz, 2200 to 2290 MHz or 2310 to 2390 MHz without design modifications, and designed with a switch to allow shutoff of equipment.

2.4.7 Transmitter Modulated Bandwidth. Refer to appendix A for telemetering station standards for the level of undesired emissions outside the authorized bandwidth, for channel bandwidth definitions and for spacing allocations, excluding those for space radio communications in 1435 to 1535, 2200 to 2300, and 2310 to 2390 MHz bands.

2.5. UHF Telemetry Receiver Systems

The following subparagraphs describe the characteristics of these receiver systems:

2.5.1 Spurious Emissions (0.150 to 10,000 MHz). RF energy, both radiated from the unit and antenna-conducted, shall be within the limits specified in MIL-STD 461 or in other applicable military standards or specifications.

2.5.2 Frequency Tolerance. The combined accuracy of all local oscillators of the receivers shall be within ±0.001 percent of the desired frequency under operating conditions during mission support.

2.5.3 Spurious Responses (0.150 to 10,000 MHz). The spurious responses shall be more than 60 dB below the fundamental frequency response.

2.5.4 Operation Flexibility. The system shall be operable over the entire 1435 to 1535 MHz, 2200 to 2290 MHz or 2310 to 2390 MHz bands without design modification and shall have variable bandwidth selection.

2.5.5 Intermediate Frequency (IF) Bandwidths (3 dB). Select receiver IF bandwidth filters from table 2-1.

NOTE

All IF bandwidths may not be available at all ranges. As new receivers are obtained, the wideband IF bandwidth filters will be added.

TABLE 2-1. RECEIVER INTERMEDIATE FREQUENCY (IF) BANDWIDTHS (3 dB)

12.5 kHz[2]	500.0 kHz	3.3 MHz
25.0 kHz[2]	750.0 kHz	4.0 MHz
50.0 kHz[2]	1,000.0 kHz	6.0 MHz
100.0 kHz	1,500.0 kHz	10.0 MHz
300.0 kHz	2,400.0 kHz	

[2]System instability may limit the use of these bandwidths.

CHAPTER 3

FREQUENCY DIVISION MULTIPLEXING TELEMETRY STANDARDS

3.1 General

In frequency division multiplexing, each data channel makes use of a separate subcarrier which occupies a defined position and bandwidth in the modulation baseband of the RF carrier. Two types of frequency modulation (FM) subcarrier formats may be used. The data bandwidth of one format type is proportional to the subcarrier center frequency, while the data bandwidth of the other type is constant, regardless of subcarrier frequency.

3.2 FM Subcarrier Characteristics

In these systems, one or more subcarrier signals, each at a different frequency, are employed to frequency modulate (FM) or phase modulate (PM) a transmitter in accordance with the RF conditions specified in chapter 2. The following paragraphs set forth the standards for utilization of FM frequency division multiplexing.

3.2.1 Each of the subcarriers conveys measurement data in FM form. The number of data channels may be increased by modulating one or more of the subcarriers with a time-division multiplex format such as Pulse Code Modulation (PCM) or Pulse Amplitude Modulation (PAM).

3.2.2 The selecting and grouping of subcarrier channels depend upon the data bandwidth requirements of the application at hand and upon the necessity to ensure adequate guardbands between channels. Combinations of both proportional-bandwidth channels and constant-bandwidth channels may be used.

3.3 FM Subcarrier Channel Characteristics

The following subparagraphs describe the characteristics of proportional-bandwidth and constant-bandwidth FM subcarrier channels:

3.3.1 Proportional-Bandwidth FM Subcarrier Channel Characteristics. Table 3-1 lists the standard proportional-bandwidth FM subcarrier channels. The channels identified with letters permit ±15 percent or ±30 percent subcarrier deviation rather than ±7.5 percent deviation but use the same frequencies as the 12 highest numbered channels. The channels shall be used within the limits of maximum subcarrier deviation. See appendix B for expected performance trade-offs at selected combinations of deviation and modulating frequency.

TABLE 3-1. PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS

±7.5% CHANNELS

Channel	Center Frequencies (Hz)	Lower Deviation Limit (Hz)	Upper Deviation Limit (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response[1, 2] (Hz)	Minimum Rise Time[2] (ms)
1	400	370	430	6	58	30	11.7
2	560	518	602	8	44	42	8.33
3	730	675	785	11	32	55	6.40
4	960	888	1,032	14	25	72	4.86
5	1,300	1,202	1,398	20	18	98	3.60
6	1,700	1,572	1,828	25	14	128	2.74
7	2,300	2,127	2,473	35	10	173	2.03
8	3,000	2,775	3,225	45	7.8	225	1.56
9	3,900	3,607	4,193	59	6.0	293	1.20
10	5,400	4,995	5,805	81	4.3	405	.864
11	7,300	6,799	7,901	110	3.2	551	.635
12	10,500	9,712	11,288	160	2.2	788	.444
13	14,500	13,412	15,588	220	1.6	1,088	.322
14	22,000	20,350	23,650	330	1.1	1,650	.212
15	30,000	27,750	32,250	450	.78	2,250	.156

[1, 2] and [3] See footnotes at end of table.

TABLE 3-1 (Con.) PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS

Channel	Center Frequencies (Hz)	Lower Deviation Limit (Hz)	Upper Deviation Limit (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response[1, 2] (Hz)	Minimum Rise Time[2] (ms)
±7.5% CHANNELS							
16	40,000	37,500	43,000	600	.58	3,000	.117
17	52,500	48,562	56,438	790	.44	3,938	.089
18	70,000	64,750	75,250	1,050	.33	5,250	.067
19	93,000	86,025	99,975	1,395	.25	6,975	.050
20	124,000	114,700	133,300	1,860	.19	9,300	.038
21	165,000	152,624	177,375	2,475	.14	12,375	.029
22	225,000	208,125	241,875	3,375	.10	16,875	.021
23	300,000	277,500	322,500	4,500	.08	22,500	.016
24	400,000	370,000	430,000	6,000	.06	30,000	.012
25	560,000	518,000	602,000	8,400	.04	42,000	.008
±15% CHANNELS[3]							
A	22,000	18,700	25,300	660	.53	3,300	.106
B	30,000	25,500	34,500	900	.39	4,500	.078
C	40,000	34,000	46,000	1,200	.29	6,000	.058

1, 2 and 3 See footnotes at end of table.

TABLE 3-1 (Con.) PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS

±15 CHANNELS[3]

Channel	Center Frequencies (Hz)	Lower Deviation Limit (Hz)	Upper Deviation Limit (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response (Hz)	Minimum Rise Time (ms)
D	52,500	44,625	60,375	1,575	.22	7,875	.044
E	70,000	59,500	80,500	2,100	.17	10,500	.033
F	93,000	79,500	106,950	2,790	.13	13,950	.025
G	124,000	105,400	142,600	3,720	.09	18,600	.018
H	164,000	140,240	189,750	4,950	.07	24,750	.014
I	225,000	191,250	258,750	6,750	.05	33,750	.010
J	300,000	255,500	345,000	9,000	.04	45,000	.008
K	400,000	340,000	460,000	12,000	.03	60,000	.006
L	560,000	476,000	644,000	16,800	.02	84,000	.004
±30% CHANNELS[4]							
AA	22,000	15,400	28,600	1,320	.265	6,600	.053
BB	30,000	21,000	39,000	1,800	.194	9,000	.038
CC	40,000	28,000	52,000	2,400	.146	12,000	.029
DD	52,500	36,750	68,250	3,150	.111	15,750	.022
EE	70,000	49,000	91,000	4,200	.083	21,000	.016
FF	93,000	65,100	120,900	5,580	.063	27,900	.012

1, 2, 3, and [4]See footnotes at end of table.

TABLE 3-1 (Con.) PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS

±30% CHANNELS[4]

Channel	Center Frequencies (Hz)	Lower Deviation Limit (Hz)	Upper Deviation Limit (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response (Hz)	Minimum Rise Time (ms)
GG	124,000	86,800	161,200	7,440	.047	37,200	.009
HH	165,000	115,500	214,500	9,900	.035	49,500	.007
II	225,000	157,500	292,500	13,500	.026	67,500	.005
JJ	300,000	210,000	390,000	18,000	.019	90,000	.004
KK	400,000	280,000	520,000	24,000	.015	120,000	.003
LL	560,000	392,000	728,000	33,600	.010	168,000	.002

[1]Round off to nearest Hz.

[2]The indicated maximum data frequency response and minimum rise time is based upon the maximum theoretical response that can be obtained in a bandwidth between the upper and lower frequency limits specified for the channels. See appendix B for determining possible accuracy versus response tradeoffs.

[3]Channels A through L may be used by omitting adjacent lettered and numbered channels. Channels 13 and A may be used together with some increase in adjacent channel interference.

[4]Channels AA through LL may be used by omitting every four adjacent double lettered and lettered channels and every three adjacent numbered channels. Channels AA through LL may be used by omitting every three adjacent double lettered and lettered channels and every two adjacent numbered channels with some increase in adjacent channel interference.

3.3.2 Constant-Bandwidth FM Subcarrier Channel Characteristics. Table 3-2 lists the standard constant-bandwidth FM subcarrier channels. The letters A, B, C, D, E, F, and G identify the channels for use with maximum subcarrier deviations of ±2, ±4, ±8, ±16, ±32, ±64, and ±128 kHz, along with maximum frequency responses of 2, 4, 8, 16, 32, 64, and 128 kHz, respectively. The channels shall be used within the limits of maximum subcarrier deviation. See appendix B for expected performance trade-offs at selected combinations of deviation and modulating frequency.

3.4 Tape Speed Control and Flutter Compensation

Tape speed control and fluttter compensation for FM/FM formats may be accomplished as indicated in subparagraph 6.8.4, chapter 6. The standard reference frequency use shall be in accordance with the criteria for table 3-3 when the reference signal is mixed with data.

A CHANNELS	B CHANNELS	C CHANNELS	D CHANNELS	E CHANNELS	F CHANNELS	G CHANNELS
Deviation limits = ± 2 kHz Nominal frequency response = 0.4 kHz Maximum frequency response = 2 kHz[2]	Deviation limits = ± 4 kHz Nominal frequency response = 0.8 kHz Maximum frequency response = 4 kHz[2]	Deviation limits = ± 8 kHz Nominal frequency response = 1.6 kHz Maximum frequency response = 8 kHz[2]	Deviation limits = ± 16 kHz Nominal frequency response = 3.2 kHz Maximum frequency response = 16 kHz[2]	Deviation limits = ± 32 kHz Nominal frequency response = 6.4 kHz Maximum frequency response = 32 kHz[2]	Deviation limits = ± 64 kHz Nominal frequency response = 12.8 kHz Maximum frequency response = 64 kHz[2]	Deviation limits = ± 128 kHz Nominal frequency response = 25.6 kHz Maximum frequency response = 128 kHz[2]
Center Frequency (kHz)	Center Frequency (kHz)	Center Frequency (kHz)	Center Frequency (kHz)	Center Frequency (kHz)	Center Frequency (kHz)	Center Frequency (kHz)
		32 [3]	64	128	256	512
16	32	64	128	256	512	1024
24	48	96	192	384	768	
32	64	128	256	512	1024	
40	80	160	320	640		
48	96	192	384	768		
56	112	224	448	896		
64	128	256	512	1024		
72	144	288	576			
80	160	320	640			
88	176	352	704			
96	192	384	768			
104						
112						
120						
128						
136						
144						
152						
160						
168						
176						

[1] The constant bandwidth channel designation shall be the channel center frequency in kilohertz and the channel letter indicating deviation limit, for example, 16A, indicating f_c = 16 kHz, deviation limit of ±2 kHz.

[2] The indicated maximum frequency is based upon the maximum theoretical response that can be obtained in a bandwidth between deviation limits specified for the channel. See discussion in appendix B for determining practical accuracy versus frequency response tradeoffs.

[3] Prior to using a channel outside the enclosed area, the user should verify the availability of range assets to support the demodulation of the channel selected.

[4] Appendix F relates the former subcarrier nomenclature to the new designation.

TABLE 3-2. Constant Bandwidth FM Subcarrier Channels[1, 4]

TABLE 3-3. REFERENCE SIGNAL USAGE

Reference Frequencies for Tape Speed and Flutter Compensation

Reference Frequency (kHz ±0.01%)
960[1]
480[1]
240[1]
200
100
50
25
12.5
6.25
3.125

If the reference signal is recorded on a separate tape track, any of the listed reference frequencies may be used provided the requirements for compensation rate of change are satisfied.

If the reference signal is mixed with the data signal, consideration must be given to possible problems with intermodulation sum and difference frequencies. Also, sufficient guard band must be allowed between the reference frequency and any adjacent data subcarrier.

[1]These frequencies are for flutter compensation only and not for capstan servo speed control. In addition, the 240 kHz reference signal may be used as a detranslation frequency in a constant-bandwidth format.

CHAPTER 4

PULSE CODE MODULATION (PCM) STANDARDS

4.1 General

These standards define recommended pulse train structure and design characteristics for the implementation of Pulse Code Modulation (PCM) telemetry systems. The PCM data are transmitted as serial binary-coded time-division multiplexed samples using the sequence of pulses within each sample to represent a discrete magnitude of the data.

4.2 Word and Frame Structure

The PCM frame shall contain a known number of bit intervals, all of equal duration, unless special identification bits within the bit stream indicate a change. The duration of the bit interval and the number of bit intervals per frame shall remain fixed from frame to frame. Figure 4-1 is a graphical representation of the following paragraphs:

4.2.1 Minor Frame. In PCM formats, the minor frame is defined as that period which includes one complete cycle of commutation having the highest rate.

4.2.2 Major Frame. The major frame includes one or more minor frames and is defined as that period in which all data is sampled once.

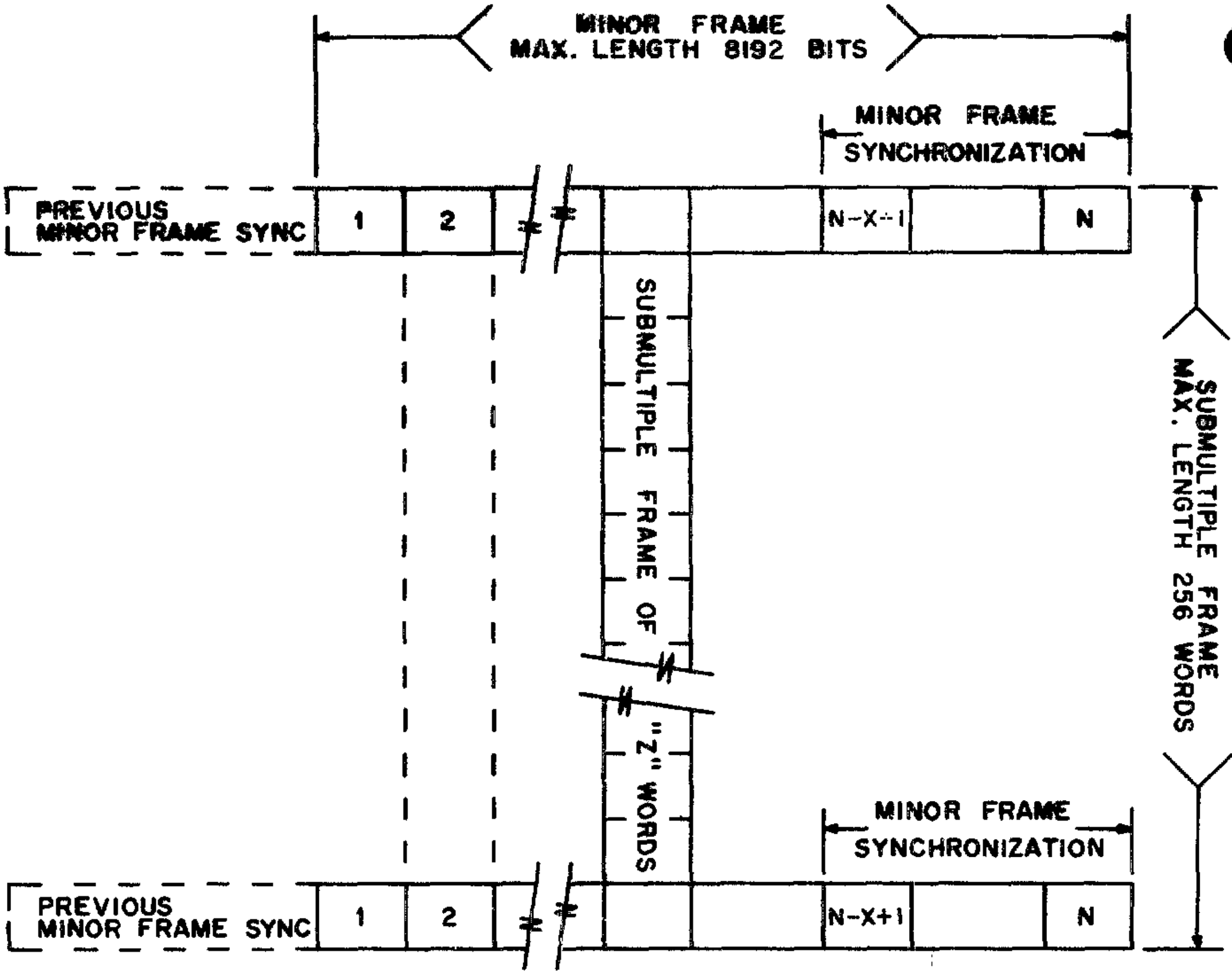
4.2.3 Submultiple Frame. The submultiple frame is defined as that period which includes one cycle of commutation having a rate as a submultiple of the minor frame rate.

4.2.4 Major Frame Length. The length of a major frame shall have a maximum of 8,192 bits/minor frame times 256 words/submultiple frame equaling 2,097,152 bits/major frame.

4.2.5 Minor Frame Length. The length of a minor frame shall not exceed 8,192-bit intervals, including the intervals devoted to synchronization.

4.2.6 Minor Frame Synchronization. The minor frame synchronization information shall consist of a digital word not shorter than 16 bits nor longer than 33 bits in consecutive bit intervals. Recommendations concerning synchronizaton patterns are shown in appendix C.

4.2.7 Word Length. Individual words shall not be less than 4 bits nor more than 64 bits in length. Within these limits, words of different length may be multiplexed in a single minor frame. Equipment limitations may require constant word lengths; however, the length of a word in any position within a minor frame shall be constant, except during changes caused by special identification bits appearing in the bit stream.



- SUBMULTIPLE FRAME SYNCHRONIZATION LOCATION IS DEPENDENT ON METHOD CHOSEN IN PARAGRAPH 4 4.1
- BY DEFINITION A MAJOR FRAME CONTAINS (N)(Z) WORDS.

"Z" = THE NUMBER OF WORDS IN LONGEST SUBMULTIPLE FRAME.

"N" = THE NUMBER OF WORDS IN MINOR FRAME.

"X" = THE NUMBER OF WORDS IN MINOR FRAME SYNC.

Figure 4-1. PCM Major Frame Structure.

4.2.8 Special Words. The assignment of word positions to convey special information on a programmed basis in designated minor frames is permissible. The number of bits in the substituted words, including identification and padding bits, shall equal exactly the number of bits in the replaced words.

4.2.9 Word Numbering. To provide consistent notation, the first word after synchronization shall be numbered "one." Each subsequent word shall be numbered sequentially for minor frames and submultiple frames.

4.2.10 Binary Bit Representation. The following conventions for representing binary "one" and "zero" are permissible:

NRZ-L	DBIØ-M	BIØ-L
NRZ-M	DBIØ-S	BIØ-M
NRZ-S		BIØ-S

Graphic and verbal descriptions of these conventions are shown in figure 4-2. Only one convention shall be used in a single PCM pulse train.

4.3 Bit Rate

The maximum bit rate is limited only by the requirements in chapter 2. Receiver intermediate-frequency (IF) bandwidths should be selected from table 2-1. The minimum bit rate shall be 10 bps.

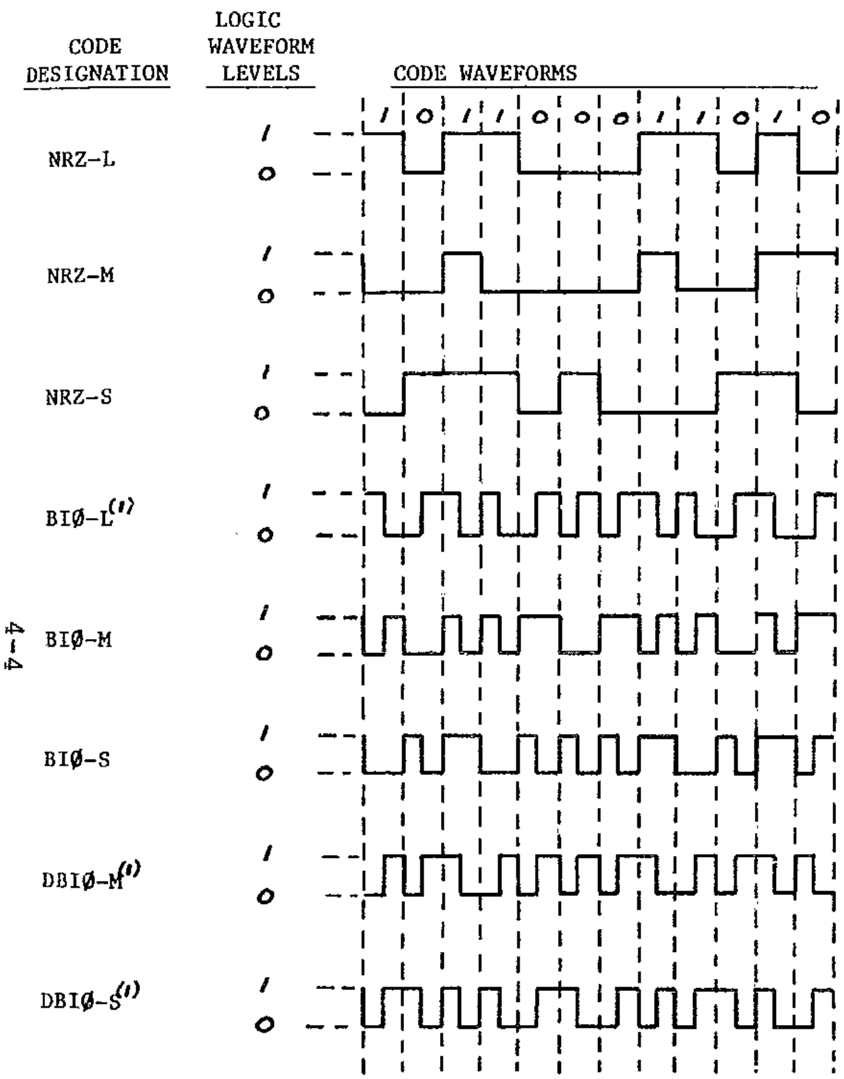
4.3.1 Bit Rate Accuracy and Stability. During any period of desired data, the bit rate should not differ from the specified nominal bit rate by more than 1 percent of the nominal rate.

4.3.2 Bit Jitter. Any transition in the PCM waveform occurring within interval P should occur within 0.1-bit period of the time at which such transition is expected to occur based on the measured average bit period as determined during the immediately preceding interval P. The interval P, for the purpose of this requirement, shall be equal to the measured time for five successive minor frames.

$$\text{Average Bit Period} = \frac{P}{\text{Specific Bits Per Minor Frame} \times 5}$$

4.4 Multiple and Submultiple Sampling

Data sampling at rates which are multiples or submultiples of the minor frame rate is permissible. When submultiple sampling is employed, the restrictions on minor frame length (subparagraph 4.2.5) and bit jitter (subparagraph 4.3.2) are applicable to the submultiple frame.



CODE DEFINITIONS

NON-RETURN-TO-ZERO-LEVEL
"One" is represented by one level.
"Zero" is represented by the other level.

NON-RETURN-TO-ZERO-MARK
"One" is represented by a change in level.
"Zero" is represented by no change in level.

NON-RETURN-TO-ZERO-SPACE
"One" is represented by no change in level.
"Zero" is represented by a change in level.

BI-PHASE-LEVEL (SPLIT PHASE)
Level change occurs at center of every bit.
"One" is represented by a "one" level with transition to the "zero" level.
"Zero" is represented by a "zero" level with transition to the "one" level.

BI-PHASE-MARK
Level change occurs at the beginning of every bit period.
"One" is represented by a midbit level change.
"Zero" is represented by no midbit level change.

BI-PHASE-SPACE
Level change occurs at the beginning of every bit period.
"One" is represented by no midbit level change.
"Zero" is represented by a midbit level change.

DIFFERENTIAL-BI-PHASE-MARK
Level change occurs at the center of each bit period.
"One" is represented by no level change at the beginning of the bit period.
"Zero" is represented by a level change at the beginning of the bit period.

DIFFERENTIAL-BI-PHASE-SPACE
Level change occurs at the center of each bit period.
"One" is represented by a level change at the beginning of the bit period.
"Zero" is represented by no level change at the beginning of the bit period.

(1) These codes may be derived from the corresponding NRZ codes by inverting the level for the last half of each bit interval.

Figure 4-2. PCM Code Definition

4.4.1 Submultiple Frame Synchronization Methods. Recommended methods for identifying submultiple channels are as follows:

4.4.1.1 The beginning of a submultiple frame may be identified by a unique digital word within the submultiple frame and occupying the same word intervals as the submultiple frame. Each submultiple sequence has a fixed and known relationship to the submultiple frame identification word.

4.4.1.2 The beginning of a submultiple frame may be identified by a unique digital word replacing the frame synchronization word indicating the start of the submultiple sequence.

4.4.1.3 Each submultiple synchronization word within the submultiple frame may contain identification bits to indicate the position of that word within the submultiple frame.

4.4.2 Maximum Submultiple Frame Length. The interval of any submultiple frame, including the time devoted to synchronizing or channel identification information, shall not exceed 256 times the interval of the minor frame in which it occupies a recurring position.

4.5 RF and Subcarrier Modulation

Described in the following subparagraphs are FM and PM RF carriers and PCM/FM/FM subcarriers:

4.5.1 FM. The frequency deviation of an FM RF carrier or a subcarrier is symmetrical about the carrier or subcarrier frequency. The deviation is the same for all occurrences of the same level.

4.5.2 PM. The phase deviation of a PM carrier is symmetrical about the unmodulated carrier. The deviation is the same for all occurrences of the same level.

4.5.3 PCM/FM/FM. The subcarrier channel shall be chosen so that the maximum frequency response for the channel, as shown in tables 3-1 and 3-2, is greater than the reciprocal of twice the shortest period between transitions in the PCM waveform.

4.6 Premodulation Filtering

Premodulation filtering is recommended to confine the radiated RF spectrum (see appendix A).

CHAPTER 5

PULSE AMPLITUDE MODULATION (PAM) STANDARDS

5.1 General

This standard defines the recommended pulse train structure and design characteristics for the implementation of PAM telemetry systems. Pulse Amplitude Modulation (PAM) data are transmitted as time division multiplexed analog pulses with the amplitude of the information channel pulse being the analog-variable parameter.

5.2 Frame and Pulse Structure

Each frame consists of a constant number of time-sequenced channel intervals. The maximum frame length shall be 128 channel time intervals per frame, including the intervals devoted to synchronization and calibration. The pulse and frame structure shall conform to either figure 5-1 or 5-2.

5.2.1 Commutation Pattern. The information channels are allocated equal and constant time intervals within the PAM frame. Each interval ("T" in figures 5-1 and 5-2) contains a sample pulse beginning at the start of the interval and having amplitude determined by the amplitude of the measurand of the corresponding information channel according to a fixed relationship (usually linear) between the minimum level (zero amplitude) and the maximum level (full-scale amplitude). For a 50 percent duty cycle (RZ-PAM), the zero level shall be 20 to 25 percent of the full amplitude level as shown in figure 5-1. The pulse width shall be the same in all time intervals except for the intervals devoted to synchronization. The duration shall be either 0.5T ±0.05T, as shown in figure 5-1, or T ±0.05T, as shown in figure 5-2.

5.2.2 In-Flight Calibration. It is recommended that in-flight calibration be used, and channels 1 and 2, immediately following the frame synchronization interval, be used for zero and full-scale calibration, respectively. For RZ-PAM, channel 3 may be used for an optional half-scale calibration, and for NRZ-PAM, the channel interval preceding channel 1 may be used for half-scale calibration if set to 50 percent.

5.2.3 Frame Synchronization Interval. Each frame is identified by the presence within it of a synchronization interval.

5.2.3.1 Fifty Percent Duty Cycle (RZ-PAM). The synchronization pattern interval shall have a duration equal to two information channel intervals (2T) and shall be full-scale amplitude for 1.5T followed by the reference level or zero baseline for 0.5T (see figure 5-1).

5.2.3.2 One Hundred Percent Duty Cycle (NRZ-PAM). The synchronization pattern is in the order given: zero level for a period of T, full-scale amplitude for a period of 3T, and a level not exceeding 50 percent full-scale amplitude for a period T (see figure 5-2).

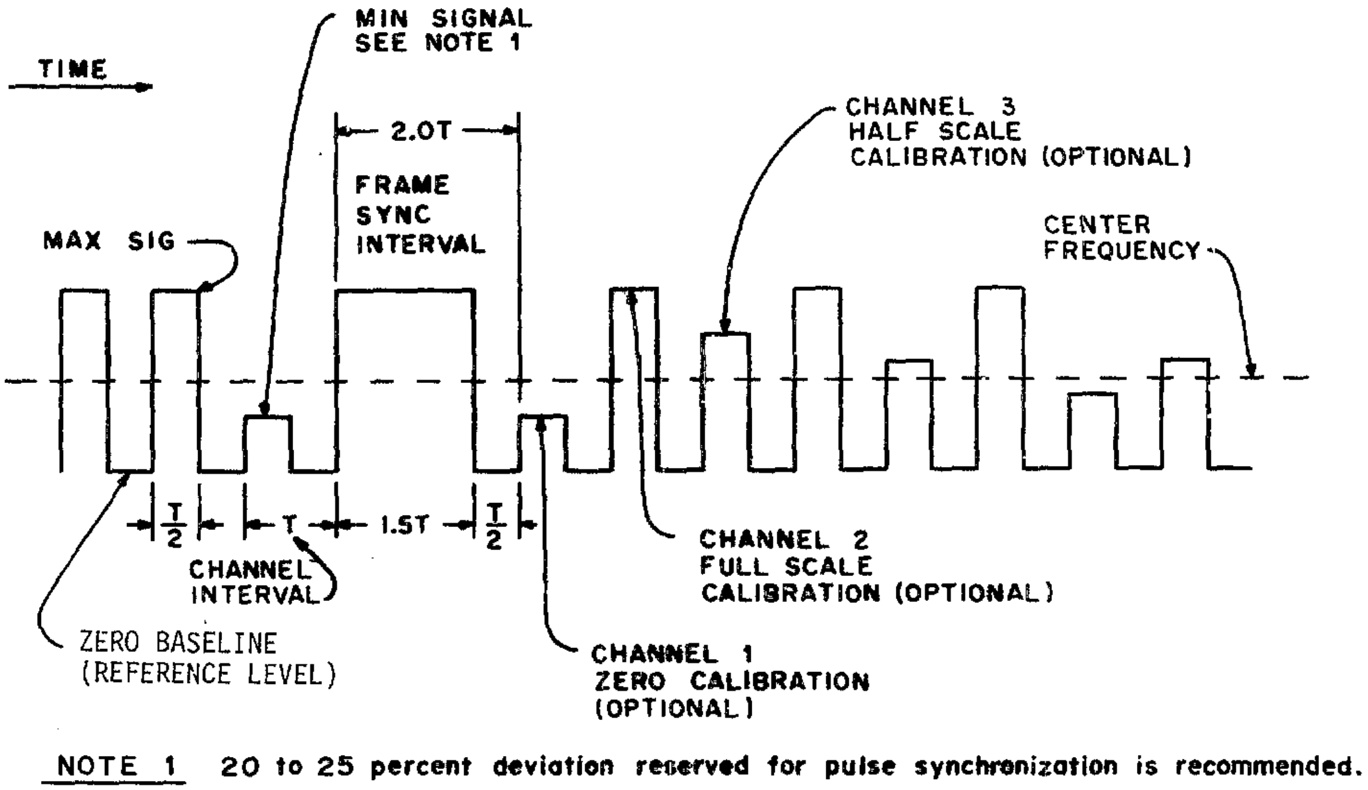


Figure 5-1. 50 Percent Duty Cycle PAM with Amplitude Synchronization.

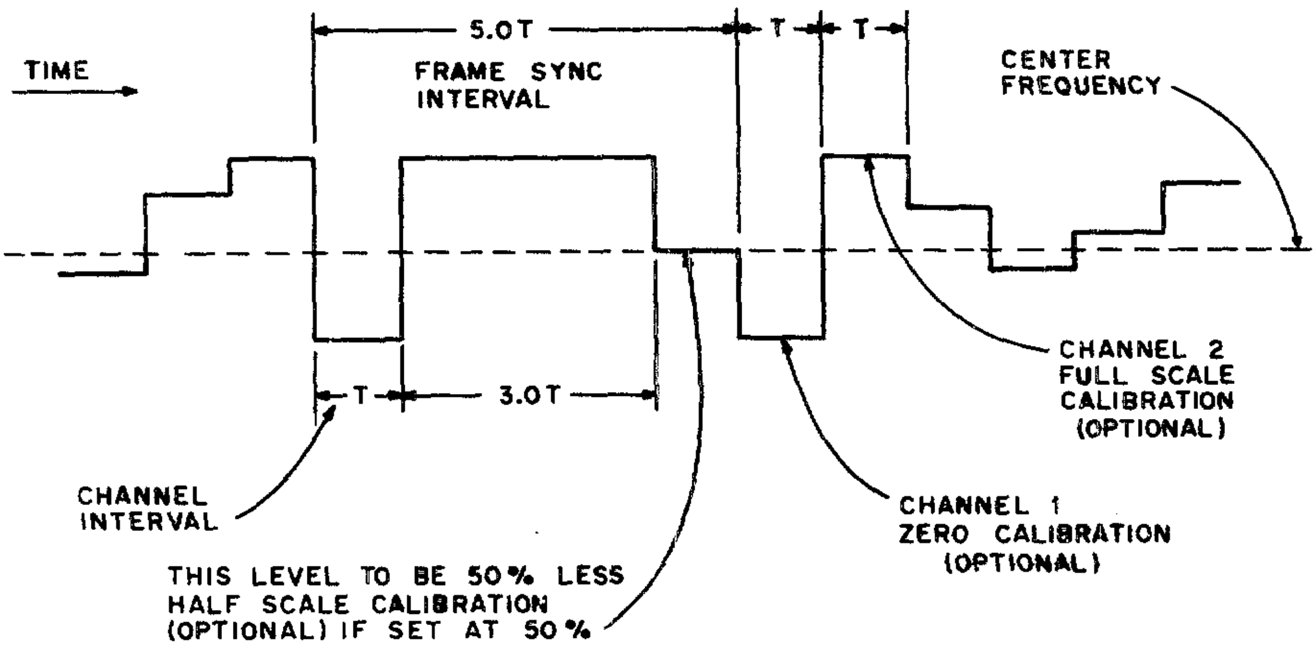


Figure 5-2. 100 Percent Duty Cycle PAM with Amplitude Synchronization.

5.2.4 Maximum Pulse Rate. The maximum pulse rate should not be greater than that permitted by the following:

5.2.4.1 PAM/FM/FM. The reciprocal of the shortest interval between transitions in the PAM pulse train shall not be greater than one-fifth of the total (peak-to-peak) deviation specified in chapter 3 and tables 3-1 and 3-2 for the FM subcarrier selected.

5.2.4.2 PAM/FM. The reciprocal of the shortest interval between transitions in the PAM pulse train shall be limited by whichever is the narrower of the following:

5.2.4.2.1 One-half of the 3 dB frequency of the premodulation filter when employed.

5.2.4.2.2 One-fifth of the intermediate frequency (IF) bandwidth (3 dB points) selected from the IF bandwidths are listed in table 2-1.

5.3 Frame and Pulse Rate

The frame and pulse parameters listed below may be used in any combination:

A minimum rate of 0.125 frames per second.

A maximum pulse rate as specified in subparagraph 5.2.4.

5.3.1 Long Term Accuracy and Stability. During a measured period of desired data, the time between the occurrence of corresponding points in any two successive frame synchronization intervals should not differ from the reciprocal of the specified nominal frame rate by more than 5 percent of the nominal period.

5.3.2 Short Term Stability. During a measured period, P for the occurrence of 1000-channel intervals, the time between the start of any two successive channel intervals (synchronization intervals excepted) should not differ from the average channel interval established by the formula $Tavg = \frac{P}{1000}$ by more than 1 percent of the average interval.

5.4 Multiple and Submultiple Sampling Rates

Data multiplexing at sampling rates which are multiples and submultiples of the frame rate is permissible.

5.4.1 Submultiple Frame Synchronization. The beginning of the longest submultiple frame interval is identified by the transmission of a synchronization pattern. All other submultiple frames have a fixed and known relationship to the identified submultiple frames.

5.4.1.1 Fifty Percent Duty Cycle (RZ). The synchronization pattern has a full-scale amplitude pulse in two successive occurrences of channel intervals allocated to data channels of the identified submultiple frame. The first such pulse has a duration equal to the channel interval; the second pulse immediately follows the first pulse and has a duration nominally one-half the channel interval. There is no return to zero between the two pulses.

5.4.1.2 One Hundred Percent Duty Cycle (NRZ). The synchronization pattern has information in five successive occurrences of a channel interval allocated to data channels of the identified submultiple frame. The amplitude of the data channels assigned for synchronization is as follows:

5.4.1.2.1 First occurrence - zero amplitude.

5.4.1.2.2 Second, third and fourth occurrences - full-scale amplitude.

5.4.1.2.3 Fifth occurrence - not more than 50 percent of full-scale amplitude.

5.4.2 Maximum Submultiple Frame Length. The interval of any submultiple frame, including the time devoted to synchronizing information, shall not exceed 128 times the interval of the frame in which it occupies a recurring position.

5.5 Frequency Modulation

The frequency deviation of an FM carrier or subcarrier, which represents the maximum and minimum amplitude of a PAM waveform, should be equal and opposite with respect to the assigned carrier or subcarrier frequency. The deviation should be the same for all occurrences of the same level.

5.6 Premodulation Filtering

A maximally linear phase response, premodulation filter, is recommended to restrict the radiated spectrum (see appendix A).

CHAPTER 6

MAGNETIC TAPE RECORDER AND REPRODUCER STANDARDS

6.1 Introduction

6.1.1 These standards define terminology for longitudinal fixed-head recorder and reproducer systems and establish the recorder and reproducer configuration required to ensure cross play compatibility between tapes recorded at one facility and reproduced at another. Acceptable performance levels and a minimum of restrictions consistent with compatibility in interchange transactions are delineated. While the standards may serve as a guide in the procurement of magnetic tape recording equipment, they are not intended to be employed as substitutes for purchase specifications. Other standards are in preparation by the American National Standards Institute (ANSI) and the International Standards Organization (see appendix D).

6.1.2 Wherever feasible, quantitative performance levels are given which must be met or exceeded to comply with these standards. Standard test methods and measurement procedures shall be used to determine such quantities, including those contained in volume III of IRIG Document 118-79, Test Methods for Recorder/Reproducer Systems and Magnetic Tape.

6.1.3 United States (U. S.) engineering units are the original dimension in these standards. Conversions from U. S. engineering units (similar to British Imperial Units) to Systeme International d' Unitès (SI) units have been done according to ANSI Z210.1-1976 (and International Standards Organization 370) Method A, except as noted. Standards applying to magnetic tapes are contained in chapter 7 of this document.

6.2 Definitions

6.2.1 Bias Signal, High Frequency. A high-frequency sinusoidal signal linearly added to the analog data signal in direct recording to linearize the magnetic recording characteristic.

6.2.2 Bi-Phase (Bi-Ø). A method of representing "one" or "zero" levels in PCM systems wherein a level change is forced to occur in every bit period. In bi-phase recording, the bi-phase level (split-phase) method is employed.

6.2.3 Bit Error. In PCM systems, a bit error has occurred when the expected bit level is not present; for example, a "zero" level is present when a "one" is expected, or a "one" level is present when a "zero" level is expected.

6.2.4 Bit Error Rate (BER). Number of bits in error in a predetermined number of bits transmitted or recorded, for example, 1 in 10^6 or a BER of 10^{-6}.

6.2.5 Bit Packing Density, Linear. Number of bits recorded per inch or per millimeter of tape length. For serial PCM recording, the number of bits per unit length of a single track.

6.2.6 Bit Slip. The increase or decrease in detected bit rate by one or more bits with respect to the actual bit rate.

6.2.7 Cross Play. Reproducing a previously recorded tape on a recorder and reproducer system other than that used to record the tape.

6.2.8 Cross Talk. Undesired signal energy appearing in a reproducer channel as a result of coupling from other channels.

6.2.9 Data Azimuth (Dynamic). The departure from the head segment gap azimuth angles (static) because of the dynamic interface between the heads and the moving tape.

6.2.10 Data Scatter. The distance between two parallel lines (as defined under Gap Scatter) in the plane of the tape, which contains all data transitions recorded simultaneously with the same head, at the same instant of time.

6.2.11 Data Spacing. For interlaced head systems, the distance on tape between simultaneous events recorded on odd and even heads.

6.2.12 Direct Recording (ac Bias Recording). A magnetic recording technique employing a high-frequency bias signal which is linearly added to the data signal. The composite signal is then used as the driving signal to the record-head segment. The bias signal, whose frequency is well above the highest frequency that can be reproduced by the system, transforms the recording of the data signal so that it is a more nearly linear process.

6.2.13 Double-Density Recording. Direct, FM or PCM recording on magnetic tape at bandwidths equal to those used in wideband instrumentation recording, but at one-half the wideband tape speeds specified in IRIG Standard 106-80 and earlier telemetry standards. Special record and reproduce heads and high output tapes (see chapter 7) are required for double-density recording.

6.2.14 Dropout. An instantaneous decrease in reproduce signal amplitude of a specified amplitude and duration.

6.2.15 Edge Margin. The distance between the outside edge of the highest number track and the tape edge (see figure 6-1).

6.2.16 Edge Margin Minimum. The minimum value of edge margin.

6.2.17 FM Recording. Recording on magnetic tape using frequency-modulated record electronics to obtain response from dc to an upper specified frequency. FM systems forfeit upper bandwidth response of direct record systems to obtain low frequency and dc response not available with direct recording.

6.2.18 Flux Transition. A 180° change in the flux pattern of a magnetic medium, brought about by a reversal of poles within the medium.

6.2.19 Flux Transition Density. Number of flux transitions per inch or per millimeter of track length.

6.2.20 Flutter. Undesired changes in the frequency of signals during the reproduction of a magnetic tape produced by speed variations of the magnetic tape during recording or reproducing.

6.2.21 Gap Length (Physical). The dimension between leading and trailing edges of a record or reproduce head-segment gap measured along a line perpendicular to the leading and trailing edges of the gap.

6.2.22 Gap Scatter (Record Head). The distance between two parallel lines are defined as follows:

6.2.22.1 The two lines pass through the geometric centers of the trailing edges of the two outermost head segment gaps within a record head. The geometric centers of the other head segment gap trailing edges lie between the two parallel lines.

6.2.22.2 The two parallel lines lie in the plane of the tape and are perpendicular to the head reference plane (see figure 6-4).

6.2.23 Gap Scatter (Reproduce Head). Defined as for record head gap scatter, except that the reference points for reproduce heads are the geometric centers of the center lines of the head segment gaps (see figure 6-4).

6.2.24 Head (Record or Reproduce). A group of individual head segments mounted in a stack.

6.2.25 Head Designation. For interlaced heads, the first head of a record or reproduce pair over which the tape passes in the "forward" direction contains odd-numbered head segments and is the "odd" head. The second head containing even-numbered head segments is the "even" head. For non-interlaced heads, that is, in-line heads, both odd- and even-numbered head segments are contained within a single head.

6.2.26 Heads, In-Line. A single record head and a single reproduce head are employed. Odd and even record head segment gaps are in-line in the record head. Odd and even reproduce head segment gaps are in-line in the reproduce head.

6.2.27 Head Reference Plane. The plane, which may be imaginary, is parallel to the reference edge of the tape and perpendicular to the plane of the tape. For purposes of this definition, the tape shall be considered as perfect (see figures 6-2 through 6-4).

6.2.28 Head Segment, Record or Reproduce. A single transducer that records or reproduces one track (see figure 6-4).

6.2.29 Head Segment Gap Azimuth (Record or Reproduce Heads). The angle formed in the plane of the tape between a line perpendicular to the head reference plane and a line parallel to the trailing edge of the record head segment gap or parallel to the center line of the reproduce head segment gap.

6.2.30 Head Segment Gap Azimuth Scatter. The angular deviations of the head segment gap azimuth angles within a head.

6.2.31 Head Segment Numbering. Numbering of a head segment corresponds to the track number on the magnetic tape on which that head segment normally operates. For interlaced heads, the odd head of a pair contains all odd-numbered segments, while the even head will contain all even-numbered segments (see figures 6-2 and 6-3). In-line heads will contain odd and even segments in the same head stack.

6.2.32 Head Spacing. For interlaced head systems, the distance between odd and even heads.

6.2.33 Head Tilt. The angle between the plane tangent to the front surface of the head at the center line of the head segment gaps and a line perpendicular to the head reference plane (see figure 6-4).

6.2.34 Heads, Interlaced. Two record heads and two reproduce heads are employed. Head segments for alternate tracks are in alternate heads.

6.2.35 High Density Digital Recording (HDDR). Recording of digital data on a magnetic medium resulting in a flux transition density in excess of 591 transitions per millimeter (15,000 transitions per inch) per track.

6.2.36 Individual Track Data Azimuth Difference. Angular deviation of the data azimuth of an individual odd or even recorded track from the data azimuth of other odd or even tracks. The difficulty in making direct optical angular measurements requires this error to be expressed as a loss of signal amplitude experienced when the tape is reproduced with an ideal reproducing head, whose gap is aligned to coincide with the data azimuth of all tracks in one head as compared to the azimuth which produces maximum signal for an individual track (see figure 6-4).

6.2.37 Non Return to Zero-Level (NRZ-L). A binary method of representation for PCM signals where "one" is represented by one level, and "zero" is defined as the other level in a bi-level system.

6.2.38 Record Level Set Frequency. Frequency of a sinusoidal signal used to establish the standard record level in direct record systems. Normally, 10 percent of the upper band edge (UBE) frequency.

6.2.39 Reference Tape Edge. When viewing a magnetic tape from the oxide surface side with the earlier recorded portion to the observer's right, the reference edge is the top edge of the tape (see figure 6-1).

6.2.40 Reference Track Location. Location of the center line of track number 1 from the reference edge of tape.

6.2.41 Standard Record Level. For a magnetic tape recorder meeting IRIG standards and operating in the direct record mode, the input signal level produces 1 percent third harmonic distortion of the record level set frequency.

6.2.42 Tape Skew. Motion of a magnetic tape past a head such that a line perpendicular to the tape reference edge has an angular displacement (static or dynamic) from the head gap center lines.

6.2.43 Tape Speed, Absolute (S_{abs}). Absolute tape speed is the tape speed during recording and reproducing. The peripheral velocity of the capstan minus any tape slip, regardless of tape tension and environment.

6.2.44 Tape Speed, Effective (S_{eff}). The tape speed modified by the effects on tape of operating conditions such as tension, tape materials, thickness, temperature, and humidity. The effective tape speed should be equal to the selected speed of the recorder, for example, 60 ips, 120 ips, regardless of operating conditions.

6.2.45 Tape Speed Errors. Errors are the departures of the effective speed from the selected tape speed.

6.2.46 Track Location. Location of the nth track center line from the reference track center line.

6.2.47 Track Numbering. The reference track is designated as track number 1. Tracks are numbered consecutively from the reference track downward when viewing the oxide surface of the tape with the earlier recorded portion of the tape to the observer's right (see figure 6-1).

6.2.48 Track Spacing. Distance between adjacent track center lines on a magnetic tape (see figure 6-1).

6.2.49 Track Width. The physical width of the common interface of the record head segment at the gaps. This definition does not include the effects of fringing fields which will tend to increase the recorded track width by a small amount.

6.3 General Consideration for Longitudinal Recording

Standard recording techniques, tape speeds and tape configurations are required to provide maximum interchange of recorded telemetry magnetic tapes between the test ranges. Any one of the following methods of information storage or any compatible combination may be used simultaneously: direct recording, predetection recording, FM recording, or PCM recording. Double-density recording may be used when the length of recording time is critical; however, it must be used realizing that performance parameters such as signal-to-noise ratio, cross talk and dropouts may be degraded (see paragraph 2.0, appendix D).

6.3.1 Tape Speeds. The standard tape speeds for instrumentation magnetic tape recorders are shown in table 6-1.

6.3.2 Tape Widths. The standard nominal tape widths are 12.7 mm (1/2 in.) and 25.4 mm (1 in.) (see table 7-1, Tape Dimensions).

6.3.3 Record and Reproduce Bandwidths. For the purpose of these standards, three system bandwidth classes are designated: intermediate band, wideband and double-density (see table 6-1). Interchange of tapes between the bandwidth classes is **NOT** recommended.

6.4 Recorded Tape Format

The parameters related to recorded tape format and record and reproduce head configurations determine compatibility between systems that are vital to interchangeability (cross play) of recorded magnetic tapes. Refer to the definitions in paragraph 6.2, figures 6-1 through 6-5 and tables 6-2 through 6-5. See appendix D for configurations not included in these standards.

6.4.1 Track Width and Track Spacing. Refer to figure 6-1 and tables 6-2 through 6-5.

6.4.2 Track Numbering. The tracks on a tape are numbered consecutively from track 1 through track n with track 1 located nearest the tape reference edge, as shown in figure 6-1.

6.4.3 Data Spacing. For interlaced formats, the spacing on tape between simultaneous events on odd and even tracks is nominally 38.1 mm (1.5 in.) (see paragraph 6.4.4.1).

6.4.4 Head Placement. The standard technique for intermediate band, wideband and 28-track double density is to interlace the heads, both the record and the reproduce, to provide alternate tracks in separate heads. Thus, to record on all tracks of a standard-width tape, two interlaced record heads are used; to reproduce all tracks of a standard-width tape, two interlaced reproduce heads are used. For 14-track double density, the standard technique uses one in-line record head and one in-line reproduce head.

6.4.4.1 Interlaced Head Placement. Two heads comprise the record head pair or the reproduce head pair. Mounting of either head pair is done in such a manner that the center lines drawn through the head gaps are parallel and spaced 38.10 ± 0.05 mm (1.500 ± 0.002 in.) apart, as shown in tables 6-2, 6-3 and 6-5, for systems that include head azimuth adjustment. The dimension between gap center lines includes the maximum azimuth adjustment required to meet system performance requirements. For systems with fixed heads, that is, heads without an azimuth adjustment, the spacing between gap center lines shall be 38.10 ± 0.03 mm (1.500 ± 0.001 in.) (see figures 6-2 and 6-3).

6.4.4.2 Head Identification and Location. A head segment is numbered to correspond to the track number that segment records or reproduces. Tracks 1, 3, 5, ... are referred to as the "odd" head segments.

TABLE 6-1. RECORD AND REPRODUCE PARAMETERS

Tape Speed mm/s	(ips)	±3 dB Reproduce Pass Band kHz[1]	Direct Record Bias Set Frequency (UBE) kHz[2]	Direct Record Level Set Frequency (10% of UBE) kHz
INTERMEDIATE BAND			(OVERBIAS 3dB)	
3048.0	(120)	0.3-600	600	60.0
1524.0	(60)	0.3-300	300	30.0
762.0	(30)	0.2-150	150	15.0
381.0	(15)	0.1- 75	75	7.5
190.5	(7-1/2)	0.1-37.50	37.5	3.75
95.2	(3-3/4)	0.1-18.75	18.75	1.875
47.6	(1-7/8)	0.1- 9.38	9.38	0.938
WIDEBAND			(OVERBIAS 2dB)	
6096.0	(240)	0.8-4,000	4,000	400
3048.0	(120)	0.4-2,000	2,000	200
1524.0	(60)	0.4-1,000	1,000	100
762.0	(30)	0.4- 500	500	50
381.0	(15)	0.4- 250	250	25
190.5	(7-1/2)	0.4- 125	125	12.5
95.2	(3-3/4)	0.4- 62.5	62.5	6.25
47.6	(1-7/8)	0.4- 31.25	31.25	3.12
DOUBLE DENSITY			(OVERBIAS 2 dB)	
3048.0	(120)	2-4,000	4,000	400
1524.0	(60)	2-2,000	2,000	200
762.0	(30)	2-1,000	1,000	100
381.0	(15)	2- 500	500	50
190.0	(7-1/2)	1- 250	250	25
95.2	(3-3/4)	.5- 125	125	12.5

[1] Passband response reference is the output amplitude of a sinusoidal signal at the Record Level Set Frequency recorded at Standard Record Level. The Record Level Set Frequency is 10 percent of the Upper Band Edge Frequency (0.1 UBE).

[2] When setting record bias level, a UBE frequency input signal is employed. The signal input level is set 5 to 6 dB below Standard Record Level to avoid saturation effects which could result in erroneous bias level settings. The record bias current is adjusted for maximum reproduce output level and then increased until the output level decreases by the number of dB indicated in the table (see paragraph 4.1.3.3 of volume III, IRIG Document 118-79).

TABLE 6-2. DIMENSIONS - RECORDED TAPE FORMAT, 7 TRACKS INTERLACED ON 12.7 mm (1/2 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Parameters	Millimeters		Inches
	Maximum	Minimum	
Track Width	1.397	1.143	0.050±0.005
Track Spacing	1.778		0.070
Head Spacing:			
Fixed Heads	38.125	38.075	1.500±0.001
Adjustable Heads	38.151	38.049	1.500±0.002
Edge Margin, Minimum	0.127		0.005
Reference Track Location	1.067	0.965	0.040±0.002
Track Location Tolerance	0.051	-0.051	±0.002

Track Number	Location of nth track: Millimeters		Inches
	Maximum	Minimum	
1 (Reference)	0.000	0.000	0.000
2	1.829	1.727	0.070
3	3.607	3.505	0.140
4	5.385	5.283	0.210
5	7.163	7.061	0.280
6	8.941	8.839	0.350
7	10.719	10.617	0.420

TABLE 6-3. DIMENSIONS - RECORDED TAPE FORMAT, 14 TRACKS INTERLACED ON 25.4 mm (1 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Parameters	Millimeters		Inches
	Maximum	Minimum	
Track Width	1.397	1.143	0.050±0.005
Track Spacing	1.778		0.070
Head Spacing:			
Fixed Heads	38.125	38.075	1.500±0.001
Adjustable Heads	38.151	38.049	1.500±0.002
Edge Margin, Minimum	0.279		1.011
Reference Track Location	1.168	1.067	0.044±0.002
Track Location Tolerance	0.051	-0.051	±0.002

Track Number	Location of nth track: Millimeters Maximum	Millimeters Minimum	Inches
1 (Reference)	0.000	0.000	0.000
2	1.829	1.727	0.070
3	3.607	3.505	0.140
4	5.385	5.283	0.210
5	7.163	7.061	0.280
6	8.941	8.839	0.350
7	10.719	10.617	0.420
8	12.497	12.395	0.490
9	14.275	14.173	0.560
10	16.053	15.951	0.630
11	17.831	17.729	0.700
12	19.609	19.507	0.770
13	21.387	21.285	0.840
14	23.165	23.063	0.910

TABLE 6-4. DIMENSIONS - RECORDED TAPE FORMAT, 14 TRACKS IN-LINE ON 25.4 mm (1 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Parameters	Millimeters		Inches
	Maximum	Minimum	
Track Width	0.660	0.610	0.25±0.001
Track Spacing	1.778		0.070
Head Spacing	N/A		N/A
Edge Margin, Minimum*	1.118		0.044
Reference Track Location	0.698	0.622	0.0260±.0015
Track Location Tolerance	0.038	-0.038	±0.0015

Track Number	Location of nth track: Millimeters		Location of nth track: Inches
	Maximum	Minimum	
1 (Reference)	0.000	0.000	0.000
2	1.816	1.740	0.070
3	3.594	3.518	0.140
4	5.372	5.296	0.210
5	7.150	7.074	0.280
6	8.928	8.852	0.350
7	10.706	10.630	0.420
8	12.484	12.408	0.490
9	14.262	14.186	0.560
10	16.040	15.964	0.630
11	17.818	17.742	0.700
12	19.596	19.520	0.770
13	21.374	21.298	0.840
14	23.152	23.076	0.910

*Track location and spacing are the same as the odd tracks of the 28-track interlaced format (see table 6-5). Edge margin for track 1 is only 0.229 mm (0.009 in.).

TABLE 6-5. DIMENSIONS - RECORDED TAPE FORMAT, 28 TRACKS INTERLACED ON 25.4 mm (1 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Parameters	Millimeters		Inches
	Maximum	Minimum	
Track Width	0.660	0.610	0.025±0.001
Track Spacing	0.889		0.035
Head Spacing:			
Fixed Heads	38.125	38.075	1.500±0.001
Adjustable Heads	38.151	38.049	1.500±0.002
Edge Margin, Minimum	0.229		0.009
Reference Track Location	0.699	0.622	0.0260±0015
Track Location Tolerance	0.038	-0.038	±0.0015

Track Number	Location of nth track: Millimeters		Inches
	Maximum	Minimum	
1 (Reference)	0.000	0.000	0.000
2	0.927	0.851	0.035
3	1.186	1.740	0.070
4	2.705	2.629	0.105
5	3.594	3.518	0.140
6	4.483	4.407	0.175
7	5.372	5.296	0.210
8	6.261	6.185	0.245
9	7.150	7.074	0.280
10	8.039	7.963	0.315
11	8.928	8.852	0.350
12	9.817	9.741	0.385
13	10.706	10.630	0.420
14	11.595	11.519	0.455
15	12.484	12.408	0.490
16	13.373	13.297	0.525
17	14.262	14.186	0.560
18	15.151	15.075	0.595

TABLE 6-5 (Con.) DIMENSIONS - RECORDED TAPE FORMAT, 28 TRACKS INTERLACED ON 25.4 mm (1 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Track Number	Location of nth track Millimeters Maximum	 Minimum	 Inches
19	16.040	15.964	0.630
20	16.929	16.853	0.665
21	17.818	17.742	0.700
22	18.707	18.631	0.735
23	19.596	19.520	0.770
24	20.485	20.409	0.805
25	21.374	21.298	0.840
26	22.263	22.187	0.875
27	23.152	23.076	0.910
28	24.041	23.965	0.945

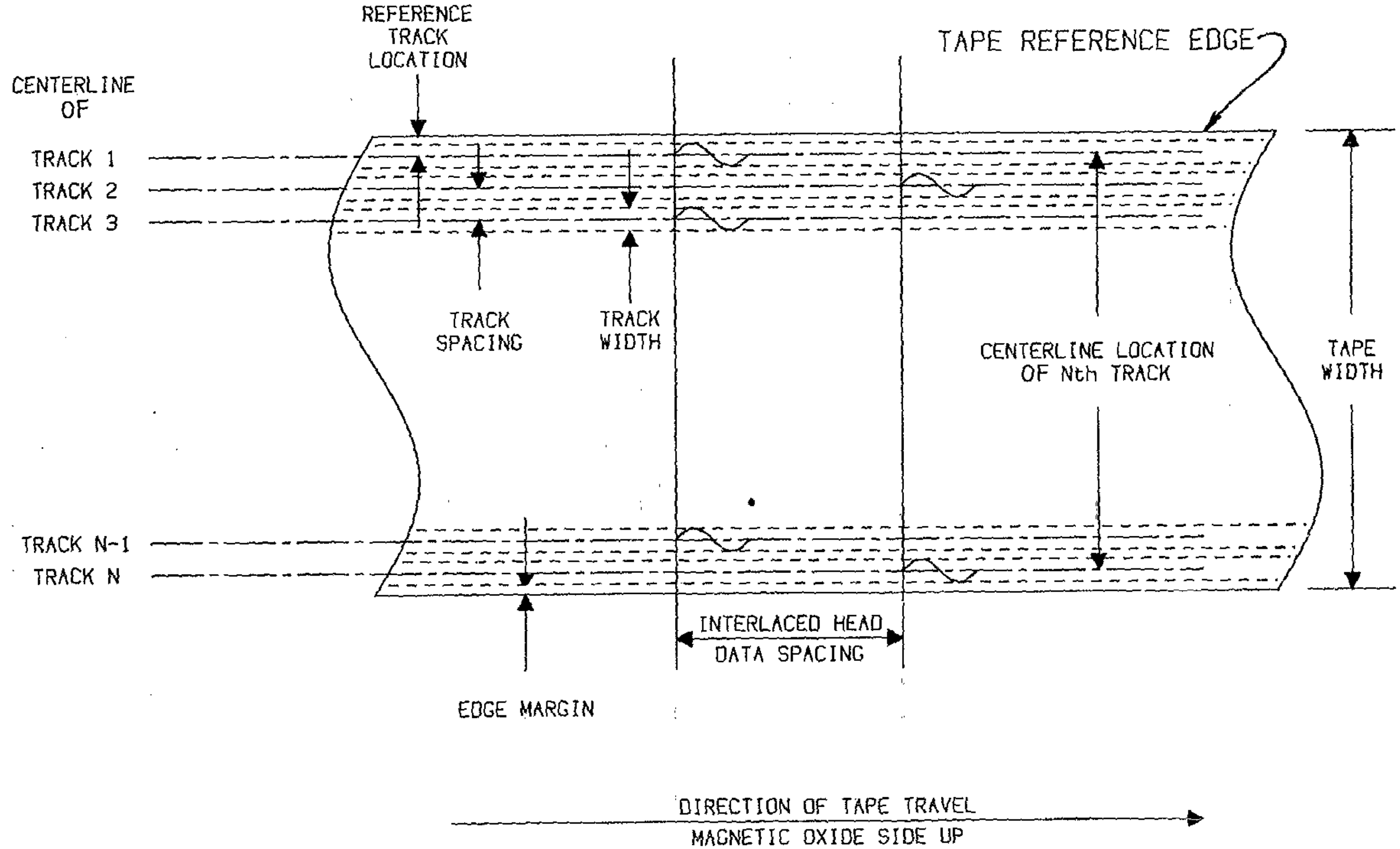


FIGURE 6-1. RECORDED TAPE FORMAT

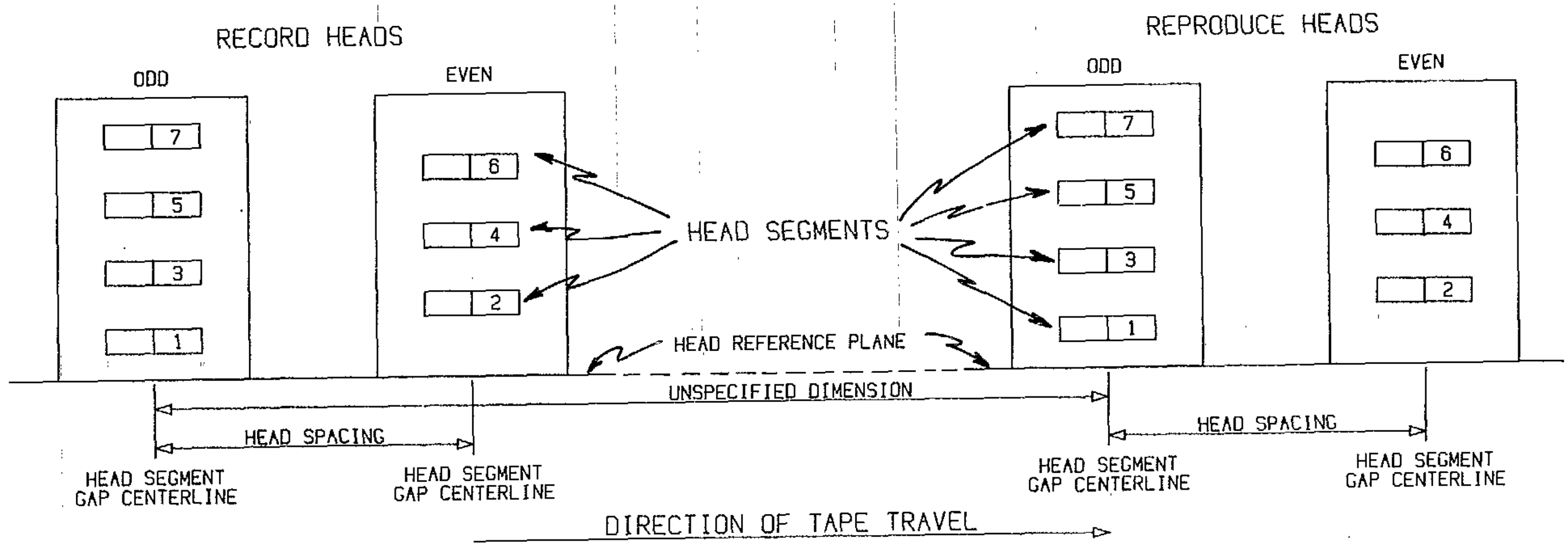


FIGURE 6-2. RECORD AND REPRODUCE HEAD AND HEAD SEGMENT IDENTIFICATION AND LOCATION (7-TRACK INTERLACED SYSTEM)

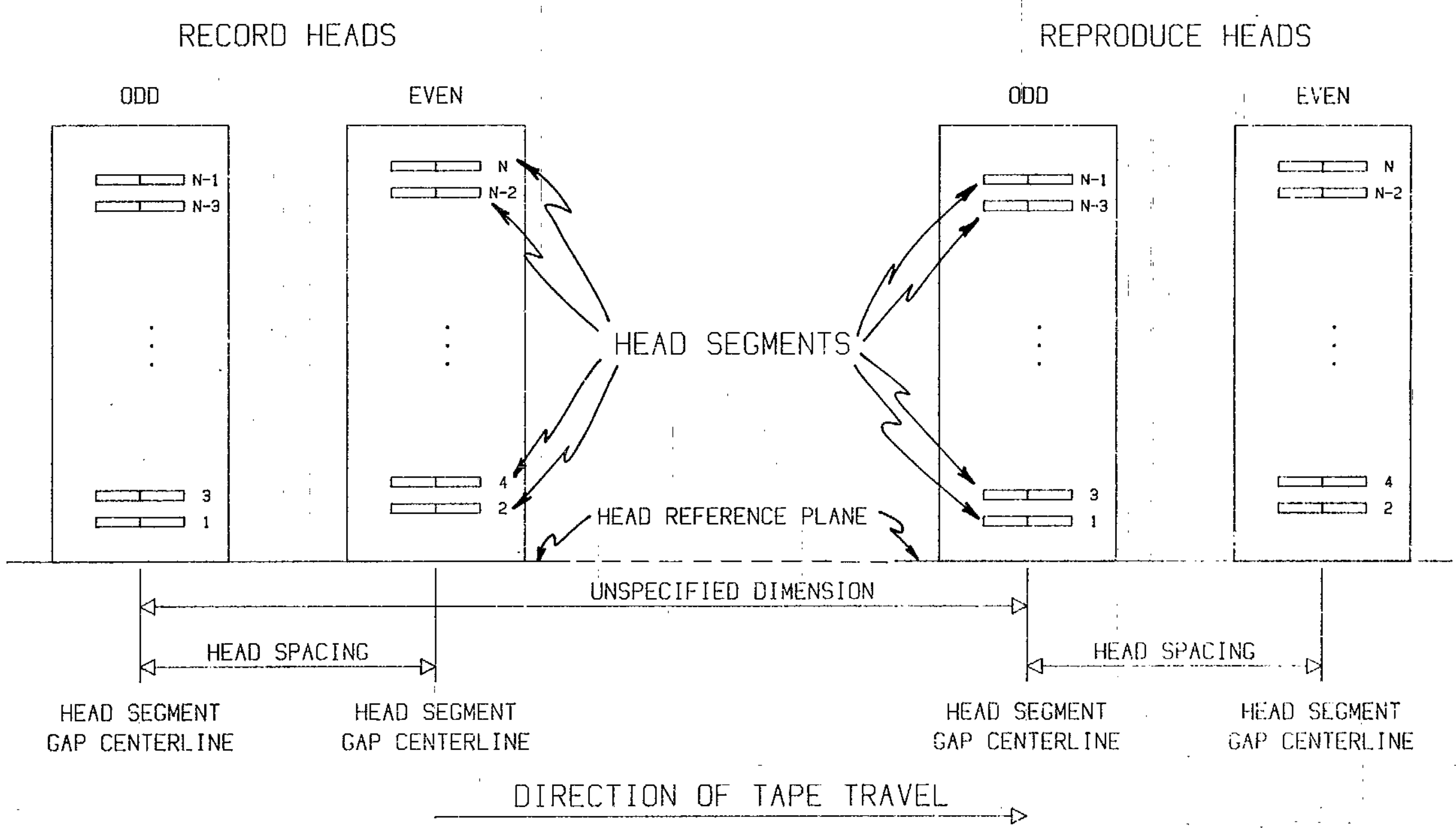


FIGURE 6-3. RECORD AND REPRODUCE HEAD AND HEAD SEGMENT IDENTIFICATION AND LOCATION (N-TRACK INTERLACED SYSTEM)

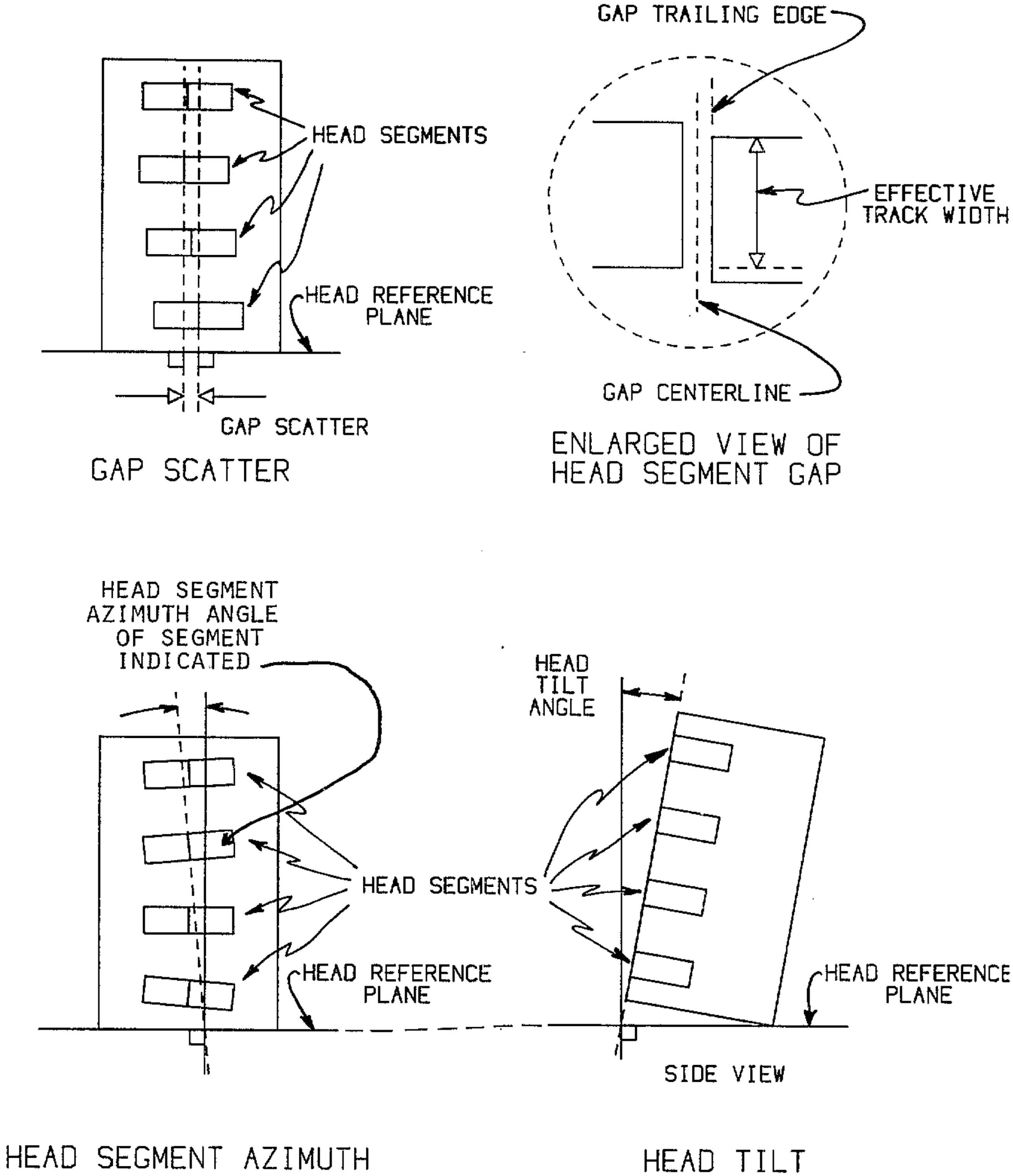


FIGURE 6-4. HEAD AND HEAD SEGMENT MECHANICAL PARAMETERS

Tracks 2, 4, 6, ... are referred to as the "even" head segments. For interlaced heads, the head containing the odd numbered segments (odd-head) is the first head in a pair of heads (record or reproduce) over which an element of tape passes when moving in the forward record or reproduce direction (see figures 6-2 and 6-3).

6.4.4.3 In-Line Head Placement. An in-line head shall occupy the position of head number 1 in an interlaced system.

6.4.4.4 Head Segment Location. Any head segment within a head shall be located within ±0.05 mm (±0.002 in.) of the nominal (dimension from table without tolerances) position required to match the track location as shown in figure 6-1 and tables 6-2 through 6-5.

6.5 Head and Head Segment Mechanical Parameters

The following subparagraphs describe the mechanical parameters of the head and head segments:

6.5.1 Gap Scatter. Gap scatter shall be 0.003 mm (0.0001 in.) or less for 12.7 mm (1/2 in.) tape and 0.005 mm (0.0002 in.) or less for 25.4 mm (1 in.) tape (see figure 6-4 and appendix D).

6.5.2 Head Segment Gap Azimuth Alignment. The head segment gap azimuth shall be perpendicular to the head reference plane to within ±0.29 mrad (±1 minute of arc).

6.5.3 Head Tilt. The plane tangent to the front surface of the head at the center line of the head segment gaps shall be perpendicular to the head reference plane within ±0.87 mrad (±3 minutes of arc) for intermediate-band recorders and ±0.29 mrad (±1 minute of arc) for wideband and double-density recorders (see figure 6-4).

6.5.4 Record Head Segment Gap Parameters. The parameters for the length and azimuth alignment are described in the following subparagraphs:

6.5.4.1 Record Head Segment Gap Length. The record gap length (the perpendicular dimension from the leading edge to the trailing edge of the gap) shall be 2.16 micrometers ±0.5 micrometer (85±20 microinch) for wideband recorders and 0.89 micrometer ±.012 micrometer (35±5 microinch) for double-density recorders (see figure 6-4 and paragraph 6, appendix D).

6.5.4.2 Record Head Stack Gap Azimuth Alignment. The record head stack azimuth shall be perpendicular to the head reference surface to within ±0.29 mrad (±1 minute of arc). See paragraph 1.2, volume III, IRIG Document 118-79 for suggested test procedure.

6.5.4.3 Reproduce Head Segment Gap Azimuth Alignment. The reproduce head segment azimuth alignment shall match that of the record head segment as indicated by reproducing an UBE frequency signal on a selected track and setting the reproduce head azimuth for the maximum output. At this azimuth setting, the output of any other track in the reproduce head shall be within 2 dB of the output at its own optimum azimuth setting (see paragraph 1.3, volume III, IRIG Document 118-79).

6.6 Head Polarity

See chapter 1, volume II, IRIG Document 118-79 and appendix D of this document for additional information.

6.6.1 Record Head Segment. Each record-head winding shall be connected to its respective amplifier in such a manner that a positive going pulse referenced to system ground at the record amplifier input will result in the generation of a specific magnetic pattern on a segment of tape passing the record head in the normal direction of tape motion. The resulting magnetic pattern shall consist of a polarity sequence of south-north-north-south.

6.6.2 Reproduce Head. Each reproduce-head segment winding shall be connected to its respective amplifier in such a manner that an area of a tape track exhibiting a south-north-north-south magnetic pattern will produce a positive going pulse with respect to system ground at the output of the reproducer amplifier.

6.7 Magnetic Tape Reel Characteristics

Magnetic tape and reel characteristics are specified in chapter 7. It is recommended that all recorder and reproducer systems at a particular range be calibrated for operational use against a reference tape of the type used by the range for each bandwidth class of recorder and reproducer system. Additional supplementary procurement specifications may be required to meet a particular operational requirement of the ranges.

6.7.1 Tape Widths. The standard nominal tape widths are 12.7 mm (1/2 in.) and 25.4 mm (1 in.) (see table 7-1, Tape Dimensions).

6.7.2 Tape Guiding. The tape guidance system restricts the tape angular motion to $\pm$0.15 mrad ($\pm$30 seconds of arc) as measured by the interchannel time displacement error (ITDE) of outer tracks on the same head stack. Make sure the guidance system does not damage the tape.

6.8 Direct-Record and Reproduce Systems

Direct recording is a method of recording information signals on magnetic tape using high-frequency ac bias recording (see paragraph 6.2, Definitions). Three classes of systems, intermediate band, wideband and double-density, are included in these standards (see table 6-1).

6.8.1 Direct-Record Parameters. The following subparagraphs describe the direct-record parameters:

6.8.1.1 The input impedance at all frequencies in the intermediate band shall be 75 ohms nominal, while the input impedance for wideband

and double-density recorders shall be 75 ohms nominal across the specified band.

6.8.1.2 Input adjustment and gain shall be provided to permit sine-wave signals of 0.35 to 3.5 Vrms to be adjusted to produce standard record level.

6.8.1.3 Ideally, the recorded flux level on tape versus frequency should be constant. To approach this ideal, the record amplifier transfer characteristic is basically a constant current versus frequency but with a superimposed compensation characteristic to correct only for loss of recording efficiency with frequency. Results of the test described in subparagraph 4.8, volume III, IRIG Document 118-79, with the output amplitude at the 2 percent (.02) upper band edge (UBE) frequency, the 0 dB reference shall be no greater than the following:

Percent of UBE Frequency	dB Difference
10	0.5
50	1.0
80	1.6
100	2.0

6.8.1.4 Record bias setting information is contained in table 6-1. The high-frequency bias signal for intermediate-band recorders shall have a wavelength on tape of less than 1.524 micrometers (60 micro-inches). For wideband and double-density recorders, the bias frequency shall be greater than 3.5 times the highest direct record frequency for which the recorder and reproducer system is designed (see appendix D).

6.8.2 Standard Record Level. The standard record level (synonymous with the term normal record level used in IRIG Document 118-79) for direct record systems is the input level of the record level set frequency which produces an output signal containing 1.0 percent third harmonic distortion. The conditions necessary to establish the standard record level include appropriate selection of the sinusoidal reference frequency (record level set frequency) as indicated in table 6-1 and proper reproduce amplifier termination as defined in figure 4.1-1, volume III, IRIG Document 118-79. A 1.0 percent third harmonic distortion content is achieved when the level of the third harmonic of the record level set frequency is 40 ± 1 dB below the level of a sinusoidal signal of 0.3 percent of UBE frequency which is recorded at the standard record level (see Record Level, paragraph 5.0, appendix D for information regarding standard test and operating practices).

6.8.3 Reproduce Parameters. The following subparagraphs describe the reproduce parameters:

6.8.3.1 The output impedance for intermediate-band recorders shall be 75 ohms nominal across the passbands specified in table 6-4. For wideband and double-density recorders, the output impedance shall be 75 ohms nominal across the specified passband.

6.8.3.2 When reproducing a signal at the record level set frequency (recorded at the standard record level), the output level shall be a minimum of 1 Vrms with a third harmonic distortion of 1.0 percent and a maximum second harmonic distortion of 0.5 percent when measured across a resistive load of 75 ohms. Lack of proper output termination will not cause the reproduce amplifier to oscillate.

6.8.4 Tape Speed and Flutter Compensation. The average or long-term tape speed must be the same during record and reproduce to avoid frequency offsets which may result in erroneous data. To minimize this problem, a reference signal may be applied to the tape during record and the signal used to servo-control the tape speed upon reproduce. However, since servo-control systems have limited correction capabilities and to minimize the amount of equipment required at the ranges, tape speeds and servo-control signals shall conform to the following standards:

6.8.4.1 The effective tape speed throughout the reel or any portion of the reel (in absence of tape-derived servo-speed control) shall be within ±0.2 percent of the standard speed as measured by the procedures described in chapter 2, volume III, IRIG Document 118-79.

6.8.4.2 Sinusoidal or square wave speed-control signals are recorded on the tape for the purpose of servo control of tape speed during playback. The operating level for speed-control signals shall be 10±5 dB below standard record level when mixed with other signals or standard record level when recorded on a separate track.

6.8.4.3 The constant-amplitude speed-control signal shall be used on a separate track for optimum servo-speed correction. The speed-control signal may be mixed with other signals if recording requirements so demand and system performance permits. Mixing of the speed-control signal with certain types of signals may degrade system performance for tapes which are to be reproduced on tape transports with low time-base error capstan drive systems (refer to manufacturer). Table 6-6 lists speed-control signal frequencies. The speed-control signal may also be used as a flutter correction signal.

6.8.4.4 Signals to be used for discriminator flutter correction systems are listed in tables 3-3 and 6-6. See subparagraph 6.8.4.3 and table 3-3 for restrictions on use of flutter correction signals.

6.9 Timing Signal Recording

Modulated-carrier, time-code signals (IRIG-A, IRIG-B and IRIG-G) are used widely and other formats are available. When recording IRIG-B time-code signals, care must be taken to ensure that low-frequency response to 100 Hz is provided. The direct-record, low-frequency cutoff of some intermediate-band and most wideband recorders is 400 to 800 Hz. For these systems, IRIG-B time-code signals should be recorded on an FM track or on an FM subcarrier. The widest bandwidth subcarrier available should be employed to minimize time delay[3]. For double-density systems, all time-code signals should be recorded on an FM track or an FM subcarrier.

TABLE 6-6. CONSTANT-AMPLITUDE SPEED-CONTROL SIGNALS[1]

Tape Speed mm/s	Tape Speed ips	Frequency[2] kHz			
6096	(240)	400	±0.01%	800	±0.01%
3049	(120)	200	±0.01%	400	±0.01%
1524	(60)	100	±0.01%	200	±0.01%
762	(30)	50	±0.01%	100	±0.01%
381	(15)	25	±0.01%	50	±0.01%
190.5	(7-1/2)	12.5	±0.01%	25	±0.01%
95.5	(3-3/4)	6.5	±0.01%	12.5	±0.01%
47.6	(1-7/8)	3.125	±0.01%	6.25	±0.01%

[1]May also serve as discriminator flutter-correction reference signal (see table 3-3).

[2]The higher set of speed-control signals was intended for use primarily with wideband systems, but either set may be used with intermediate-band or wideband systems. Only the high frequencies are recommended for double-density systems. When interchanging tapes, care should be taken to ensure that the recorded speed-control signal is compatible with the reproduce system's speed-control electrons.

NOTE

Caution should be used when multiplexing other signals with the speed-control signal. In the vicinity of the frequency speed-control signal (fsc ±10 percent), the level of individual extraneous signals including spurious, harmonics and noise must be 40 dB or more below the level of the speed-control signal. A better procedure is to leave one octave on either side of the speed-control signal free of other signals.

----

[3]Timing code formats are found in IRIG Document 200-70, IRIG Standard Time Formats (TCG) and IRIG Document 205-77, IRIG Standard Parallel Binary Time Code Formats (TCG).

6.9.1 Predetection Recording. Predetection signals consist of FM or PM or phase shift keying (PSK) signals which have been translated in frequency response. These signals will be recorded by direct (high frequency bias) recording. Parameters for these signals are in table 6-7.

6.9.2 Tape Signature Recording. For data processing using wideband and double-density recorders and reproducers, a tape signature recorded before or after the data, or both before and after the data, provides a method of adjusting the reproducer head azimuth and reproduce equalization. A means is also provided for verifying the proper operation of equipment such as playback receivers and bit synchronizers used to retrieve the recorded data. A pulse code modulation (PCM) signature is recommended where primarily PCM data is recorded. A swept-frequency or white-noise signature may be used for other data such as frequency division multiplexing (FDM) or wideband FM. The procedures for recording and using these signatures are given in paragraph 7.0, appendix D.

TABLE 6-7. PREDETECTION CARRIER PARAMETERS

Tape Speed				Predetection Carrier Center Frequency [1, 2] kHz	
mm/s	(ips)	mm/s	(ips)		
Wideband		Double-Density		A	B
6096	(240)	3048.0	(120)	1800	2400
3048	(120)	1524.0	(60)	900	1200
1524	(60)	762.0	(30)	450.0	600
762	(30)	381.0	(15)	225.0	300
381	(15)	109.5	(7.5)	112.5	150

[1]The predetection record/playback passband is the carrier center frequency ±66.7 percent.

[2]Use center frequencies in column B when data bandwidth exceeds the capabilities of those in column A.

6.10 FM Record Systems

For these FM record systems, the input signal modulates a voltage-controlled oscillator, and the output is delivered to the recording head. High-frequency bias may be used but is not required. The following standards shall apply:

6.10.1 Tape and Reel Characteristics. Paragraph 7.0 and all related subparagraphs shall apply.

6.10.2 Tape Speeds and Corresponding FM Carrier Frequencies. See table 6-8.

6.10.3 FM Record/Reproduce Parameters. See table 6-8.

6.10.4 Speed Control and Compensation. Subparagraph 6.8.4 shall apply. Note that a separate track is always required for speed-control and flutter-compensation signals with a single-carrier FM system.

6.10.5 FM Record Parameters. For FM record systems, an input voltage of 1.0 to 10.0 V peak-to-peak shall be adjustable to produce full frequency deviation.

6.10.5.1 Deviation Direction. Increasing positive voltage gives increasing frequency. Predetection recorded tapes may be recorded with reverse deviation direction because of the frequency translation techniques employed. Care should be exercised when interchanging predetection tapes with conventional wideband FM systems.

6.10.5.2 Intermediate-Band FM Record Systems. Recommended input impedance is 75 ohms ±10 percent at all frequencies in the specified passband. An input resistance of 500 ohms minimum, shunted by a capacitance of 250 pf maximum, may be used at the option of the ranges.

6.10.5.3 Wideband and Double-Density FM Recorded Systems. Input impedance is 75 ohms ±10 percent at all frequencies in the specified passband.

6.10.6 FM Reproduce Systems. Output levels are for signals recorded at full deviation.

6.10.6.1 Intermediate-Band FM Systems. Output of these intermediate-band FM systems is 3 V peak-to-peak minimum across a resistance of 75 ohms minimum from dc to the maximum specified frequency. A signal of increasing frequency at the input of the reproduce system gives a positive-going signal at the output. Equipment presently in use may require a load resistance of 10,000 ohms minimum. Use of lower load resistance should be coordinated with the ranges.

6.10.6.2 Wideband and Double-Density FM Systems. Output is 2 V peak-to-peak minimum across a load impedance of 75 ohms ±10 percent. Increasing input frequency gives a positive-going output voltage.

6.11 PCM Recording

PCM may be successfully recorded using several different methods. Methods included in these standards are predetection recording, post-detection recording and serial high density digital recording (HDDR). Parallel HDDR methods are not included.

TABLE 6-8. INTERMEDIATE WIDEBAND AND DOUBLE-DENSITY FM RECORD PARAMETERS

Tape Speed mm/s (ips): Intermediate Band FM	Tape Speed mm/s (ips): Wideband FM	Carrier Center Frequency kHz	Carrier Deviation Limits[1]: Plus Deviation kHz	Carrier Deviation Limits[1]: Minus Deviation kHz	Modulation Frequency kHz	Response At Band Limits dB[2]
	Group I					
47.6 (1-7/8)		3.375	4.725	2.025	dc to 0.625	±1
95.2 (3-3/4)	47.6 (1-7/8)	6.750	9.450	4.050	dc to 1.250	±1
190.5 (7-1/2)	95.2 (3-3/4)	13.500	18.900	8.100	dc to 2.500	±1
381.0 (15)	190.5 (7-1/2)	27.000	37.800	16.200	dc to 5.000	±1
762.0 (30)	381.0 (15)	54.000	75.600	32.400	dc to 10.000	±1
1524.0 (60)	762.0 (30)	108.000	151.200	64.800	dc to 20.000	±1
3048.0 (120)	1524.0 (60)	216.000	302.400	129.600	dc to 40.000	±1
	3048.0 (120)	432.000	604.800	259.200	dc to 80.000	±1
Double Density	**Wideband FM**					
	Group II					
	47.6 (1-7/8)	14.062	18.281	9.844	dc to 7.810	±1, -3
	95.2 (3-3/4)	28.125	36.562	19.688	dc to 15.620	±1, -3
95.2 (3-3/4)	190.5 (7-1/2)	56.250	73.125	39.375	dc to 31.250	±1, -3
190.5 (7-1/2)	381.0 (15)	112.500	146.250	78.750	dc to 62.500	±1, -3
381.0 (15)	762.0 (30)	225.000	292.500	157.500	dc to 125.000	±1, -3
762.0 (30)	1524.0 (60)	450.000	585.000	315.000	dc to 250.000	±1, -3
1524.0 (60)	3048.0 (120)	900.000	1170.000	630.000	dc to 500.000	±1, -3
3048.0 (120)	6096.0 (240)	1800.000	2340.000	1260.000	dc to 1000.000	±1, -3

[1] Input voltage levels per subparagraph 6.4.1.

[2] Frequency response referred to 1-kHz output for FM channels 13.5 kHz and above, and 100 Hz for channels below 13.5 kHz.

6.11.1 Predetection PCM Recording. This method employs direct recording of the signal obtained by heterodyning the receiver IF signal to one of the center frequencies listed in table 6-7 without demodulating the serial PCM signal (see figure 6-5). The maximum recommended bit rate for predetection recording of NRZ data is equal to the predetection carrier frequency; for example, 900 kb/s for a 900 kHz predetection carrier. The maximum recommended bit rate for predetection recording of bi-phase (BiØ) data is equal to one-half the predetection carrier frequency. For bit rates greater than one-half the maximum recommended rates, the preferred method of detection is to convert the signal to a higher frequency before demodulation.

6.11.2 Postdetection PCM Recording. The serial PCM signal (plus noise) at the video output of the receiver demodulator is recorded by direct or wideband FM recording methods without first converting the PCM signal to bi-level form (see figure 6-5). Table 6-9 lists maximum bit rates versus tape speed for these recording methods. The minimum recommended reproduce bit rates are 10 kb/s for Postdetection Direct BiØ and 10 bits per second for Postdetection FM (see paragraph 4.3, chapter 4, Pulse Code Modulation (PCM) Standards).

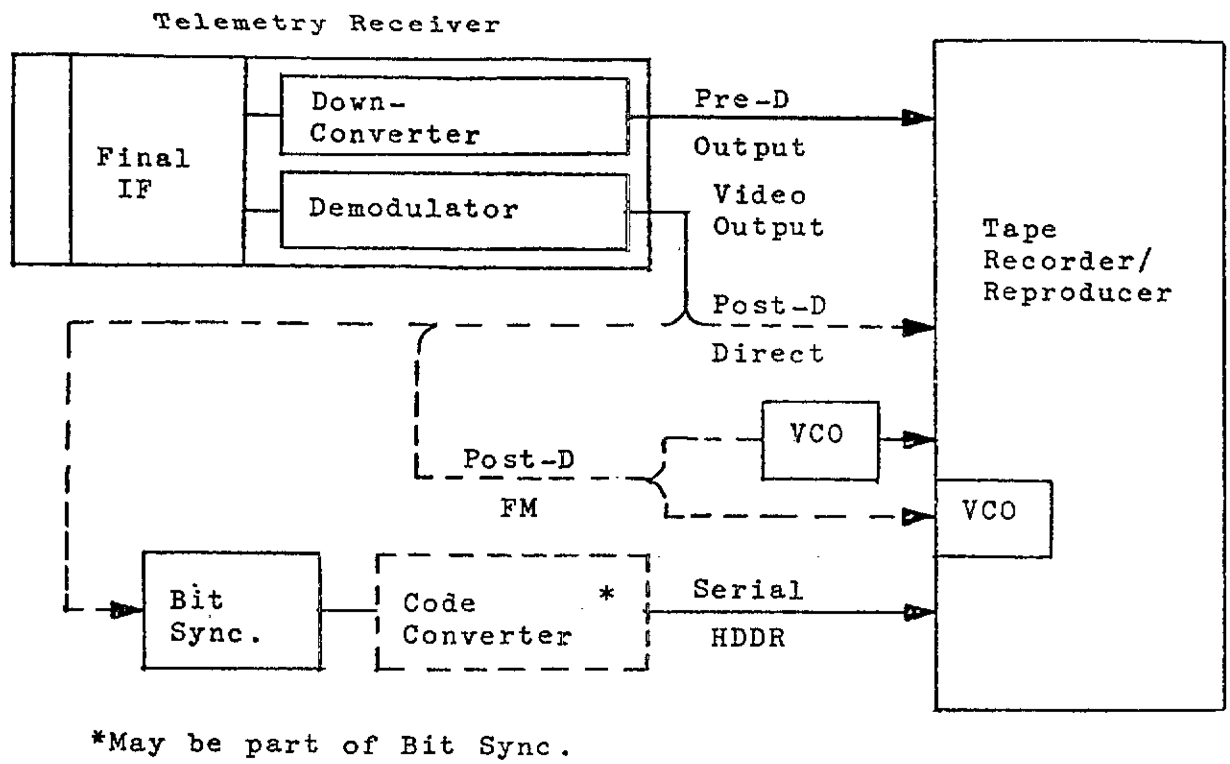
6.11.3 Serial High Density Digital Recording (HDDR). Serial HDDR is a method of recording PCM data on a magnetic tape which involves applying the data to one track of the recorder as a bi-level signal.

6.11.4 This paragraph deals with standards for direct recording of PCM telemetry data using a wideband analog instrumentation recorder or reproducer system. Direct recording is described in paragraph 6.8. The recommended PCM codes, maximum bit rates, record and reproduce parameters, and the magnetic tape requirements are also described.

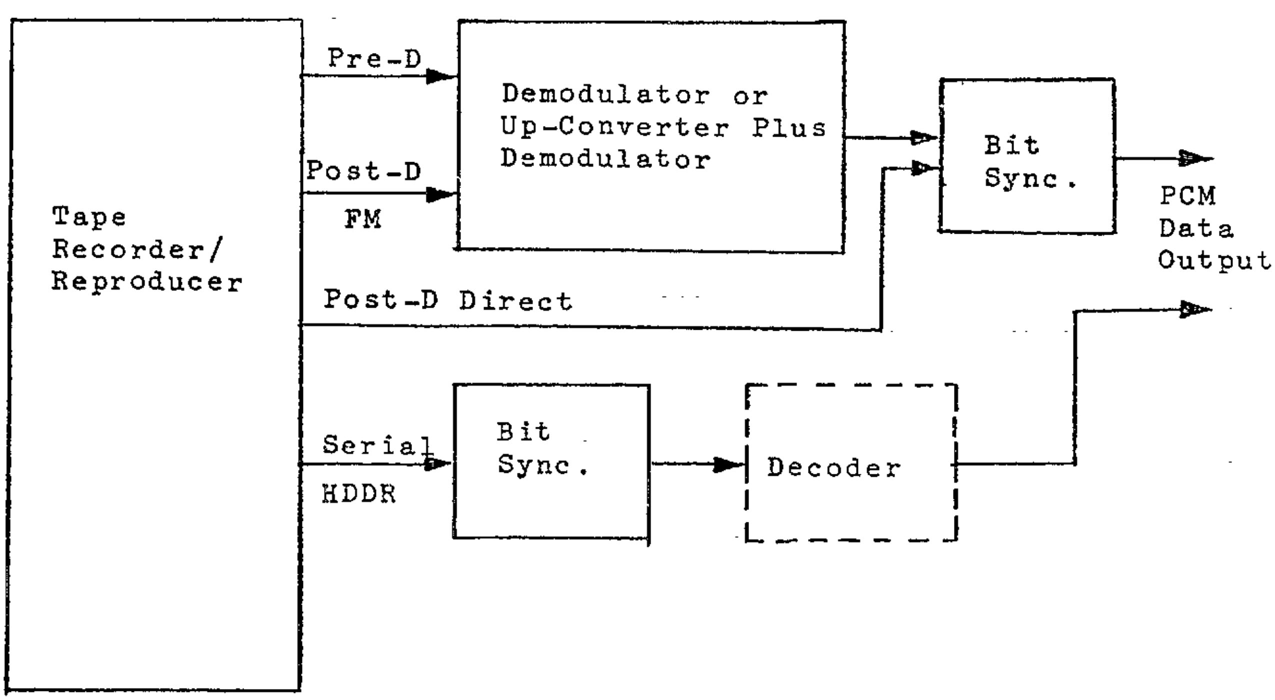
6.11.4.1 PCM Codes. The recommended codes for serial high density PCM recording are bi-phase level (BiØ-L) and randomized non return to zero-level (RNRZ-L). The maximum recommended bit packing densities are 590 b/mm (15 kb/in.) for BiØ-L and 980 b/mm (25 kb/in.) for RNRZ-L. Refer to table 6-10 for maximum recommended bit rates versus standard tape speeds. The minimum recommended reproduce bit rates are 5 kb/s for BiØ-L and 200 kb/s for RNRZ-L. Details of the implementation are discussed in paragraph 3.0, appendix D.

6.11.4.2 BiØ-L Code. The BiØ-L code is recommended for direct recording under the following conditions: the bit rate of the data to be recorded does not exceed the maximum bit rates for BiØ-L (see table 6-10), and the amount of tape required for mission recording by this method is not a severe operational constraint.

6.11.4.3 RNRZ-L Code. The RNRZ-L code is recommended for direct recording under any of the following conditions: the bit rate of the data to be recorded exceeds the maximum recommended bit rates for BiØ-L (see table 6-10) or maximum tape recording time is needed.



PCM-Record Mode



PCM-Reproduce Mode

Figure 6-5. PCM Record and Reproduce Configurations.

TABLE 6-9. MAXIMUM RECOMMENDED BIT RATES, POSTDETECTION RECORDING*

Tape Speed				Post-D Direct	Post-FM	
m/s	(ips)	mm/s	(ips)	BiØ (kb/s)	BiØ (kb/s)	NRZ (kb/s)
Wideband		Double Density				
6096.0	(240)	3048.0	(120)	1800	900	1800
3048.0	(120)	1524.0	(60)	900	450	900
1524.0	(60)	762.0	(30)	450	225	450
762.0	(30)	381.0	(15)	225	112	225
381.0	(15)	109.5	(7-1/2)	112	56	112
190.0	(7-1/2)	95.2	(3-3/4)	56	28	56
95.2	(3-3/4)	---	---	28	14	28
47.6	(1-7/8)	---	---	14	7	14

***Direct Recording of NRZ signals is NOT recommended unless the signal format is carefully designed to eliminate low-frequency components for any data expected.**

TABLE 6-10. MAXIMUM RECOMMENDED BIT RATES

Tape Speed					
mm/s	ips	mm/s	ips	BiØ-L (kb/s)	RNRZ-L (kb/s)
Wideband		Double Density			
6096.0	(240)	3048.0	(120)	3600	6000
3048.0	(120)	1524.0	(60)	1800	3000
1524.0	(60)	762.0	(30)	900	1500
762.0	(30)	381.0	(15)	450	750
381.0	(15)	190.5	(7-1/2)	225	375
190.5	(7-1/2)	95.2	(3-3/4)	112	187**
95.2	(3-3/4)	---	---	56	93**
47.6	(1-7/8)	---	---	28	46**

****Reproducing data at bit rates less than 200 kb/s is not recommended when using RNRZ-L (see appendix D for details).**

6.11.4.3.1 To minimize baseline wander anomalies, RNRZ-L is NOT recommended if the reproduced bit rate is less than 200 kb/s.

6.11.4.3.2 RNRZ-L shall be implemented using a 15-stage shift register and modulo-2 adders (see figure 6-6). The randomized bit stream to be recorded is generated by adding (modulo-2) the input bit stream to the modulo-2 sum of the outputs of the 14th and 15th stages of the shift register. In the decoder, the randomized bit stream is the input to the shift register (see figure 6-6).

6.11.4.4 <u>Record Parameters</u>. The record parameters are explained in the following subparagraphs:

6.11.4.4.1 High-density PCM data shall be recorded in compliance with the direct record parameters detailed in subparagraph 6.8.1 including the use of an ac bias signal level which produces the required 2 dB overbias condition.

6.11.4.4.2 The peak-to-peak level of the PCM input signal shall be equal to twice the rms value of the signal amplitude used to establish the standard record level with a tolerance of ±25 percent (see subparagraph 6.8.2).

6.11.4.4.3 The signal to be recorded must be bi-level. Bi-level signals are signals where only two levels are present. Therefore, signals containing noise must be converted to bi-level signals before they are recorded.

6.11.4.4.4 In order to minimize the effects of tape dropouts, serial high-density digital data should not be recorded on the edge tracks of the tape.

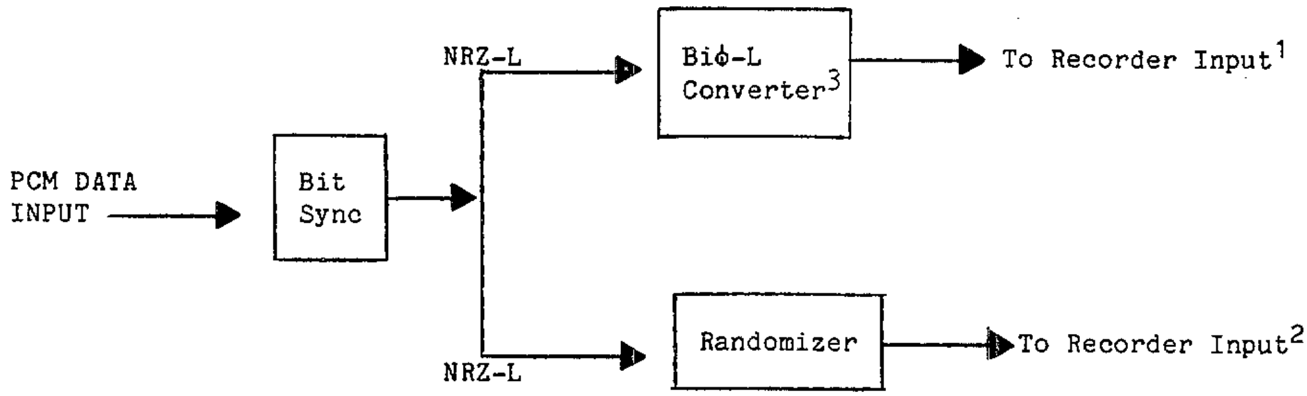
6.11.4.5 <u>Reproduce Parameters</u>. All reproduce parameters in subparagraph 6.8.3 shall apply.

6.11.4.5.1 <u>PCM Signature</u>. A PCM signature should be recorded before and/or after the data to provide a method for adjusting the reproduce head azimuth and the reproducer equalizers. The data rate of the PCM signature should be the same as the rate of the data to be recorded (see paragraph 7.0, appendix D for tape signature recording).

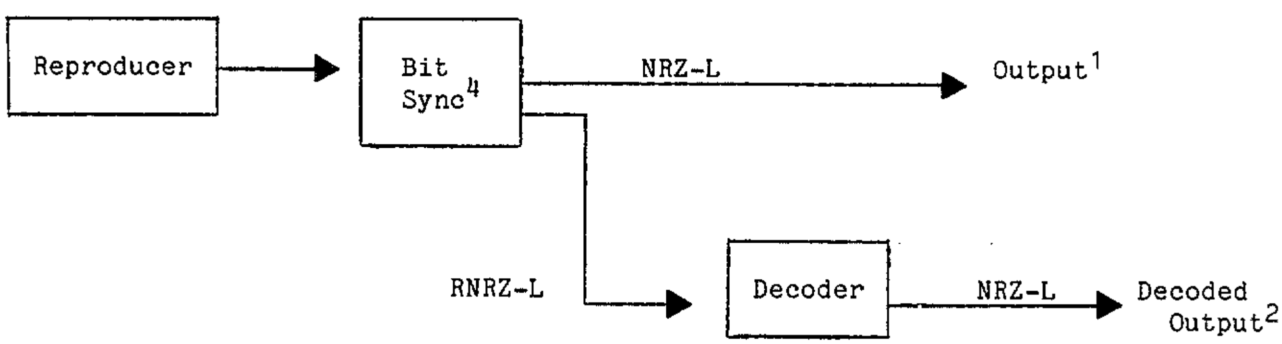
6.11.4.5.2 <u>Phase Equalizer</u>. Correct phase equalization is very important to the reconstruction of the serial high-density digital data. Adjustable phase equalizers are desirable but not mandatory.

6.11.4.6 <u>Magnetic Tape</u>. High-density digital (HDD) magnetic tapes are recommended; however, wideband instrumentation tapes can be used on recorder and reproducer systems with 1.27 mm (0.050 in.) track widths (see chapter 7).

6.11.4.7 <u>Tape Copying</u>. The following practices are recommended when making copies of original data tapes:



(See figure D-1, appendix D.)



(See figure D-2, appendix D.)

---

[1]When Biϕ-L is recorded.

[2]When RNRZ-L is recorded.

[3]The Biϕ-L converter may be an integral part of the Bit Sync.

[4]Bit Sync input code selector set to NRZ-L if RNRZ-L is recorded or to Biϕ-L if Biϕ-L is recorded.

Figure 6-6. Serial High Density Digital Record and Reproduce.

6.11.4.7.1 Convert data reproduced from the original tape to a bi-level signal prior to recording a copy,

6.11.4.7.2 Align reproduce head azimuth to original tape,

6.11.4.7.3 Adjust reproducer equalizers correctly, and

6.11.4.7.4 Prior to recording the copy, use the recorded PCM signature to optimize the quality of the reproduced data.

6.11.4.8 PCM Bit Synchronizer. The PCM bit synchronizer should contain circuitry to reestablish the baseline reference PCM signal (a dc restorer circuit). This circuit is essential when reproducing RNRZ-L at reproduced bit rates less than 1 Mb/s. The PCM bit synchronizer loop bandwidth should be selected for optimum performance between 0.1 percent and 3 percent of the bit rate.

NOTE

If an appropriate PCM bit synchronizer is not available, the tape can be copied directly; however, the SNR will be decreased.

CHAPTER 7

MAGNETIC TAPE STANDARDS

7.1 General

These standards define terminology, establish key performance criteria, and reference test procedures for longitudinally-oriented oxide, unrecorded magnetic tape designed for instrumentation recording[1]. Classes of tapes include Standard Resolution (SR) tapes used for intermediate band recording, High Resolution (HR) tapes used for wideband recording, High Density Digital (HDD) tapes used for high-density digital (PCM) recording, and High Energy (HE) tapes used for double-density recording. Coercivities of SR, HR and HDD tapes are in the range of 275 to 350 oersteds. High energy tapes have coercivities of 600 to 800 oersteds. Nominal base thickness is 25.4 micrometers (1.0 mil) and nominal coating thickness is 5 micrometers (200 microinches) for all tapes. Some SR tapes are also available with 38.1 micrometers (1.5 mil) base (see table 7-1). Where required, limits are specified to standardize configurations and to establish the basic handling characteristics of the tape. Limits placed on the remaining requirements must be determined by the tape user in light of the intended application and interchangeability requirements imposed on the tape (see table 7-4 for examples of suggested requirement limits).

7.2 Definitions

Underlined terms appearing within definitions indicate that these terms are defined elsewhere in paragraph 7.2. For the purpose of this standard, the following definitions apply:

7.2.1 Back Coating. A thin coating of conductive material (for example, carbon) is bonded to the surface of a magnetic tape opposite the magnetic-coated surface for reducing electrostatic charge accumulation and for enhancing high-speed winding uniformity. Resistivity of the back coating should be 1 megohm per square or less, whereas the oxide-coated magnetic surface resistivity is much higher (also see magnetic oxide coating).

7.2.2 Base. The material on which the magnetic oxide coating (and back coating, if employed) is applied in the manufacture of magnetic tapes. For most applications, polyester-base materials are currently employed.

----

[1]**Federal Specifications W-T-001553[SH] and W-R-175 may be used to replace paragraphs contained in this chapter where applicable. High output and HDD tapes are not included in the Federal Specifications. Other standards are referenced in paragraph 1.0, appendix D.**

TABLE 7-1. TAPE DIMENSIONS

Tape Widths	millimeters	inches
	12.7 +0, -0.10	0.500 +0, -0.004
	25.4 +0, -0.10	1.000 +0, -0.004

Tape Thickness[1]	millimeters	inches	
Base Material	.025	.0010	Nominal[2]
Oxide Thickness	.005	.0002	Nominal

Tape Length by Reel Diameters (reels with 76 mm (3 in.) center hole)

Reel Diameter	Nominal Tape Length[3]	Minimum True Length[4]
266 mm (10.5 in.)	1,100 m (3,600 ft)	1,105 m (3,625 ft)
" " " "	1,400 m (4,600 ft)	1,410 m (4,625 ft)
356 mm (14.0 in.)	2,200 m (7,200 ft)	2,204 m (7,230 ft)
" " " "	2,800 m (9,200 ft)	2,815 m (9,235 ft)
381 mm (15.0 in.)	3,290 m (10,800 ft)	3,303 m (10,835 ft)
408 mm (16.0 in.)	3,800 m (12,500 ft)	3,822 m (12,540 ft)

[1]Base thickness of 0.038 mm (.0015 in.) is being phased out by manufacturers.

[2]Actual tape base material thickness slightly less due to manufacturing conventions.

[3]Original dimensions are in feet. Metric conversions are rounded for convenience.

[4]Tape-to-flange radial clearance (E-value) is 3.18 mm (0.125 in.).

7.2.3 Bias Level. The level of high-frequency ac bias current or voltage in a direct-record system needed to produce a specified level of an upper-band edge (UBE) frequency sine-wave signal at a particular tape speed. Usually adjusted to produce maximum output or increased beyond maximum to depress the output 2 dB.

7.2.4 Bi-Directional. Ability of a magnetic tape to record and to reproduce a specified range of signals within specified tolerances of various characteristics when either end of the tape on the reel is used as the "leading" end.

7.2.5 Binder. Material in which the magnetic oxide particles or back-coating particles are mixed to bond them to the base material.

7.2.6 Blocking. Failure of the magnetic coating to adhere to the base material because of layer-to-layer adhesion in a wound tape pack.

7.2.7 Center Tracks. On a recorded tape, center tracks are those which are more than one track distance from either edge of the tape; for example, tracks 2 through 6 of a 7-track tape, tracks 2 through 13 of a 14-track tape, or tracks 2 through 27 of a 28-track tape.

7.2.8 Dropout. A reproduced signal of abnormally low amplitude caused by tape imperfections severe enough to produce a data error. In digital systems, dropouts produce bit errors.

7.2.9 Edge Tracks. The data tracks nearest the two edges of a recorded magnetic tape, for example, tracks 1 and 7 of a 7-track tape.

7.2.10 Erasure. Removal of signals recorded on a magnetic tape to allow reuse of the tape or to prevent access to sensitive or classified data. Instrumentation recorders and reproducers do not usually have erase heads, so bulk erasers or degaussers must be employed. For high-energy tapes, it may not be possible to erase a tape adequately to meet stringent classified data protection requirements.

7.2.11 E-Value. The radial distance by which the reel flanges extend beyond the outermost layer of tape wound on a reel under a tape tension of 3.33 to 5.56 newtons (12 to 20 ounces of force) per inch of tape width. Inadequate E-value may prohibit the use of protective reel bands.

7.2.12 High-Density Digital (HDD) Magnetic Tape. Instrumentation magnetic tape with nominal base thickness of 1 mil and coercivity of 275 to 350 oersteds used to record and reproduce high-density digital (PCM) signals with per-track bit densities of 25 kilobits per inch or greater.

7.2.13 High-Energy (HE) Magnetic Tape. Magnetic tapes having coercivity of 600 to 800 oersteds and nominal base thickness of 1 mil used for double-density analog recording and high-density digital recording above 33 kilobits per inch.

7.2.14 High-Resolution (HR) Magnetic Tape. Instrumentation magnetic tape used for recording on wideband recorder and reproducer systems. HR and HDD tapes may have identical coatings and coercivities (275 to 350 oersteds) but differ in the extent and type of testing conducted by the manufacturer.

7.2.15 Layer-to-Layer Signal Transfer (Print-Through). Transfer of a signal to a layer of a wound magnetic tape originating from a signal recorded on an adjacent layer of tape on the same reel. Saturation-level recorded signals and tape storage at elevated temperatures are likely contributors to this effect.

7.2.16 Magnetic Oxide Coating. Material applied to a base material to form a magnetic tape. The magnetic oxide coating contains the oxide particles, the binder and other plasticizing and lubricating materials necessary for satisfactory operation of the magnetic tape system (also see back coating).

7.2.17 Manufacturer's Center Line Tape (MCT). A tape selected by the manufacturer from his production, where the electrical and physical characteristics are employed as reference standards for all production tapes to be delivered during a particular contractual period. Electrical characteristics include, but are not limited to, bias level, record level, output at 0.1 UBE, and wavelength response. MCTs are not usually available for procuring agency use.

7.2.18 Manufacturer's Secondary Center Line Tape (MSCT). A tape selected by a manufacturer from his production and provided in lieu of an MCT. On the MSCT, the electrical characteristics may depart from the MCT characteristics, but calibration data referenced in the MCT are provided. All other characteristics of the MSCT are representative of the manufacturer's product.

7.2.19 Modulation Noise. Noise riding on a reproduced signal that is proportional to the amplitude of the recorded signal (below saturation) and results from tape-coating irregularities in particle size, orientation, coercivity, and dispersion.

7.2.20 Record Level. The level of record current or voltage required to achieve a specified reproduce output level with bias level previously set to the correct value. In direct record systems, standard record level is the level of a 0.1 UBE frequency signal required to produce 1 percent third harmonic distortion in the reproduced output signal because of tape saturation.

7.2.21 Scatterwind. Lateral displacements of tape wound on a reel which gives an irregular appearance to the side surfaces of a tape pack. Scatterwind can result from such things as poorly controlled tape tension, guiding, static electrical charge, and poor tape slitting.

7.2.22 Shedding. Loss of magnetic coating from tape during operation on a tape transport. Excessive shedding causes excessive dropout.

7.2.23 Short Wavelength Output Uniformity. A measure of high-frequency reproduce signal amplitude uniformity caused by oxide coating variations.

7.2.24 Standard Resolution Magnetic Tape. Standard resolution tapes are used for intermediate band recording systems. Coercivities are in the range of 275 to 350 oersteds.

7.2.25 Upper Band Edge (UBE). The highest frequency that can be recorded and reproduced at a particular tape speed in the direct record mode. UBE signals are used in setting bias level; 0.1 UBE signals are used to set record level.

7.2.26 Wavelength Response. The record and reproduce characteristic of a magnetic tape which depends on tape formulation, coating thickness, and other tape physical parameters and is a function of the wavelength recorded on the tape (tape speed divided by signal frequency) rather than the actual frequency recorded.

7.2.27 Working Length. Length of tape usable for reliable recording and reproduction of data. Actual tape length on a reel exceeds the working length to provide for tape start and stop at each end of the reel without loss of data.

7.2.28 Working Reference Tape (WRT). A tape or tapes of the same type as an MCT or MSCT selected by the user and calibrated to the MCT or MSCT. WRTs are employed in conducting tests on tape types during a procurement activity and for aligning and testing recorder and reproducer systems to minimize running the MCT or MSCT.

7.3 General Requirements for Standard Tapes and Reels

The following subparagraphs describe the requirements for tapes and reels:

7.3.1 Reference Tape System. To establish a set of test procedures which can be performed independently and repeatably on different manufacturers' tape transports, a center line reference tape system employing Manufacturer's Center Line Tapes (MCT), Manufacturer's Secondary Center Line Tapes (MSCT) or Working Reference Tapes (WRT) as required, should be used. The reference tape system provides a center line tape against which tape or tape recorder specifications may be tested or standard tapes for aligning operational recorders.

7.3.1.1 Manufacturer's Center Line Tape (MCT) (see subparagraph 7.2.17). The electrical characteristics provided for a Manufacturer's Center Line Tape include, but are not limited to, bias level, record level, wavelength response, and output at 0.1 UBE wavelength. The physical characteristics of the MCT shall also represent the manufacturer's production and shall be representative of all production tape delivered during any resultant contractual period.

7.3.1.2 Manufacturer's Secondary Center Line Tape (MSCT) (see subparagraph 7.2.18). On the MSCT, the electrical characteristics are calibrated to the manufacturer's reference tape, and calibration data are supplied with the MSCT. The physical characteristics of the MSCT shall represent the manufacturer's production.

7.3.1.3 Working Reference Tape (WRT) (see subparagraph 7.2.28). Working Reference Tapes shall be of the same type as those under procurement or test and shall be used in place of a MCT or MSCT for all applicable test procedures.

NOTE

The MCT or MSCT shall be a full-length tape of either 12.7 mm (1/2 in.) or 25.4 mm (1 in.) width, wound on a 266.7 mm (10 1/2 in.) or 355.6 mm (14 in.) reel or as designated by the tape user. The center one-third of the working tape length shall be used as the calibrated working area.

7.3.1.4 Test Recorder and Reproducer. A laboratory-quality test recorder shall be designated for use with the reference tape system during any magnetic tape procurement and test program. The recorder selected shall meet the requirements in chapter 6.

7.3.1.5 MCT/MSCT/WRT Use. Using the MCT or MSCT as a reference, the tape user performs all tests necessary to determine if the manufacturer's center line performance values meet operational and recorder requirements. All acceptable center line tapes are retained by the tape user as references in subsequent acceptance test procedures performed in support of resultant contracts or contractual periods. A working reference tape (WRT), which has been calibrated to an MCT or MSCT, is used as the actual working reference in the applicable testing procedures outlined in appendix B, volume III, IRIG Document 118-79. Dropout tests should use a tape other than the MSCT or WRT.

7.3.2 Marking and Identifying. See Federal Specification W-T-01553[SH].

7.3.3 Packaging. Specified by user.

7.3.4 Winding. The tape shall be wound on the reel or hub with the oxide surface facing toward the hub ("A" wind). The front of the wound reel is defined as that flange visible when viewing the tape reel with the loose end of the tape hanging from the viewer's right.

7.3.5 Reels and Hubs. Reels and hubs shall conform to the tape user specified requirements of Federal Specification W-R-175 (also see appendix D).

7.3.6 Radial Clearance (E-Value) (see subparagraph 7.2.11). For all tape lengths use 3.175 mm (0.125 in.).

7.3.7 Flammable Materials. Flammable materials shall not be a part of the magnetic tape. Flammable materials will ignite from a match flame and will continue to burn in a still carbon dioxide atmosphere.

7.3.8 Toxic Compounds. Compounds which produce toxic effects in the environmental conditions normally encountered under operating and storing conditions as defined in subparagraph 7.4.2 shall not be part of the magnetic tape. Toxicity is defined as the property of the material which has the ability to do chemical damage to the human body. Highly toxic or corrosive compounds produced under conditions of extreme heat shall be identified and described by the manufacturer.

7.4 General Characteristics of Tapes and Reels

The following subparagraphs describe the general characteristics for tapes and reels:

7.4.1 Dimensional Specifications. Magnetic tape shall be supplied on flanged reels in the standard lengths, widths and base thicknesses outlined in table 7-1. Reel and hub diameters are taken from Federal Specification W-R-175.

7.4.2 Environmental Conditions. The tape shall be able to withstand, with no physical damage or performance degradation, any natural combination of operating or nonoperating conditions as defined in subparagraphs 7.4.2.1 and 7.4.2.2 below. The test procedure outlined in subparagraph 3-57a, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.4.2.1 Tape Storing Conditions. Magnetic tape is subject to deterioration at extremes of temperature and humidity. In some cases the damage is reversible, but irreversible damage may occur, especially with long-term storage in unfavorable conditions.

7.4.2.2 Operating Environment. Recommended limits:

Condition	Range
Temperature:	4° to 30°C (40° to 85°F)
Humidity:	20 to 60 percent RH noncondensing
Pressure:	Normal ground or aircraft operating altitude pressures. For very high altitudes, tape users should consult with manufacturers to determine if tape and recorder compatibility is affected by low atmospheric pressure.

NOTES

(1) Binder/oxide system tends to become sticky and unusable above 50°C (125°F).

(2) At low humidities, tape binder and oxide system tend to dry out and oxide and binder adhesion can be unsatisfactory. Brown stains on heads may appear below 40 percent RH.

(3) At high humidities, abrasivity is increased and other performance problems may arise.

7.4.2.3 Nonoperating Environment. Temperature and Relative Humidity:

Short Term - 0° to 45°C (32° to 115°F) and 10 to 70 percent RH noncondensing

Long Term - 1° to 30°C (33° to 85°F) and 30 to 60 percent RH noncondensing

NOTE

Experience has shown that with long exposure to temperatures below freezing, lubricants and plasticizers tend to migrate out of the oxide coating resulting in poor lubrication and gummy surface deposits.

7.4.3 Other Characteristics. Storage life, bi-directional performmance, frictional vibration, and scatterwind characteristics shall conform to Federal Specification W-T-001553[SH] unless otherwise specified by the tape user at the time of purchase.

7.5 Physical Characteristics of Tapes and Reels . As specified in Federal Specification W-T-001553[SH] and W-R-175.

7.6 Magnetic and Electrical Characteristics. The following subparagraphs describe required magnetic and electrical tape characteristics:

7.6.1 Bias Level. The bias level (see subparagraph 7.2.3) required by the magnetic tape shall not differ from the bias level requirements of the reference tape by more than the amount specified by the tape user. The test procedure outlined in subparagraph 3-65a, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.2 Record Level. The record level (see subparagraph 7.2.20) required by the magnetic tape shall not differ from the record level requirements of the reference tape by more than the amount specified by the tape user. The test procedure outlined in subparagraph 3-65b, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.3 Wavelength Response. The output of the magnetic tape, measured at the wavelength values listed in table 7-2, Measurement Wavelengths, shall not differ from the output of the reference tape by more than the amounts specified by the tape user. Wavelength response requirements shall be specified in terms of output after having normalized the output to zero at the 0.1 UBE wavelength. The test procedure outlined in subparagraph 3-65c, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement (see table 7-4A, Suggested Wavelength Response Requirements).

TABLE 7-2. MEASUREMENT WAVELENGTHS

Standard-Resolution Tape		High-Resolution & HDD Tape		High-Energy Tape	
µm	(mils)	µm	(mils)	µm	(mils)
7620.00	(300.000)	3810.00	(150.000)	254.00	(10.000)
1524.00	(60.000)	254.00	(10.000)	25.40	(1.000)
254.00	(10.000)	25.40	(1.000)	12.70	(0.500)
25.40	(1.000)	6.35	(0.250)	6.35	(0.250)
12.70	(0.500)	3.18	(0.125)	3.18	(0.125)
6.35	(0.250)	2.54	(0.100)	2.54	(0.100)
3.18	(0.125)	2.03	(0.080)	1.52	(0.060)
		1.52	(0.060)	1.02	(0.040)
				0.76	(0.030)

7.6.4 Output at 0.1 UBE Wavelength. The wavelength output of the magnetic tape shall not differ from the 0.1 UBE wavelength of the reference tape by more than the amount specified by the tape user. The test procedure outlined in subparagraph 3-65c, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.5 Short Wavelength Output Uniformity. The short wavelength output of the magnetic tape shall be sufficiently uniform that a signal recorded and reproduced throughout the working tape length in either direction of longitudinal tape motion shall remain free from long-term amplitude variation to the extent specified by the tape user. The test procedure outlined in subparagraph 3-65d, appendix B, of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.6 Dropouts. The instantaneous nonuniformity (dropout) output of a recorded signal, caused by the magnetic tape, shall not exceed the center track and edge track limits specified by the tape user on the basis of dropouts per 30.48 m (100 ft) of nominal working tape length. The nominal dropout count shall be determined by totaling all the dropouts per track over the working tape length and dividing by the total number of 30.48 m (100 ft) intervals tested.

A second method of specifying the allowable dropout count is to specify the maximum number per track for each 30.48 m (100 ft) interval tested. This method may be preferred if critical data is recorded in specific areas of the working tape length, but a specified number of dropouts per hundred feet greater than the average values may be expected.

NOTE

Dropout test results are very dependent on the tape transport used for the test and will vary from run to run on a given transport. Edge tracks tend to contain more dropouts than the center tracks, and more dropouts are allowed on the edge tracks. Refer to table 7-4.

7.6.6.1 For Standard Resolution (SR) tapes, a dropout is defined as a 6 dB reduction in output signal amplitude for a period of 10 microseconds or longer when recording and reproducing a signal of 400 kHz at 120 ips. Signal losses of 6 dB or greater, which exceed the 10 microsecond time period, shall constitute a dropout count for each 10 microsecond time period occurring in the given signal loss. The test procedure outlined in subparagraph 3-65e, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.6.2 For High Resolution (HR) tapes, a dropout is defined as a 6 dB reduction in amplitude for a period of 5 microseconds or more of a 1 MHz sine-wave signal recorded and reproduced at a tape speed of 120 ips. Signal losses of 6 dB or more which exceed the 5 microsecond time period shall constitute a dropout count for each 5 microsecond time period occurring in the given signal loss. Track definitions are given in subparagraphs 7.2.7 and 7.2.9. Test procedures are as in subparagraph 7.6.6.1 above.

7.6.6.3 For High Density Digital (HDD) tapes, a dropout is defined as a 12 dB or greater reduction in amplitude for a period of 1 microsecond or more of a square-wave test signal of maximum density recorded and reproduced at 120 ips or 60 ips. On at least every other track (7 tracks) of the odd head of a 28-track head assembly (alternatively, every other track of the even head) record and reproduce a square-wave test signal of 2 MHz at 3048 mm/s (120 ips) or 1 MHz at 1524 mm/s (60 ips). The record level shall be set slightly above saturation by adjusting the record current to produce maximum reproduce output and increasing the record current until the output signal is reduced to 90 percent of maximum. For playback, a reproduce amplifier and a threshold detector shall be used. The signal-to-noise ratio of the test signal at the input to the threshold detector shall be at least 25 dB, and the detector shall detect any signal loss of 12 dB or more below reference level. The reference level shall be established by averaging the test signal output level over a 10 m (30 ft) nominal tape length in the vicinity of a dropout.

7.6.6.4 For each of the seven tracks tested, the accumulated duration in microseconds of detected dropout events shall be displayed and used to display directly the dropout rate for each track scaled appropriately for the tape working length. Signal losses of 12 dB or more which exceed the 1 microsecond time period shall constitute a dropout count for each microsecond time period occurring in the given signal loss.

7.6.6.5 For high-energy tapes, a dropout is defined as for high-resolution tapes except that a 1 MHz signal is recorded and reproduced at 60 ips.

7.6.7 Durability. The magnetic tape shall resist deterioration in magnetic and electrical performance because of wear to the coating surface. Signal losses, as defined below, caused by surface wear shall not occur in excess of the per-pass limits specified in table 7-3 for the first 35 passes.

Signal losses in excess of those limits specified above shall not occur during either a record, record and reproduce or uninterrupted reproduce pass of the working tape length. Signal loss is a reduction in signal amplitude of 3 dB or greater for a time period of 3 through 10 seconds of a recorded and reproduced short wavelength signal. Where a continuous loss of signal of 3 dB or greater exceeds the 10 second time period, a signal loss count shall be required for every sequential 10 second time period occurring in the given signal loss. The test procedure outlined in subparagraph 3-65f, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

TABLE 7-3. DURABILITY SIGNAL LOSSES

Designated Tape Length		Number of Allowable Signal Losses (per pass)
meters	feet	
762	(2500)	2
1097	(3600)	2
1402	(4600)	2
1524	(5000)	2
2195	(7200)	3
2804	(9200)	3
3292	(10800)	4

7.6.8 Modulation Noise. The amplitude modulation super-imposed upon a recorded and reproduced signal by the magnetic tape shall not exceed the limits specified by the tape user. The test procedure outlined in subparagraph 3-65g, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.9 Layer-to-Layer Signal Transfer. A signal resulting from layer-to-layer signal transfer shall be reduced in amplitude from the original signal a minimum of 40 dB for 25.4 micrometers (1.0 mil) tape and 46 dB for 38.1 micrometer (1.5 mils) tape. The test procedure outlined in subparagraph 3-65h, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.10 Erasure Ease. For SR, HR, and HDDR tapes, an erase field of 79.58 kA/M (1000 oersteds) shall effect at least a 60 dB reduction in output amplitude of a previously recorded 25.4 micrometers (1.0 mil) wavelength signal. For HE tapes, an erase field of 160 kA/m (2000 oersteds) shall effect at least a 60 dB reduction of a previously recorded 25.4 micrometers (1.0 mil) wavelength signal. The test procedure outlined in subparagraph 3-65i, appendix B, volume III of IRIG Document 118-79 shall be used to determine compliance with this requirement.

7.6.11 Suggested Tape Requirement Limits. Table 7-4 lists some suggested limits to be used for instrumentation tape.

TABLE 7-4. SUGGESTED TAPE REQUIREMENT LIMITS

Par. No.	Tape Requirement	Suggested Limits		
7.6.1	Bias Level	±2.0 dB from MCT		
7.6.2	Record Level	±2.0 dB from MCT		
7.6.3	Wavelength Response (See table 7-4A.)			
7.6.4	Output at 0.1 UBE Wavelength	1.5 dB from MCT		
7.6.5	Short Wavelength Output Uniformity	SR Tape	HR Tape	HE Tape
		3.0 dB	4.5 dB	TBD
7.6.6	Dropouts per 30 m (100 ft) (average)	Center Tracks		Edge Tracks
		20	SR Tape	25
		10	HR Tape	40
		TBD	HDD Tape	TBD
		20	HE Tape	80
7.6.7	Durability (See table 7-3.)			
7.6.8	Modulation Noise	1 dB maximum		

TABLE 7-4A. SUGGESTED WAVELENGTH RESPONSE REQUIREMENTS

SR TAPE

Measurement Wavelength µm	(mils)	SR Response
7620.00	(300.000)	1.5
1524.00	(60.000)	1.0
50.80	(2.000)	0.0
25.40	(1.000)	1.0
12.70	(0.500)	1.0
6.35	(0.250)	1.5
3.18	(0.125)	2.0

HR AND HDD TAPE

Measurement Wavelength µm	(mils)	HR Response (dB)	HDD Response (dB)
3810.00	(150.000)	1.00	2.00
254.00	(10.000)	1.00	1.00
15.14	(0.600)	0.00	0.00
6.35	(0.250)	1.50	1.50
3.18	(0.125)	2.00	2.00
2.54	(0.100)	2.50	2.50
2.03	(0.080)	2.50	2.50
1.52	(0.060)	3.00	3.00

HIGH-ENERGY TAPE

Measurement Wavelength µm	(mils)	HE Wavelength Response (dB)
25.40	(1.000)	2.00
12.70	(0.500)	2.00
7.62	(0.300)	0.00
3.18	(0.125)	2.50
1.52	(0.060)	2.50
1.02	(0.040)	3.00
0.76	(0.030)	3.50

APPENDIX A

FREQUENCY MANAGEMENT PLAN FOR UHF TELEMETRY BANDS

APPENDIX A

FREQUENCY MANAGEMENT PLAN FOR UHF TELEMETRY BANDS

1.0 Purpose

This plan was prepared with the assistance of the RCC Frequency Management Group (FMG) to provide guidelines for the most effective use of allocated UHF telemetry bands 1435 to 1535 MHz, 2200 to 2290 MHz and 2310 to 2390 MHz to retain documentation on the VHF, 225 to 260 MHz, frequency band.

2.0 Scope

This plan is to be used as a guide by managers and users of telemetry frequencies in the above bands at national, service or other Department of Defense (DOD) test ranges and facilities, and is based primarily on information obtained from empirical and theoretical analyses, from judgments formulated on past experience, and on expectations of future requirements and equipment characteristics. Moreover, this plan is designed to alleviate the congestion of the allocated telemetry spectrum where it is expected to be a problem, that is, at the national ranges and adjacent areas.

3.0 225 to 260 MHz Frequency Band

Essential air-ground telemetering for guided missiles, spacecraft and upper atmosphere research was conducted in the past on a primary basis on 44 channels (500 kHz bandwidth) in the 225 to 260 MHz portion of the military communications band, 225 to 400 MHz. Telemetering for manned and unmanned aircraft was also authorized in this band on a secondary basis. The Military Communications-Electronics Board (MCEB) directed DOD agencies to remove all telemetering operations from this band after 1 January 1970. However, budgetary limitations and technical constraints have prevented certain operations from being converted to the 1435 to 1535 MHz, 2200 to 2290 MHz and 2310 to 2390 MHz bands, which have been allocated to satisfy displaced and future telemetry needs.[1]

3.1 225 to 260 MHz Frequency Band Use

This frequency band is allocated to fixed and mobile communication services and until such time as all telemetry use of this frequency band is terminated, standards for the 225 to 260 MHz frequencies will be retained in this appendix. The MCEB will consider temporary VHF telemetry waivers on an individual basis subject to the following limitations:

---

[1] **Military Communications-Electronics Board Memoranda: MCEB-M 92-65, 19 February 1965; 105-69, 24 February 1969; 323-72, 1 August 1972; and 151-76, 7 April 1976.**

3.1.1 Military test vehicles used in the test must be part of the current inventory and originally configured with 225 to 260 MHz telemetry systems.

3.1.2 Available facts must clearly support the contention that the use of telemetry equipment in the 1435 to 1535 MHz, 2200 to 2290 MHz or 2310 to 2390 MHz bands would be prohibitively expensive or impractical, or that significant test program slippage would occur if conversion or retrofit is required.

3.1.3 Ranges and test sites selected to support the proposed operations should be able to provide VHF telemetry support without installing additional equipment.

3.1.4 Operations will be limited to the frequency bands listed in table A-1 below.

TABLE A-1. RADIO FREQUENCY TELEMETRY ASSIGNMENTS

226.7 MHz	237.0 MHZ	246.3 MHZ	259.7 MHz
230.4 MHz	239.4 MHz	248.6 MHz	
231.9 MHz	240.2 MHz	250.7 MHz	
232.9 MHz	244.3 MHz	253.8 MHz	
235.0 MHz	245.3 MHz	256.2 MHz	

3.1.5 VHF telemetry use on the foregoing frequencies will not be a barrier in satisfying communications needs for which the 225 to 400 MHz band is primarily allocated.

3.1.6 Frequency allocation applications proposing development or procurement of new telemetry equipment designed to operate in the 225 to 260 MHz band will not be approved.[2]

---

[2]Certain short-term waivers granted to DOD components will permit some flexibility in effecting full conversion to UHF telemetry. Users with waivers which permit continued operations in the 225 to 260 MHz band will adhere to telemetering standards contained in this appendix.

3.2 225 to 260 MHz Transmitter Systems

The following subparagraphs furnish 225 to 260 MHz transmitter systems criteria:

3.2.1 Frequency Tolerance. The specified frequency tolerance is applicable for all operations in which the conducted power level is greater than -25 dBm for a duration of 1 or more seconds. The transmitter RF carrier, modulated or unmodulated, shall be within ±0.01 percent of the assigned frequency under all operating conditions and environments. If radiated measurements become necessary for the determination of frequency, the ±0.01 percent frequency tolerance shall apply when a field intensity of greater than 150 microvolts per meter for 1 or more seconds is experienced at any radial distance of 30.48 m (100 ft) from the transmitter antenna systems.

3.2.2 Power. The maximum allowable power shall be 100 watts; the power used should never be more than absolutely necessary for reliable telemetry transmission.

3.2.3 Spurious Emission and Interference Requirements. Telemetry equipment should meet the following criteria using test methods and equipment in accordance with applicable military standards and specifications.

3.2.3.1 Spurious Emission (Antenna-Conducted or Antenna-Radiated - 0.150 to 10,000 MHz). Emissions from the transmitter antenna system are of primary importance. Spurious and harmonic outputs, antenna-conducted (measured in the antenna transmission line) or antenna-radiated (measured in free space) shall be limited to -25 dBm.

NOTE

Radiated tests will only be used when the transmission line is inaccessible for conducted measurements. Radiated measurements will be equivalent to -25 dBm as referenced to the unmodulated carrier power.

Conducted or radiated spurious emissions will be checked under unmodulated conditions.

3.2.3.2 Interference (Conducted or Radiated). All interference voltages (0.150 to 25 MHz) conducted by the power leads and interference fields (0.150 to 10,000 MHz) radiated directly from equipment, units, or cables, shall be within the limits specified by the applicable military standards or specification.

3.2.4 Bandwidth (Transmitter Modulated). The power level in any 3 kHz bandwidth between f_o + 320 kHz and f_o + 500 kHz, and between f_o - 320 kHz and f_o - 500 kHz shall be at least 40 dB below the unmodulated carrier power in the transmission line or -25 dBm, whichever is greater. The power level in any 3 kHz bandwidth beyond f_o ±500 kHz shall be no greater than -25 dBm. All bandwidth measurements (spectrum analysis) will be made with instruments having a 3 dB resolution bandwidth of 3 kHz.

3.3 225 to 260 MHz Receiver Systems

The following subparagraphs describe the characteristics of the receiver system:

3.3.1 Spurious Emissions (0.150 to 10,000 MHz). RF energy, both radiated from the unit and antenna conducted, shall be within the limits specified in the applicable military standard or specification.

3.3.2 Frequency Tolerance. The combined errors of all local oscillators of discretely-tuned, crystal-controlled receivers shall not exceed ±0.001 percent of the assigned frequency under all operating conditions.

3.3.3 Spurious Responses (0.150 to 10,000 MHz). The spurious responses shall be more than 60 dB below the fundamental frequency response.

3.3.4 Flexibility of Operation. The system shall operate on any of the frequencies in table A-1 without design modification.

3.3.5 Bandwidth. A maximum bandwidth of 1.2 MHz (±600 MHz) as reference to the 60 dB points will be permitted.

4.0 UHF Telemetry Radio Frequency Assignments

Air and space-ground telemetering must be accommodated in the appropriate allocated UHF bands, 1435 to 1535 MHz, 2200 to 2290 MHz and 2310 to 2390 MHz to enhance unrestricted use of the 225 to 400 MHz military communications band for communications.

4.1 The bands, 1435 to 1535 MHz and 2310 to 2390 MHz, are nationally allocated for government or nongovernment telemetry use for flight testing of manned or unmanned aircraft, missiles, space vehicles, and their major components on a shared basis. The 2200 to 2290 MHz band is allocated for government fixed and mobile communications and telemetry on a coequal basis.

4.2 Narrowband telemetry channel spacing is in increments of 1 MHz beginning with frequencies 1435.5, 2200.5 and 2310.5 MHz respectively. These numbers will be used as the base from which all frequency assignments are to be made. Wideband channels are permitted and will be centered on the center frequency of narrowband channels. Accordingly, all telemetry equipment, whether for narrow, medium, or wideband channel application, must be capable of operating on any 1 MHz increment in the 1435 to 1535 MHz, 2200 to 2290 MHz or 2310 to 2390 MHZ band without infringing on adjacent bands.

5.0 Channel Bandwidth Definitions and Spacing Allocations

To satisfy various channel bandwidth requirements, the following definitions and spacing allocations will prevail:

5.1 Narrowband Channel. This channel has a bandwidth of 1 MHz or less.

5.2 Mediumband Channel. This channel has a bandwidth of more than 1 MHz but not greater than 3 MHz.

5.3 Wideband Channel. This channel has a bandwidth greater than 3 MHz but not greater than 10 MHz; the channel bandwidth assignment is determined by the service involved and is based on justifiable program requirements.

5.4 Center Frequencies. Operational flexibility may necessitate the use of channels centered on any narrowband center frequency within the allocated bands. Moreover, the bandwidth used on any particular channel will be contained within the allocated telemetry band concerned. For the purpose of designating channels to satisfy the varying bandwidths, the following normally will prevail:

5.4.1 Narrowband Channel Center Frequency - 1435 to 1535 MHz Band. From 1435.5 to 1534.5 MHz, the band can be in 1 MHz increments, for example, 1435.5, 1436.5, 1437.5.

5.4.2 Mediumband Channel Center Frequency. From 1436.5 to 1532.5 MHz, the band can be in 3 MHz increments, for example, 1436.5, 1439.5, 1442.5.[3]

5.4.3 Wideband Channel Center Frequency. From 1440.5 to 1520.5 MHz, the band can be in 10 MHz increments, for example, 1440.5, 1450.5, 1460.5.[4]

5.4.4 Narrowband Channel Center Frequency - 2200 to 2300 MHz Band. From 2200.5 to 2299.5 MHz, the band can be in 1 MHz increments, for example, 2200.5, 2201.5, 2202.5.

5.4.5 Mediumband Channel Center Frequency. From 2201.5 to 2297.5 MHz, the band can be in 3 MHz increments, for example, 2201.5, 2204.5, 2207.5.[3]

---

[3] **Center frequencies in this band are predicated on the basis that bandwidth is 3 MHz in each case.**

[4] **Center frequencies in this band are predicated on the basis that bandwidth is 10 MHz in each case.**

5.4.6 Wideband Channel Center Frequency. From 2205.5 to 2285.5 MHz, the band can be in 10 MHz increments, for example, 2205.5, 2215.5, 2225.5.[4]

5.4.7 Narrowband Channel Center Frequency - 2310 to 2390 MHz Band. From 2310.5 to 2389.5 MHz, the band can be in 1 MHz increments, for example, 2310.5, 2311.5, 2312.5.

5.4.8 Mediumband Channel Center Frequency. From 2311.5 to 2388.5 MHz, the band can be in 3 MHz increments, for example, 2311.5, 2314.5, 2317.5.[3]

5.4.9 Wideband Channel Center Frequency. From 2312.5 to 2387.5 MHz, the band can be in 5 MHz increments, for example, 2312.5, 2317.5, 2322.5.[5]

6.0 Telemetry Frequency Assignment Guidance

The following recommendations for the selection of frequency assignments are based on good engineering practices for simultaneous telemetry operations:

6.1 Geographical Separation

Two or more telemetry systems operating in a given geographical area should be separated in frequency so that no overlap exists in the authorized frequency spectrums and should include a guard band whose width is at least comparable with the assigned channel's bandwidth.

6.2 Simultaneous Operations

When two or more telemetry systems are used in a given vehicle, it is often desirable to feed the transmitters into a common antenna. For such operations, the frequency separation of the transmitters is a compromise between two opposing factors. One factor is the antenna efficiency which favors a small frequency separation. The other factor is the efficiency of the diplexer which frequently employs frequency selective circuits and favors a relatively wide frequency spacing for good efficiency. Inadequate isolation between the transmitter outputs may give rise to excessive intermodulation product levels being produced and radiated. The most predominate intermodulation products will be located at frequencies which are separated from

---

[3] **Center frequencies in this band are predicated on the basis that bandwidth is 3 MHz in each case.**

[4] **Center frequencies in this band are predicated on the basis that bandwidth is 10 MHz in each case.**

[5] **Center frequencies in this band are predicated on the basis that bandwidth is 5 MHz in each case.**

the transmitter frequencies by the differences in each pair of transmitter frequencies as indicated in subparagraph 6.3 below. Measurable intermodulation products, if they exist, should not exceed an effective value of -25 dBm in a 3 kHz bandwidth outside modulation bandwidth "B" as indicated in this appendix, paragraphs 7.2 and 7.3.

6.3 Multicarrier Operations

If only two transmitters are to be operated simultaneously, interference because of intermodulation is extremely unlikely. If three or more transmitters are operated simultaneously, likely intermodulation frequency locations are at $2f_1-f_2$, $2f_2-f_1$, $f_1+f_2-f_3$, $f_1+f_3-f_2$, and $f_2+f_3-f_1$, where f_1, f_2 and f_3 represent the output frequencies of all transmitters taken two and three at a time. The general rule for avoiding intermodulation interference (third order) is that in a group of transmitter frequencies, the separation between any pair of frequencies is not equal to the separation between any other pair of frequencies. One frequency may be common to both pairs of frequencies. The intermodulation signals will possess modulation sidebands which should be considered in critical situations.

7.0 Standards for the Level of Undesired Emissions Outside the Authorized Bandwidth for Telemetering Stations[6]

These standards are applicable to telemetering stations authorized for operation in the bands 1435 to 1535, 2200 to 2290 MHz and 2310 to 2390 MHz excluding those for space communications. Assignments to such stations include an assigned frequency and an authorized bandwidth centered on that frequency. The authorized bandwidth is identical to the emission bandwidth, which is indicated by the numerical prefix to the emission designators in the list of Frequency Assignments to Government Radio Stations and to the necessary bandwidth.

7.1 Definitions

P_t = Transmitter power in watts (unmodulated carrier)

BW = Bandwidth

Authorized BW = Emission BW = Necessary BW, in MHz

F_o = Center of BW (Assigned Frequency)

A and A' = BW to which all emissions must, as a minimum, be suppressed 60 dB or to -25 dBm whichever is greater.

B and B' = BW to which all emissions must, as a minimum, be suppressed to less than -25 dBm (in a 3 kHz bandwidth).

---

[6]**Material in paragraph 7 was taken from NTIA "Manual of Regulations and Procedures for Federal Radio Frequency Management," 1985 edition.**

7.2 Standard for Authorized Bandwidth Equal to or Less than 1 MHz

7.2.1 On each side of F_o:

Let $\frac{A}{2} = \frac{\text{Authorized BW}}{2} + \frac{\text{Authorized BW}}{2}$,

then A = 2 x Authorized BW

Power Level Limit: In any 3 kHz bandwidth outside bandwidth A, the minimum required attenuation for all emissions is 60 dB below P_t, except that it shall not be necessary in any case to attenuate below a level of -25 dBm (see value x in illustration below).

7.2.2 On each side of F_o:

Let $\frac{B}{2} = \frac{A}{2} + 0.5$ MHz,

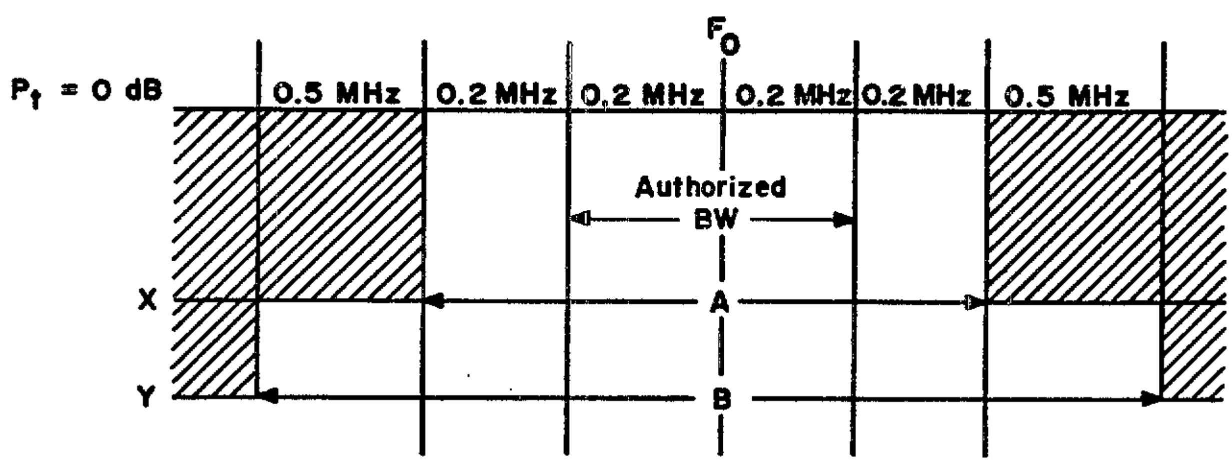
then B = (2 x Authorized BW) + 1.0 MHz

Power Level Limit: In any 3 kHz bandwidth outside bandwidth B, all emissions must be less than -25 dBm (see value y in illustration below).

EXAMPLE

Assume an Authorized BW of 0.4 MHz centered on F_o:

A = 2 x Authorized BW
= 2 x 0.4 MHZ
= 0.8 MHz
B = (2 x Authorized BW + 1.0 MHz)
= (2 x 0.4) + 1.0 MHz
= 1.8 MHz



The illustration shows the power level limit.

7.3 Standard for Authorized Bandwidth Greater than 1 MHz

7.3.1 On each side of F_o:

Let $\frac{A'}{2} = \frac{\text{Authorized BW}}{2} + 0.5$ MHz,

then A' = Authorized BW + 1.0 MHz

Power Level Limit: In any 3 kHz bandwidth outside bandwidth A', the minimum required attenuation for all emissions is 60 dB below P_t, except that it shall not be necessary in any case to attenuate below a level of -25 dBm (see value of x in illustration below).

7.3.2 On each side of F_o:

Let $\frac{B'}{2} = \frac{A'}{2} + 0.5$ MHz,

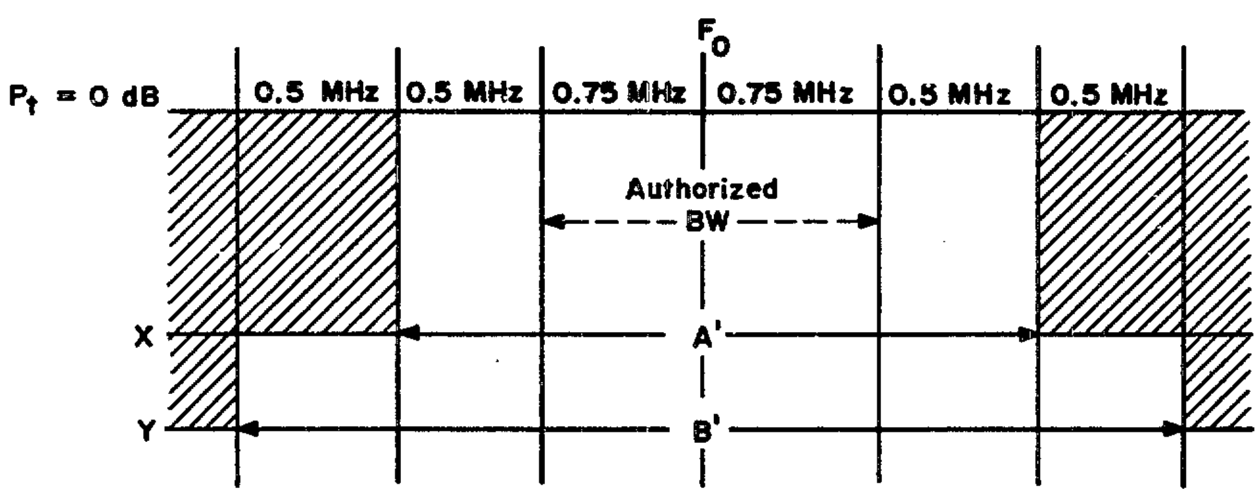
then B' = (Authorized BW) + 2.0 MHz

Power Level Limit: In any 3 kHz bandwidth outside bandwidth B', all emissions must be less than -25 dBm (see value y in illustration below).

EXAMPLE

Assume an Authorized BW of 1.5 MHz centered on F_o:

A' = Authorized BW + 1.0 MHz
= 1.5 + 1.0 MHz
= 2.5 MHz
B' = Authorized BW + 2.0 MHz
= 1.5 + 2.0 MHz
= 3.5 MHz



The illustration shows the power level limit.

APPENDIX B

USE CRITERIA FOR FREQUENCY DIVISION MULTIPLEXING

APPENDIX B

USE CRITERIA FOR FREQUENCY DIVISION MULTIPLEXING

1.0 General

Successful application of Frequency Division Multiplexing Telemetry Standards depends upon recognition of performance limits and performance tradeoffs which may be required in implementation of a system. The use criteria included in this appendix are offered in this context as a guide for orderly application of the standards which are presented in chapter 3.

It is the responsibility of the telemetry system designer to select the range of performance that will meet his data measurement requirements and at the same time permit him to operate within the limits of the standards. A designer or user must also recognize the fact that even though the standards for FM/FM multiplexing encompass a broad range of performance limits, tradeoffs such as data accuracy for data bandwidth may be necessary. Nominal values for such parameters as frequency response and rise time are listed to indicate the majority of expected use and should not be interpreted as inflexible operational limits. It must be remembered that system performance is influenced by other considerations such as hardware performance capabilities. In summary, the scope of the standards together with the use criteria are intended to offer flexibility of operation and yet provide realistic limits.

2.0 FM Subcarrier Performance

The nominal and maximum frequency response of the subcarrier channels listed in tables 3-1 and 3-2 is 10 percent and 50 percent, respectively, of the maximum allowable deviation bandwidth. The nominal frequency response of the channels employs a deviation ratio of five. The deviation ratio of a channel is defined as one-half the defined deviation bandwidth divided by the cutoff frequency of the discriminator output filter.

2.1 The use of other deviation ratios for any of the subcarrier channels listed may be selected by the range users to conform with the specific data response requirements for the channel. As a rule, the rms signal-to-noise ratio (SNR) of a specific channel varies as the three-halves power of the subcarrier deviation ratio employed.

2.2 The nominal and minimum channel rise times indicated in tables 3-1 and 3-2 have been determined from the equation which states that rise time is equal to 0.35 divided by the frequency response for the nominal and maximum frequency response, respectively. The equation is normally employed to define 10 to 90 percent rise time for a step function of the channel input signal. However, deviations from these values may be encountered because of variations in subcarrier components in the system.

3.0 FM Subcarrier Performance Tradeoffs

The number of subcarrier channels which may be used simultaneously to modulate an RF carrier is limited by the RF channel bandwidth and by the output SNR that is acceptable for the application at hand. As channels are added, it is necessary to reduce the transmitter deviation allowed for each individual channel to keep the overall multiplex within the RF channel assignment. This reduction lowers the subcarrier-to-noise performance at the discriminator inputs. Thus, the system designer's problem is to determine acceptable tradeoffs between the number of subcarrier channels and acceptable subcarrier-to-noise ratios.

3.1 Background information relating to the level of performance and the tradeoffs that may be made is included in Telemetry FM/FM Baseband Structure Study, volumes I and II, which were completed under a contract administered by the Telemetry Working Group of IRIG. The Defense Technical Information Center (DTIC) access numbers for these documents dated 14 June 1965 are AD-621139 and AD-621140. The results of the study show that proportional bandwidth channels with center frequencies up to 165 kHz and constant-bandwidth channels with center frequencies up to 176 kHz may be used within the constraints of these standards. The test criteria included the adjustment of the system components for approximately equal SNRs at all of the discriminator outputs with the receiver input near RF threshold. Intermodulation, caused by the radio-link components carrying the composite multiplex signal, limits the channel's performance under large signal conditions.

3.2 With subcarrier deviation ratios of four, channel data errors on the order of 2 percent rms were observed. Data channel errors on the order of 5 percent rms of full-scale bandwidth were observed when subcarrier deviation ratios of two were employed. When deviation ratios of one were used, it was observed that channel-data errors exceeded 5 percent. Some channels showed peak-to-peak errors as high as 30 percent. It must be emphasized, however, that the results of the tests performed in this study are based on specific methods of measurement on one system sample and that this system sample represents a unique configuration of components. Additional components having different performance characteristics will not necessarily yield the same system performance.

3.3 System performance may be improved, in terms of better data accuracy, by sacrificing system data bandwidth; that is, if the user is willing to limit the number of subcarrier channels in the multiplex, particularly the higher frequency channels, the input level to the transmitter can be increased. The SNR of each subcarrier is then improved through the increased per-channel transmitter deviation. For example, the baseband-structure study indicated that when the 165 kHz channel and the 93 kHz channel were not included in the proportional-bandwidth multiplex, performance improvement can be expected in the remaining channels equivalent to approximately 12 dB increased transmitter power.

3.4 Likewise, elimination of the five highest frequency channels in the constant-bandwidth multiplex allowed a 6 dB increase in performance.

3.5 A general formula which can be used to estimate the thermal noise performance of an FM/FM channel above threshold[1] is as follows:

$$\left(\frac{S}{N}\right)_d = \left(\frac{S}{N}\right)_c \left(\frac{3}{4}\right)^{1/2} \left[\frac{B_c}{F_{ud}}\right]^{1/2} \left(\frac{f_{dc}}{f_s}\right)\left(\frac{f_{ds}}{f_{ud}}\right)$$

where

$\left(\frac{S}{N}\right)_d$ = discriminator output signal-to-noise ratio (rms voltage ratio)

$\left(\frac{S}{N}\right)_c$ = receiver carrier-to-noise ratio (rms voltage ratio)

B_c = carrier bandwidth (receiver IF bandwidth)

F_{ud} = subcarrier discriminator output filter - 3-dB frequency

f_s = subcarrier center frequency

f_{dc} = carrier peak deviation of the particular subcarrier of interest

f_{ds} = subcarrier peak deviation

If the RF carrier power is such that the thermal noise is greater than the intermodulation noise, the above relation provides estimates accurate to within a few decibels.

---

[1]K. M. Uglow, Noise and Bandwidth in FM/FM Radio Telemetry, IRE Transaction on Telemetry and Remote Control, pp. 19-22 (May 1977).

3.6 The FM/FM composite-multiplex signal used to modulate the RF carrier may be a proportional-bandwidth format, a constant-bandwidth format, or a combination of the two types provided only that guard bands allowed for channels used in a mixed format be equal to or greater than the guard band allowed for the same channel in an unmixed format.

4.0 FM System Component Considerations

System performance is dependent upon essentially all components in the system. Neglecting the effects of the RF and recording system, data channel accuracy is primarily a function of the linearity and frequency response of the subcarrier oscillators and discriminators employed. Systems designed to transmit data frequencies up to the nominal frequency responses shown in tables 3-1 and 3-2 have generally well-known response capabilities, and reasonable data accuracy estimates can be easily made. For data-channel requirements approaching the maximum frequency response of tables 3-1 and 3-2, oscillator and discriminator characteristics are less consistent and less well-defined, making data accuracy estimates less dependable.

4.1 The effect of the RF system on data accuracy is primarily in the form of noise because of intermodulation at high RF signal conditions well above threshold. Under low RF signal conditions, noise on the data channels is increased because of the degraded SNR existing in the receiver.

4.2 Intermodulation of the subcarriers in a system is because of characteristics such as amplitude and phase nonlinearities of the transmitter, receiver, or other system components required to handle the multiplex signal under the modulation conditions employed. In systems employing preemphasis of the upper subcarriers, the lower subcarriers may experience intermodulation interference because of the difference frequencies of the high-frequency and high-amplitude channels.

4.3 The use of magnetic tape recorders for recording a subcarrier multiplex may degrade the data channel accuracy primarily because of the tape speed differences or variations between record and playback. These speed errors can normally be compensated for in present discriminator systems when the nominal response rating of the channels is employed and a reference frequency is recorded with the subcarrier multiplex.

5.0 Range Capability for FM Subcarrier Systems

See the following subparagraphs for additional range capabilities:

5.1 Receivers and Tape Recorders. The use of proportional channels greater than 93 kHz, or the corresponding constant-bandwidth channels, may require discriminators or tape recorders of a greater capability than are in current use at some ranges. It is recommended that users, who anticipate employing any of the above channels at a range, check the range's capability at a sufficiently early date to allow procurement of necessary equipment.

5.2 Discriminator Channel Selection Filters. Inclusion of the higher frequency proportional-bandwidth channels and the constant-bandwidth channels may require the ranges to acquire additional band selection filters. In addition to referencing tables 3-1 and 3-2 for acquiring channel-selector filters, consideration should also be given to acquiring discriminators corresponding to the predetection carrier frequencies shown in table 6-6. In applications where minimum time delay variation within the filter is important such as tape speed compensation or high-rate PAM or PCM, constant-delay filter designs are recommended.

APPENDIX C

PCM STANDARDS - ADDITIONAL INFORMATION AND RECOMMENDATIONS

APPENDIX C

PCM STANDARDS - ADDITIONAL INFORMATION AND RECOMMENDATIONS

1.0 Bit Rate Versus Receiver Intermediate-Frequency (IF) Bandwidth

The following subparagraphs contain information to be considered when comparing bit rate versus receiver intermediate-frequency (IF) bandwidth:

1.1 The receiver IF bandwidth should be selected from those values listed in table 2-1. Only those discrete receiver IF bandwidths listed should be used for data channel selection (optional below 12,500 Hz). The selections in table 2-1 have been made on the consideration that automatic tracking of RF carrier drift or shift will be used in the receiver. However, Doppler shift considerations may require wide RF/discriminator bandwidths for the Automatic Frequency Control (AFC) system.

1.2 For reference purposes in a well-designed PCM/FM system (NRZ-L data code) with the peak deviation equal to 0.35 times the bit rate and an IF bandwidth (3 dB) equal to the bit rate, a receiver IF SNR (power) of approximately 12 to 13 dB will result in a bit error probability (BEP) of about 1 bit error in 10^{-6} bits. A 1 dB change (increase or decrease) in this SNR will result in an order of magnitude change (10^{7} or 10^{5} from 10^{6}, respectively) in the BEP. Other data codes and modulation (PM) will have different BEP versus SNR performance characteristics.

1.3 It is recommended that the period between ensured bit transitions be a maximum of 64 bit intervals to ensure adequate bit synchronization.

2.0 Recommended PCM Synchronization Patterns

Table C-1 contains recommended frame synchronization patterns for general use in PCM telemetry. Pattern lengths shorter than 16 bits are primarily for use in submultiple frame synchronization when necessary.

The technique used in the determination of the patterns for lengths 7 through 30 was essentially that of the patterns of 2^n binary patterns of a given length, n, for that pattern with the smallest total probability of false synchronization over the entire pattern overlap portion of the ground station frame synchronization.[1] The patterns for lengths 31 through 33 were obtained from a second source.[2]

3.0 Spectral Comparisons for NRZ and BIØ[3]

Plotted in figure C-1 are the power spectral densities on NRZ, DBIØ, and BIØ coding with random data. Plotted in figure C-2 are the theoretical BEP versus SNR curves for NRZ and BIØ coding.

---

[1]A more detailed account of this investigation can be found in a paper by J. L. Maury, Jr. and J. Styles, "Development of Optimum Frame Synchronization Codes for Goddard Space Flight Center PCM Telemetry Standards," in Proceedings of the National Telemetering Conference, June 1964.

[2]The recommended synchronization patterns for lengths 31 through 33 are discussed more fully in a paper by E. R. Hill, "Techniques for Synchronizing Pulse-Code Modulated Telemetry," in Proceedings of the National Telemetering Conference, May 1963.

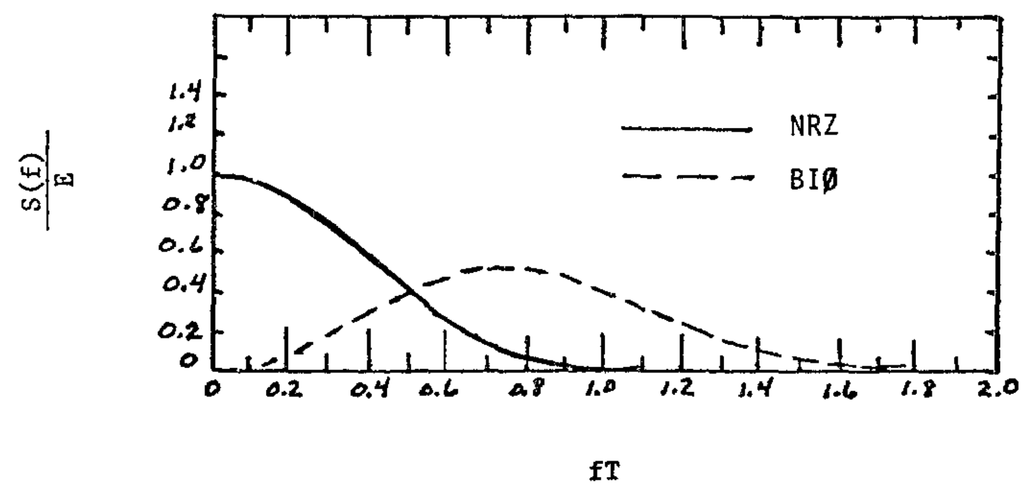
[3]Material presented in paragraph 3.0 is taken from a study by W. C. Lindsey (University of Southern California), Bit Synchronization System Performance Characterization, Modeling and Tradeoff Study, Naval Missile Center Technical Publication TP-73-10.

TABLE C-1. OPTIMUM FRAME SYNCHRONIZATION PATTERNS FOR PCM TELEMETRY

Pattern Length	Patterns						
7	101	100	0				
8	101	110	00				
9	101	110	000				
10	110	111	000	0			
11	101	101	110	00			
12	110	101	100	000			
13	111	010	110	000	0		
14	111	001	101	000	00		
15	111	011	001	010	000		
16	111	010	111	001	000	0	
17	111	100	110	101	000	00	
18	111	100	110	101	000	000	
19	111	110	011	001	010	000	0
20	111	011	011	110	001	000	00

TABLE C-1 (Con.) OPTIMUM FRAME SYNCHRONIZATION PATTERNS FOR PCM TELEMETRY

Pattern Length	Patterns										
21	111	011	101	001	011	000	000				
22	111	100	110	110	101	000	000	0			
23	111	101	011	100	110	100	000	00			
24	111	110	101	111	001	100	100	000			
25	111	110	010	110	111	000	100	000	0		
26	111	110	100	110	101	100	110	000	00		
27	111	110	101	101	001	100	110	000	000		
28	111	101	011	110	010	110	011	000	000	0	
29	111	101	011	110	011	001	101	000	000	00	
30	111	110	101	111	001	100	110	100	000	000	
31	111	111	100	110	111	110	101	000	010	000	0
32	111	111	100	110	101	100	101	000	010	000	00
33	111	110	111	010	011	101	001	010	010	011	000



S(f)/E is power spectral density normalized with respect to signal energy per bit.

f is frequency.

T is bit period.

Figure C-1. Spectral Density of Random NRZ and BIØ Coding

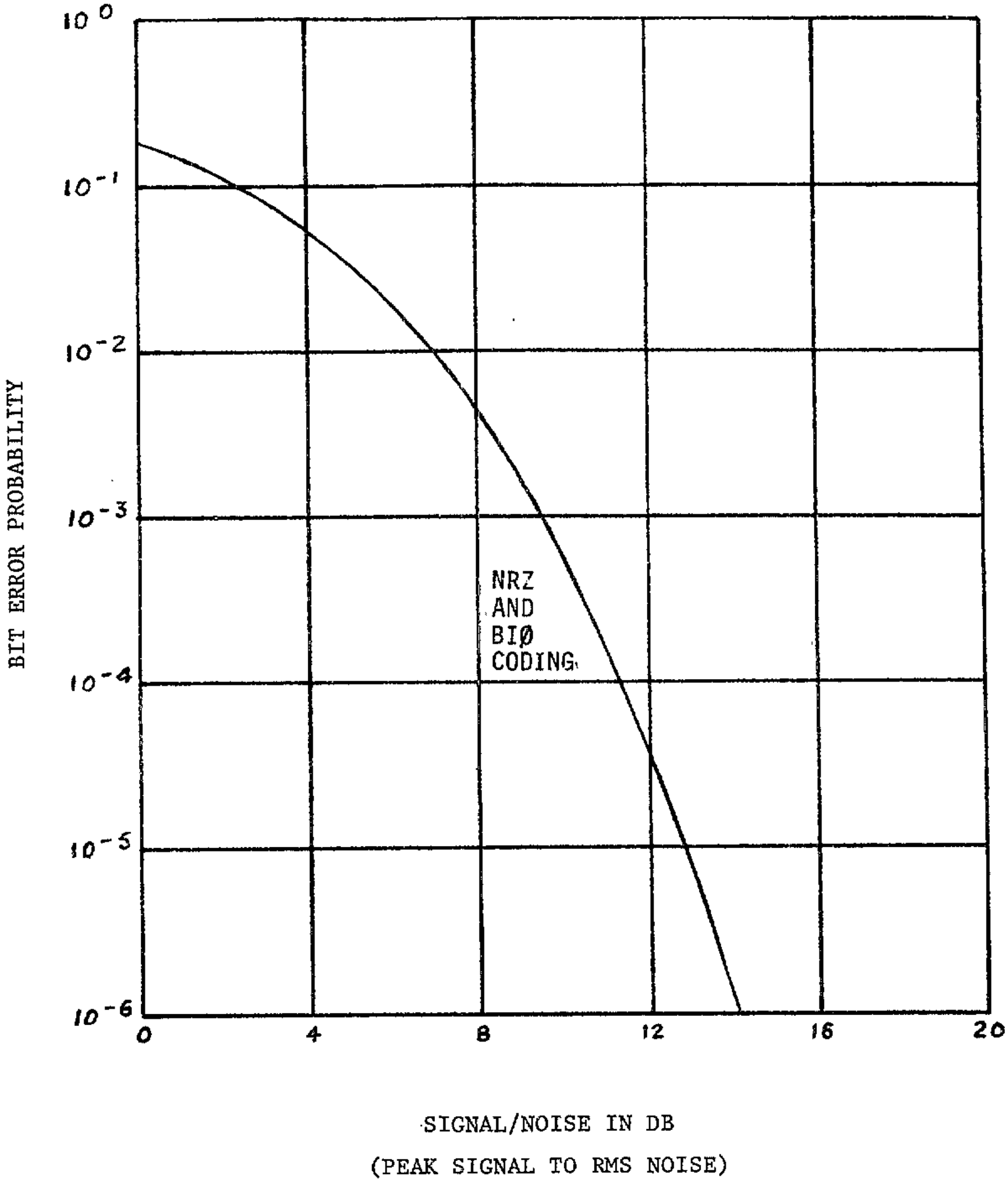


Figure C-2. Theoretical BEP Performance for Various Baseband PCM Signaling Techniques (perfect bit assumed).

APPENDIX D

MAGNETIC TAPE RECORDER AND REPRODUCER INFORMATION AND USE CRITERIA

APPENDIX D

MAGNETIC TAPE RECORDER AND REPRODUCER INFORMATION AND USE CRITERIA

1.0 Other Instrumentation Magnetic Tape Recorder Standards

The X3B6 Committee of the American National Standards Institute and its international counterpart, the ISO TC97-SC12 Committee, have prepared several standards for instrumentation magnetic tape recording. These standards are nearing completion. Status of the documents may be obtained by contacting the X3B6 Committee Chairman through

American National Standards Institute, Inc.
1430 Broadway
New York, NY 10018
Telephone (212) 354-3300

The following documents may be of interest:

ISO 1860 Information Processing - Precision reels for magnetic tape used in interchange instrumentation applications.

ISO 6068 Information Processing - Telemetry systems (including the recording characteristics of instrumentation magnetic tape) - interchange practices and recommended test methods.

ISO 6371 Information Processing - Interchange requirements and test methods for unrecorded instrumentation magnetic tape.

ISO 8441/1 High Density Digital Recording (HDDR) - Part 1: Unrecorded magnetic tape for HDDR applications.

ISO 8441/2 High Density Digital Recording (HDDR) - Part 2: Interchange requirements and test methods for HDDR applications (including the characteristics of recorded magnetic tape).

2.0 Double-Density Longitudinal Recording

Wideband double-density analog recording standards allowing recording of up to 4 MHz signals at 3096 mm/s (120 ips) are included in these standards. For interchange purposes, the current state of record and reproduce technology requires that either narrow track widths 0.635 mm (25 mils) be employed, or that heads now available from only one of the major suppliers be used. These requirements are necessary because of the difficulty in maintaining individual head-segment gap-azimuth alignment across a head close enough to keep each track's response within the ± 2 dB variation allowed by the standards. Moreover, at the lower tape speeds employed in double-density recording, the 38 mm (1.5 in.) spacing employed in interlaced head assemblies results in interchannel time displacement variations between odd and even tracks that may be unacceptable for some applications. For those reasons, it was decided that a 14-track in-line configuration on

1 inch tape should be adopted as a standard. This configuration results in essentially the same format as head number one of the 28-track interlaced configuration already in the standards.

2.1 The 14-track interlaced heads are not compatible with tapes produced on an in-line standard configuration, and if tapes must be interchanged, a cross-configuration dubbing may be required, or a change of head assemblies on the reproducing machine is necessary.

2.2 High energy magnetic tape is required for double-density systems. Such tapes are available, but may require special testing for applications requiring a low number of dropouts per track.

2.2.1 Higher Track Density Configurations. The above-referenced standards include configurations resulting in 14 and 21 tracks on 1/2 inch tape and 42 tracks on 1 inch tape in addition to the 7-, 14- and 28-track configurations listed in chapter 6. The HDDR Standards also reference an 84-track configuration on 2 inch tape. Table D-1 shows the 14 track on 1/2 inch tape, and table D-2 shows the 42 track on 1 inch tape. These configurations are not available normally at Range Commanders Council installations.

2.2.2 High-Density PCM Recording. High-density digital recording systems are available from most instrumentation recorder manufacturers. Such systems will record at linear packing densities of 33,000-bits-per-inch or more per track. Special systems are available for error detection and correction with overhead penalties depending on the type and the sophistication of the system employed. The HDDR documents listed in paragraph 1.0 reference six different systems that have been produced; others are available.

3.0 Serial HDDR

The following subparagraphs give some of the background for selection of the bi-phase and RNRZ-L systems specified in subparagraph 6.11.3, chapter 6 of this document.

3.1 Serial HDDR is a method of recording digital data on a magnetic tape where the digital data is applied to one track of the recording system as a bi-level signal. The codes recommended for serial HDDR recording of telemetry data are BiØ-L and randomized NRZ-L (RNRZ-L) (refer to paragraph 6.11, chapter 6).

3.2 In preparing paragraph 6.11 of chapter 6, the following codes were considered: Delay Modulation (Miller Code), Miller Squared, Enhanced NRZ, NRZ Level, NRZ Mark, and NRZ Space. These codes are not recommended for interchange applications at the bit rates given in paragraph 6.11.

3.3 If user bit rate requirements increase beyond those now accommodated, codes other than BiØ-L and RNRZ-L may be considered for future editions of the standards. The parallel HDDR standards being developed by the ANSI X3B6 Committee could be applicable. Other more

TABLE D-1. DIMENSIONS - RECORDED TAPE FORMAT, 14-TRACKS INTERLACED ON 12.7 mm (1/2 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Parameter	Millimeters		Inches
	Maximum	Minimum	
Track Width	0.660	0.610	0.025±0.001
Track Spacing	0.889		0.035
Head Spacing:			
Fixed Heads	38.125	38.075	1.500±0.001
Adjustable Heads	38.151	38.049	1.500±0.002
Edge Margin, Minimum	0.127		0.005
Reference Track Location	0.546	0.470	0.0200±0.0015
Track Location Tolerance	0.038	-0.038	±0.0015

Location of nth track

Track Number	Millimeters		Inches
	Maximum	Minimum	
1 (Reference)	0.000	0.000	0.000
2	0.927	0.851	0.035
3	1.816	1.740	0.070
4	2.705	2.629	0.105
5	3.594	3.518	0.140
6	4.483	4.407	0.175
7	5.372	5.292	0.210
8	6.261	6.185	0.245
9	7.150	7.074	0.280
10	8.039	7.963	0.315
11	8.928	8.852	0.350
12	9.817	9.741	0.385
13	10.706	10.630	0.420
14	11.595	11.519	0.455

TABLE D-2. DIMENSIONS - RECORDED TAPE FORMAT, 42-TRACKS INTERLACED ON 25.4 mm (1 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Parameter	Millimeters		Inches
	Maximum	Minimum	
Track Width	0.483	0.432	0.018±0.001
Track Spacing	0.584		0.023
Head Spacing:			
Fixed Heads	38.125	38.075	1.500±0.001
Adjustable Heads	38.151	38.049	1.500±0.002
Edge Margin, Minimum	0.305		0.012
Reference Track Location	0.737	0.660	0.0275±0.015
Track Location Tolerance	0.025	-0.025	±0.0001

Track Number	Location of nth track: Millimeters		Inches
	Maximum	Minimum	
1 (Reference)	0.000	0.000	0.000
2	0.610	0.559	0.023
3	1.194	1.143	0.046
4	1.778	1.727	0.069
5	2.362	2.311	0.092
6	2.946	2.896	0.115
7	3.531	3.480	0.138
8	4.115	4.064	0.161
9	4.699	4.648	0.184
10	5.283	5.232	0.207
11	5.867	5.817	0.230
12	6.452	6.401	0.253
13	7.036	6.985	0.276
14	7.620	7.569	0.299
15	8.204	8.153	0.322
16	8.788	8.738	0.345

TABLE D-2 (Con.) DIMENSIONS - RECORDED TAPE FORMAT, 42-TRACKS INTERLACED ON 25.4 mm (1 in.) WIDE TAPE (REFER TO FIGURE 6-1.)

Track Number	Location of nth track: Millimeters Maximum	Minimum	Inches
17	9.373	9.322	0.368
18	9.957	9.906	0.391
19	10.541	10.490	0.414
20	11.125	11.074	0.437
21	11.709	11.659	0.460
22	12.294	12.243	0.483
23	12.878	12.827	0.506
24	13.462	13.411	0.529
25	14.046	13.995	0.552
26	14.630	14.580	0.575
27	15.215	15.164	0.598
28	15.799	15.748	0.621
29	16.383	16.332	0.664
30	16.967	16.916	0.667
31	17.551	17.501	0.690
32	18.136	18.085	0.713
33	18.720	18.660	0.736
34	19.304	19.253	0.759
35	19.888	19.837	0.782
36	20.472	20.422	0.805
37	21.057	21.006	0.828
38	21.641	21.590	0.851
39	22.225	22.174	0.874
40	22.809	22.758	0.897
41	23.393	23.343	0.920
42	23.978	23.927	0.943

advanced techniques, which might become applicable, would also have to be reviewed.

3.4 The properties of the BiØ-L and RNRZ-L codes relevant to serial HDDR and the methods for generating and decoding RNRZ-L are described below. Recording with bias is required for interchange applications because reproduce amplifier phase and amplitude equalization adjustments for tapes recorded without bias usually differ from those required for tapes recorded with bias.

3.5 The BiØ-L and RNRZ-L codes were selected for this standard because the "level" versions are easier to generate and are usually available as outputs from bit synchronizers. "Mark" and "Space" codes also have about twice as many errors as the level codes for the same SNR. If polarity insensitivity is a major consideration, agreement between interchange parties should be obtained before these codes are used.

3.6 Some characteristics of the BiØ-L code favorable to serial HDDR are:

3.6.1 Only a small proportion of the total signal energy occurs near dc.

3.6.2 The maximum time between transitions is 1 bit period.

3.6.3 The symbols for a "one" and a "zero" are antipodal; that is, the symbols are exact opposites of each other. Therefore, the bit error probability versus SNR performance is optimum.

3.6.4 The BiØ-L can be decoded using existing bit synchronizers.

3.6.5 The BiØ-L is less sensitive to misadjustments of bias and reproducer equalizers than most other codes.

3.6.6 The BiØ-L performs well at low tape speeds and low bit rates.

3.7 The most unfavorable characteristic of the BiØ-L code is that it requires approximately twice the bandwidth of NRZ. Therefore, the maximum bit packing density that can be recorded on magnetic tape is relatively low.

3.8 Characteristics of the RNRZ-L code which favor its use for serial HDDR include:

3.8.1 The RNRZ-L requires approximately one-half the bandwidth of BiØ-L.

3.8.2 The symbols for a "one" and a "zero" are antipodal; therefore, the bit error probability versus SNR performance is optimum.

3.8.3 The RNRZ-L decoder is self-synchronizing.

3.8.4 The RNRZ-L data can be bit-synchronized and signal-conditioned using existing bit synchronizers with the input code selector set to NRZ-L.

3.8.5 The RNRZ-L code is easily generated and decoded.

3.8.6 The RNRZ-L data can be easily decoded in the reverse mode of tape playback.

3.8.7 The RNRZ-L data are bit detected and decoded using a clock at the bit rate. Therefore, the phase margin is much larger than that of codes that require a clock at twice the bit rate for bit detection.

3.8.8 The RNRZ-L code does not require overhead bits.

3.9 Unfavorable characteristics of the RNRZ-L code for serial HDDR include:

3.9.1 Long runs of bits without a transition are possible although the probability of occurrence is low, and the maximum run length can be limited by providing transitions in each data word.

3.9.2 Each isolated bit error that occurs after the data has been randomized causes 3 bit errors in the derandomized output data.

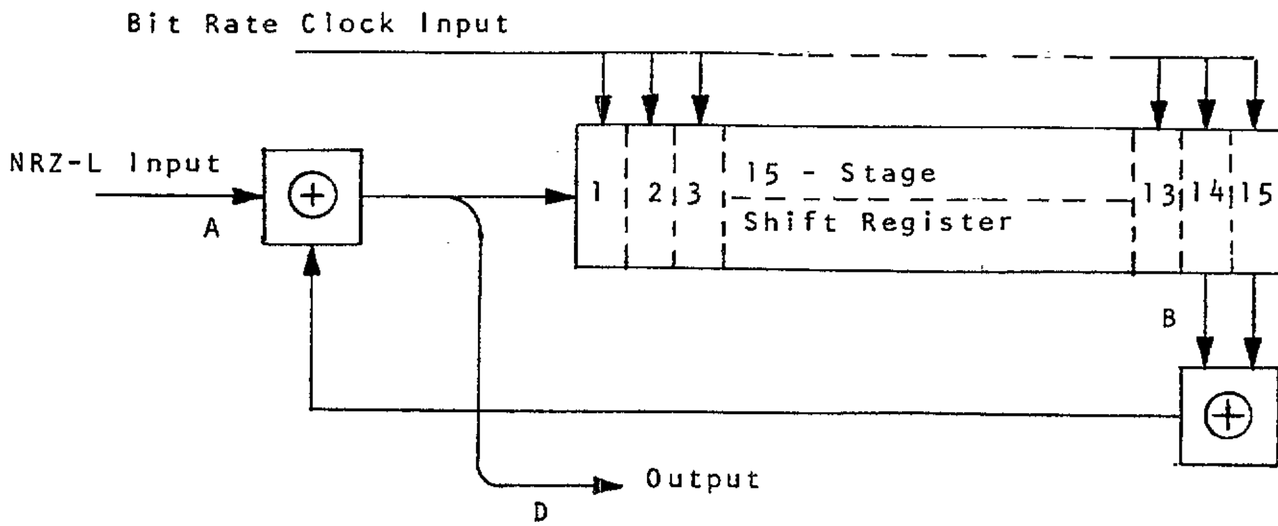
3.9.3 The decoder requires 15 consecutive error-free bits to establish and reestablish error-free operation.

3.9.4 The RNRZ-L bit stream can have a large low frequency content. Therefore, reproducing data at tape speeds which produce PCM bit rates less than 200 kb/s is not recommended unless a bit synchronizer with a specially designed dc and low frequency restoration circuitry is available.

3.10 <u>Randomizer for RNRZ-L</u>

The randomizer is implemented with a network of shift registers and modulo-2 adders (exclusive-OR gates). The RNRZ-L bit stream is generated by adding (modulo-2) the reconstructed NRZ-L PCM data to the modulo-2 sum of the outputs of the 14th and 15th stages of a shift register. The output RNRZ-L stream is also the input to the shift register (see figure D-1).

3.10.1 The properties of an RNRZ-L bit stream are similar to the properties of a pseudo-random sequence. A 15-stage RNRZ-L encoder will generate a maximal length pseudo-random sequence of $2^{15}-1$ (32,767) bits if the input data consists only of "zeros" and there is at least a single "one" in the shift register. A maximal length pseudo-random sequence is also generated when the input data consists only of "ones" and the shift register contains at least a single "zero." However, if the shift register contains all "zeros" at the moment that the input bit stream is all "zeros," the RNRZ-L output bit stream will also be all "zeros." The converse is also true: when the shift register is filled with "ones" and the input bit stream is all "ones," the RNRZ-L output bit stream will contain only "ones." In these two cases, the contents of the shift register does not change and the output data is not randomized. However, the randomizer is not permanently locked-up in this state because a change in the input data



Boolean Expression:

$$D = A \oplus B \oplus C$$

Figure D-1. Randomizer Block Diagram.

will again produce a randomized output. In general, if the input bit stream contains runs of X bits without a transition with a probability of occurrence of p(X), the output will contain runs having a length of up to (X+15) bits with a probability of ($2^{-15} \cdot p(X)$) bits. Therefore, the output can contain long runs of bits without a transition, but the probability of occurrence is low.

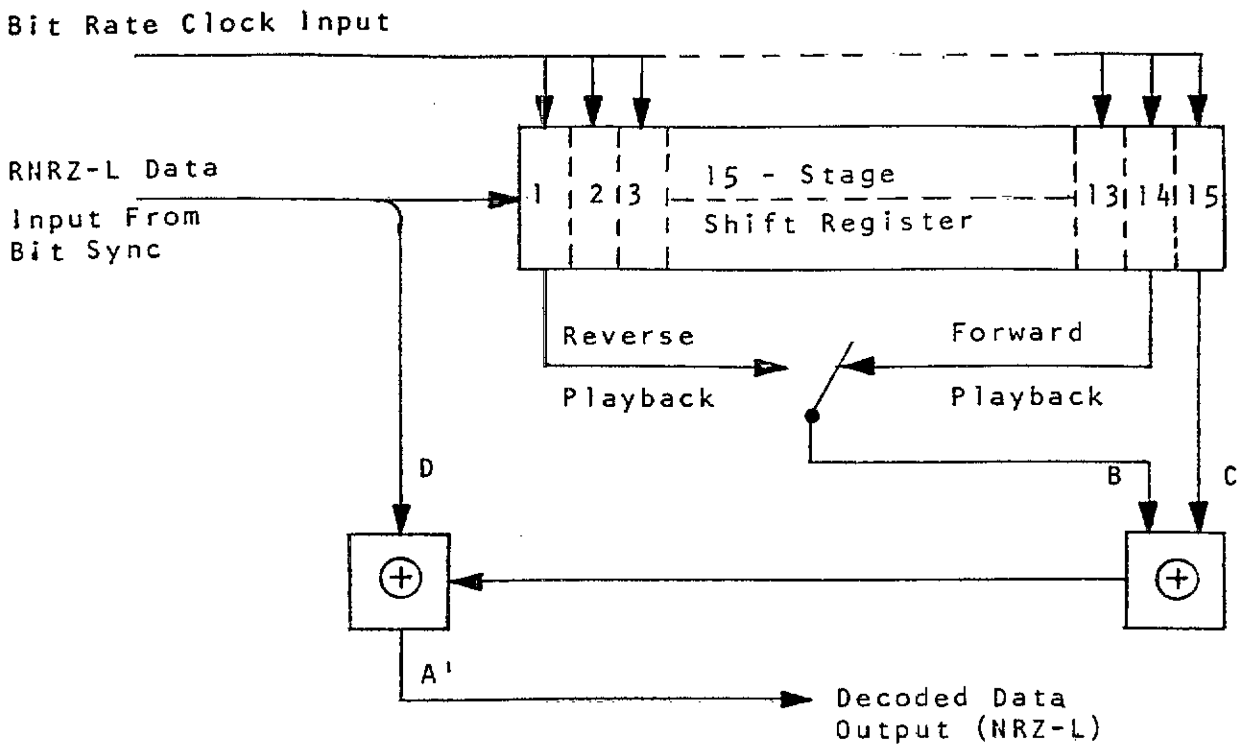
3.10.2 The RNRZ-L bit stream is decoded (derandomized) by adding (modulo-2) the reconstructed RNRZ-L bit stream to the modulo-2 sum of the outputs of the 14th and 15th stages of the shift register. The reconstructed RNRZ-L bit stream is the input to the shift register (see figure D-2). RNRZ-L data which is reproduced using the reverse playback mode of operation is decoded by adding (modulo-2) the reconstructed RNRZ-L bit stream to the modulo-2 sum of the outputs of the 1st and 15th stages of the shift register (see figure D-2). The net effect is that the decoding shift register runs "backwards" with respect to the randomizing shift register.

3.10.3 Although the RNRZ-L decoder is self-synchronizing, 15 consecutive error-free bits must be loaded into the shift register before the output data will be valid. A bit slip will cause the decoder to lose synchronization, and 15 consecutive error-free data bits must again be loaded into the shift register before the output data is valid. The decoded output data, although correct, will contain the bit slip causing a shift in the data with respect to the frame synchronization pattern. Therefore, frame synchronization must be reacquired before the output provides meaningful data.

3.10.4 The RNRZ-L decoding system has an error multiplication factor of 3 for isolated bit errors (separated from adjacent bit errors by at least 15 bits). An isolated bit error introduced after randomization will produce 3 errors in the output data; the original bit in error, plus 2 additional errors 14 and 15 bits later. In addition, a burst of errors occurring after the data has been randomized will produce a burst of errors in the derandomized output. The number of errors in the output depends on the distribution of errors in the burst and can be greater than, equal to, or less than the number of errors in the input to the derandomizer. However, the derandomization process always increases the number of bits between the first and last error in the burst by 15. Errors introduced prior to randomization are not affected by either the randomizer or the derandomizer. The reverse decoder has the same bit error properties as the forward decoder.

3.10.5 Input data containing frequent long runs of bits without transitions creates potential dc and low frequency restoration problems in PCM bit synchronizers because of the low frequency cutoff of direct recorder and reproducer systems. The restoration problem can be minimized by reproducing the data at tape speeds which produce a bit rate for which the maximum time between transitions is less than 100 microseconds. Additional methods of minimizing these effects include selecting bit synchronizers which contain special dc and low frequency restoration circuitry or recording data using BiØ-L code.

3.10.6 The power spectra of the RNRZ-L and BiØ-L codes are shown in figure D-3. The power spectral density of RNRZ-L is concentrated at



Boolean Expression:

With input data A into randomizer,

Error-Free RNRZ-L Data, $D = A \oplus B \oplus C$

(see Fig. E-1)

$$A' = D \oplus B \oplus C = A \oplus B \oplus C \oplus B \oplus C$$

$$= A \oplus B \oplus B \oplus C \oplus C \qquad \text{But} \quad B \oplus B = 0$$

$$C \oplus C = 0$$

Therefore:

$$A' = A \oplus 0 \oplus 0 = A$$

Figure D-2. Randomizer NRZ-L Decoder Block Diagram.

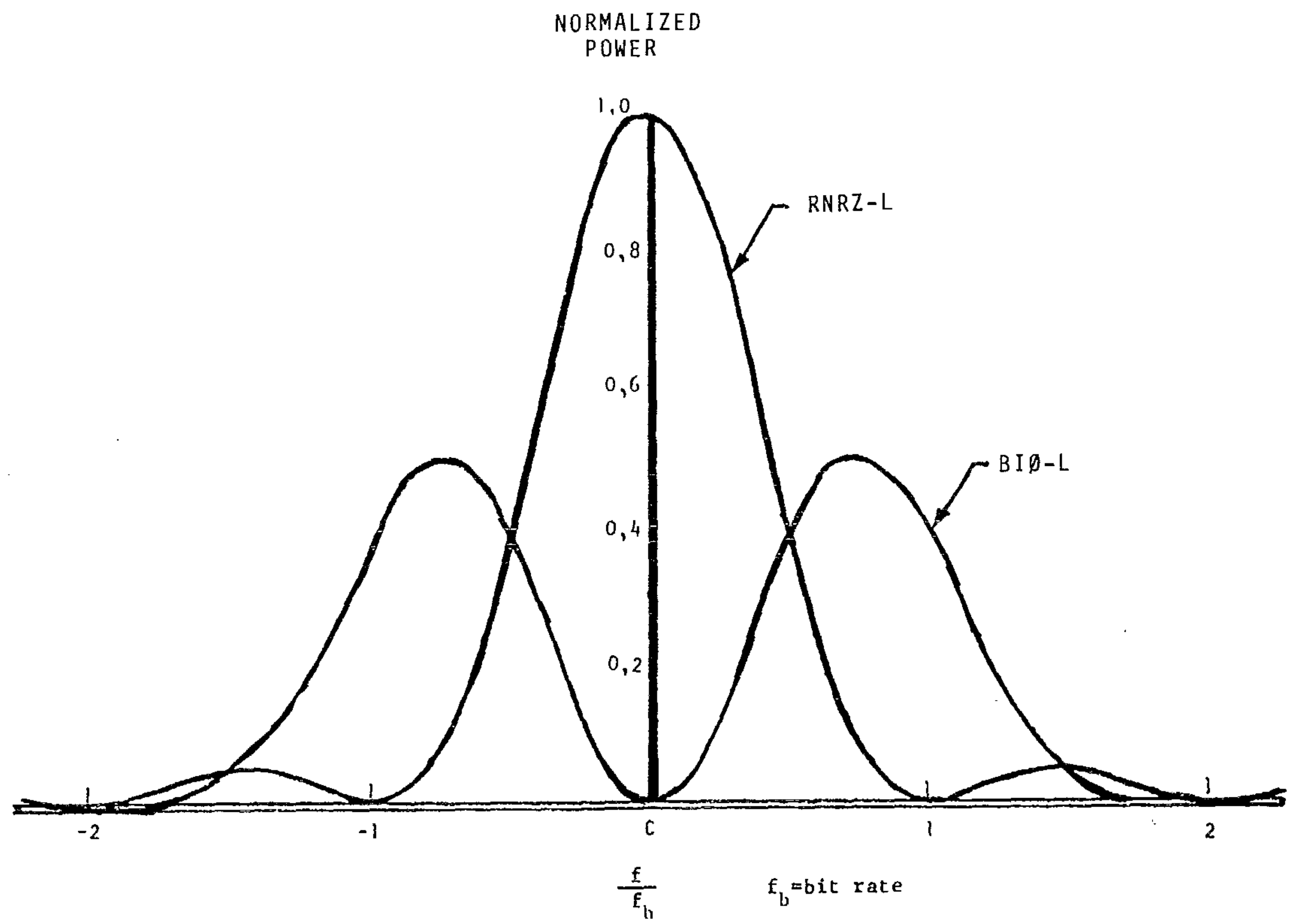


Figure D-3. Random PCM Power Spectra.

frequencies which are less than one-half the bit rate. The power spectral density of BiØ-L is concentrated at frequencies in a region around 0.75 times the bit rate. The concentration of energy in the low-frequency region (when using the RNRZ-L code) has the effect of reducing the SNR as well as creating baseline wander which the bit synchronizer must follow. Therefore, reproducing data at tape speeds which produce PCM bit rates less than 200 kb/s is not recommended when using RNRZ-L, unless a bit synchronizer with specially designed dc and low frequency restoration circuitry is available.

3.10.7 Alignment of the reproducer system is very important to reproducing high quality PCM data, that is, with the lowest possible bit error probability. A PCM signature using the standard 2047-bit pseudo-random pattern, recorded on the leader or the trailer tape, provides a good method for reproducer alignment. When a pseudo-random bit error detection system is not available or when a PCM signature signal is not recorded, the recommended procedure for reproducer alignment involves the use of the eye pattern technique. The eye pattern is the result of super positioning the "zeros" and "ones" in the PCM bit stream. The eye pattern is displayed on an oscilloscope by inserting the raw reproduced bit stream into the vertical input and the reconstructed bit-rate clock into the external synchronization input of the oscilloscope. The reproducer head azimuth, amplitude equalizers, and phase equalizers are then adjusted to produce the eye pattern with the maximum height and width opening.

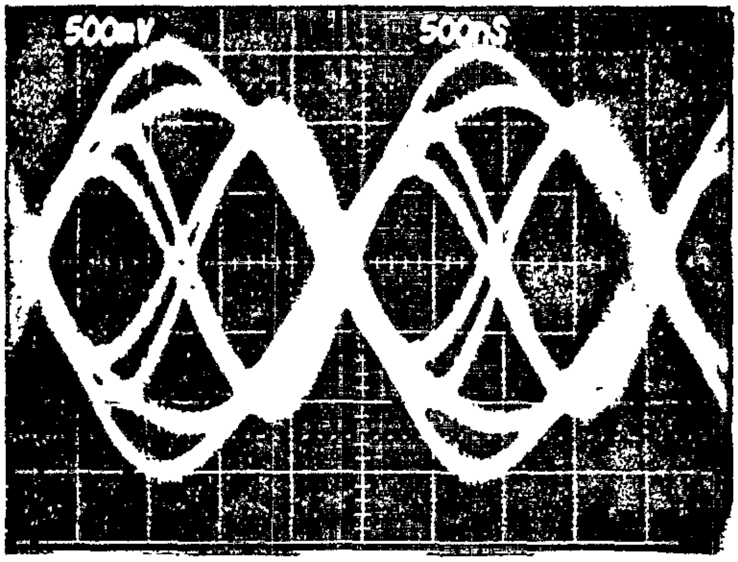
3.10.8 Sample eye patterns are shown in figures D-4 and D-5. Figure D-4A shows a typical BiØ-L eye pattern at a recorded bit packing density of 450 kb/s at 30 ips (15 kb/in). Figure D-4B shows the BiØ-L eye pattern at the output of a linear phase 400 Hz to 500 kHz bandpass filter with a bit rate of 450 kb/s. Figure D-5A shows a typical RNRZ-L eye pattern at a recorded bit packing density of 750 kb/s at 30 ips (25 kb/in). Figure D-5B shows the RNRZ-L eye pattern at the output of a linear-phase 400 Hz to 500 kHz bandpass filter with a bit rate of 750 kb/s. The extra wide traces in figure D-5 were caused by baseline wander in the RNRZ-L bit stream.

4.0 Head Parameters

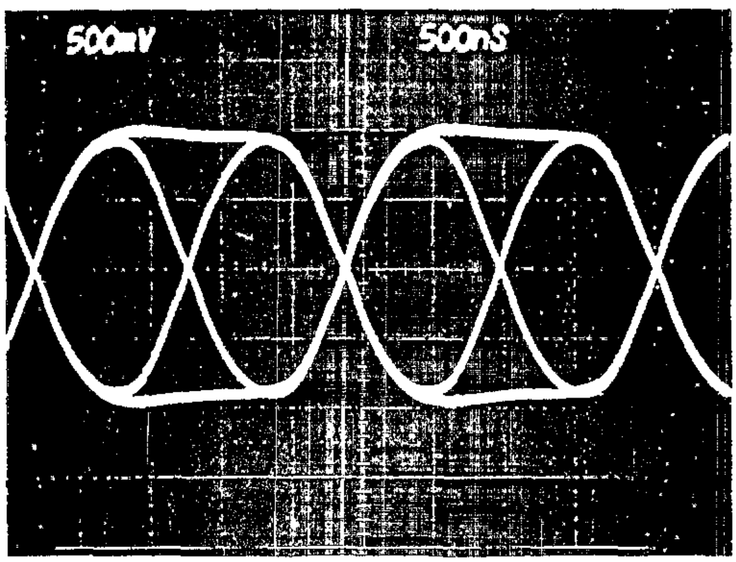
The following subparagraphs describe the head parameters:

4.1 Gap Scatter. Refer to the definitions in subparagraphs 6.2.22 and 6.2.23 in chapter 6. Gap scatter contains components of azimuth misalignment and deviations from the average line defining the azimuth. Since both components affect data simultaneity from record to reproduce, the measurement is the inclusive distance containing the combined errors. Because azimuth adjustment affects the output of wideband systems, a 5.08 micrometer (0.0002 inch) gap scatter is allowed for such recorders and reproducers. A 2.54 micrometer (0.0001 inch) gap scatter is recommended for fixed-head systems (see upper illustration in figure 6-4).

4.2 Head Polarity. The requirement that a positive pulse at a record amplifier input generate a south-north-north-south magnetic sequence and that a south-north-north-south magnetic sequence on tape

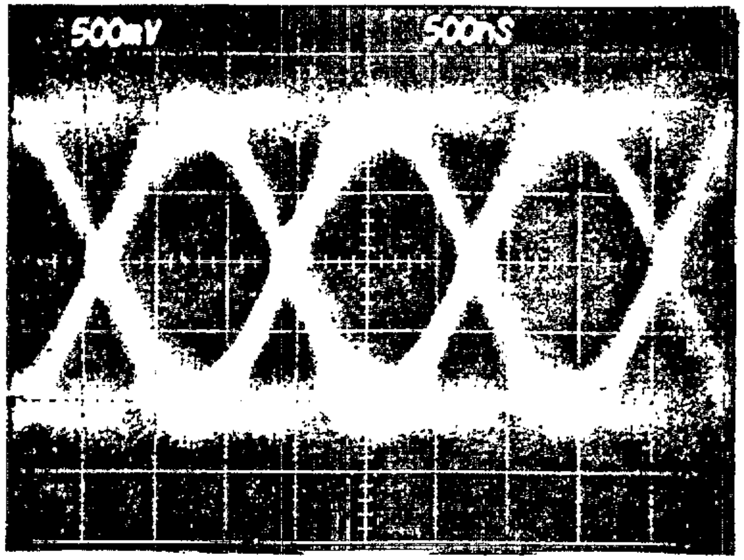


A. Typical recorder and reproducer output, 30 ips, 15 kb/in.

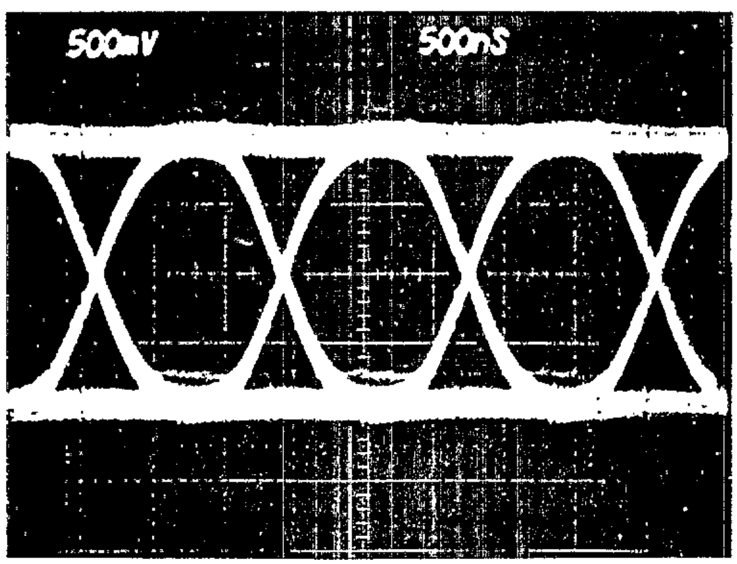


B. Linear phase bandpass filter output, 400 Hz to 500 kHz filter.

Figure D-4. Biϕ-L Eye Patterns, 450 kb/s.



A. Typical recorder and reproducer output
30 ips. 25 kb/in.



B. Linear phase bandpass filter output,
400 Hz to 500 kHz filter

Figure D-5. RNRZ-L Eye Patterns, 750 kb/s.

produce a positive pulse at the reproduce amplifier output, still leaves two interdependent parameters unspecified. These parameters are (1) polarity inversion or noninversion in record and playback amplifiers and (2) record or playback head winding sense. For the purpose of head replacement, it is necessary that these parameters be determined by the user so that an unsuspected polarity inversion, on tape or off tape, will not occur after heads are replaced.

5.0 Record Level

The standard record level (synonymous with the term "normal record level" used in IRIG Document 118-79) is established as the input level of a sinusoidal signal set at the record level set frequency which, when recorded, produces a signal containing 1.0 percent third harmonic distortion at the output of a properly terminated reproduce amplifier (see subparagraph 4.1.3.3 of volume III, IRIG Document 118-79). A 1.0 percent harmonic distortion content is achieved when the level of the third harmonic component of the record level set frequency is 40±1 dB below the level of a sinusoidal signal of 0.3 upper band edge (UBE) which is recorded at the standard record level. Standard test and operating practice is to record and reproduce sinusoidal signals at 0.1 and 0.3 UBE and adjust the equalizers as necessary to establish the reproduced output at 0.3 UBE to within ±1.0 dB of the output at 0.1 UBE. Then a 1.0 Vrms signal at the record level set frequency is applied to the record amplifier input and the record and reproduce level controls are adjusted until the reproduced output contains 1.0 percent third harmonic distortion at a level of 1.0 Vrms.

The optimum level for recording data will seldom be equal to the standard record level. Signals having noise-like spectral distribution, such as baseband multiplexes of FM subcarriers, contain high crest factors so that it may be necessary (as determined in paragraph 1.1, Noise Power Ratio (NPR) Test, volume IV, IRIG Document 118-79, Test Methods for Data Multiplex Equipment) to record at levels below the standard record level. On the other hand, for predetection and HDDR recording, signals may have to be recorded above the standard record level to give optimum performance in the data system.

6.0 Tape Cross Play Considerations (Wideband)

Cross play of tapes from intermediate-band machines on wideband machines will exhibit bias signal output because of the higher resolution of the wideband reproduce heads and the relatively low bias frequencies employed. Furthermore, care should be taken to assure that intermediate-band tapes will not damage wideband reproduce heads.

6.1 Figure D-6 illustrates the typical departure from optimum frequency response that may result when cross playing wideband tapes which were recorded with heads employing different record-head gap lengths. Line AA is the idealized output-versus-frequency plot of a machine with record bias and record level, set up per IRIG standards, using a 3.05 micrometer (120 microinch) record-head gap length and a 1.02 micrometer (40 microinch) reproduce-head gap length. Lines BB

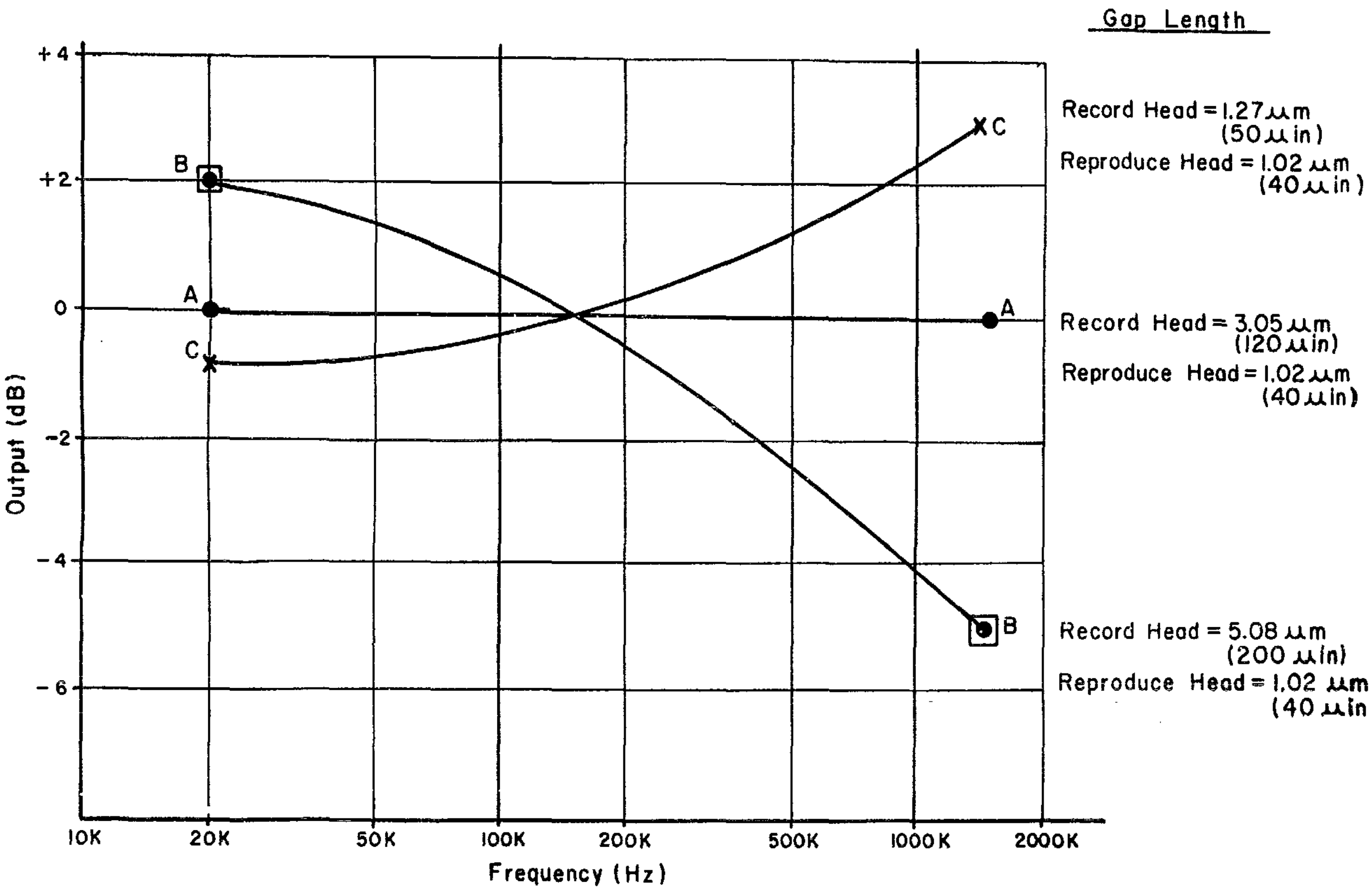


Figure D-6. Tape Cross Play

and CC represent the output response curves of the same tapes recorded on machines with 5.08 micrometer (200 microinch) and 1.27 micrometer (50 microinch) record-head gap lengths. Each of these recorders was set up individually per IRIG requirements. The tapes were then reproduced on the machine having a 1.02 micrometer (40 microinch) reproduce-head gap length without readjusting its reproduce equalization.

6.2 The output curves have been normalized to 0 dB at the 0.1 UBE frequency for the purpose of clarity. The normalized curves may be expected to exhibit a ±2.0 dB variance in relative output over the passband. The tape recorded with the shortest head segment gap length will provide the greatest relative output at the UBE.

6.3 While the examples shown are from older equipment with record gap lengths outside the limits recommended in subparagraph 6.5.4, chapter 6, they illustrate the importance of the record gap length in tape interchange applications.

7.0 Standard Tape Signature Procedures

The following subparagaphs describe the PCM signature and the swept-frequency signature:

7.1 PCM Signature Recording Procedures. Configure test equipment as described in subparagraph 2.1, volume IV, IRIG Document 118-79. The configuration should simulate the operational link as closely as possible, for example, same RF frequency, deviation, bit rate, code type, predetection frequency, receiver bandwidth, and recorder speed.

7.1.1 While recording the pseudo-random data at standard record level, adjust the signal generator output level until approximately one error per 10^5 bits is obtained on the error counter.

7.1.2 Record 30 seconds of the pseudo-random data at the beginning or end of the tape for each data track. A separate 30-second tape signature is recommended for each different data format.

7.1.3 The content, track assignments and location on the tape leader and trailer of signature signals should be noted on the tape label.

7.2 PCM Signature Playback Procedure. The following subparagraphs explain the playback procedure:

7.2.1 Optimize playback equipment such as receiver tuning and bit synchronizer setup for data being reproduced.

7.2.2 Reproduce the tape signature and observe the error rate on the error counter.

7.2.3 Optimize head azimuth for maximum signal output and minimum errors.

7.2.4 If more than one error per 10^4 bits is obtained, initiate corrective action.

7.2.5 Repeat for each data track.

7.3 Swept Frequency Signature Recording Procedure. The following subparagraphs describe the recording procedure for the swept-frequency signature:

7.3.1 Patch a sweep-frequency oscillator output to all prime data tracks (up to 6 on 7-track recorders, or up to 13 on 14-track recorders) (see appendix A, volume III of IRIG Document 118-79). As a minimum, patch the sweep oscillator to one odd and one even track.

7.3.2 Connect the sync output of the sweep oscillator to a track not used for sweep signals, preferably an outside track.

7.3.3 Record the signature signals for a minimum of 30 seconds at standard record level.

NOTE

Record levels may be either preadjusted or quickly adjusted in all tracks during the first few seconds of the signature recording.

7.3.4 The content, track assignments and location on the leader or trailer tape of signature signals should be noted on the tape label.

7.4 Swept Frequency Signature Playback Procedure. The following subparagraphs define the steps for the playback procedure:

7.4.1 Connect the sync track output of the reproducer to the sync input of the scope.

7.4.2 Select an odd-numbered sweep-signal track and connect the output of the reproducer to the vertical input of the scope. Playback the sweep signal and adjust the scope gain for an amplitude of approximately ±10 minor vertical divisions about the center baseline. Adjust the odd-track azimuth for maximum amplitude of the highest frequency segment (extreme right of the sweep pattern).

7.4.3 Observe amplitude variations through the sweep pattern and adjust the equalization, if necessary, to maintain the amplitude within the required tolerance over the required frequency range.

NOTE

A decrease of sweep signal amplitude to about 0.7 represents a 3 dB loss.

7.4.4 Repeat the playback procedure in subparagraphs 7.4.2 and 7.4.3 for azimuth and equalization adjustments of an even-numbered tape track.

7.4.5 Repeat the procedure in subparagraph 7.4.3 for equalization only of other selected prime data tracks, as required.

8.0 Equipment Required for Swept Frequency Procedures

Equipment required at the recording site consists of a sweep-frequency oscillator having a constant amplitude sweep range of approximately 400 Hz through 4.4 MHz with frequency markers at 62.5, 125, 250, and 500 kHz and 1.0, 2.0 and 4.0 MHz. The sweep range to 4.4 MHz may be used for all tape speeds because the bandwidth of the recorder and reproducer will attenuate those signal frequencies beyond its range. The sweep rate should be approximately 25 Hz. Care should be exercised in the installation of the sweep generator to ensure a flat response of the sweep signal at the input terminals of the recorder. Appropriate line-driver amplifiers may be required for long cable runs or the low impedance of paralleled inputs.

8.1 A stepped-frequency oscillator could be substituted for the sweep-frequency generator at the recording location. Recommended oscillator wavelengths at the mission tape speed are: 7.62 mm (300 mils), 3.81 mm (150 mils), 0.254 mm (10 mils), 0.0254 mm (1 mil), 0.0127 mm (0.5 mil), 0.0064 mm (0.25 mil), 0.0032 mm (0.125 mil), 0.0025 mm (0.1 mil), 0.0020 mm (0.08 mil), and 0.0015 mm (0.06 mil).

8.2 Equipment required at the playback site consists of an ordinary oscilloscope having a flat frequency response from 400 Hz through 4.4 MHz.

9.0 Fixed-Frequency Plus White Noise Procedure

The signature used in this method is the same for all applications. For direct recording of subcarrier multiplexes, only static nonlinearity (nonlinearity which is independent of frequency) is important for cross-talk control. Subparagraph 6.8.1.3 in chapter 6 provides a reference level for static nonlinearity. All formats of data recording are sensitive to SNR. Predetection recording and HDDR are sensitive to equalization. The following signature procedure satisfies all the above requirements:

9.1 Record a sine-wave frequency of 0.1 UBE (see table 6-4) with the following amplitudes:

9.1.1 Equal to the Standard Record Level, subparagraph 6.8.2, chapter 6, for direct recording of subcarrier multiplexes and HDDR.

9.1.2 Equal to the carrier amplitude to be recorded for predetection recording of PCM/FM, PCM/PM, FM/FM, and PAM/FM.

9.2 Record flat band-limited white noise of amplitude 0.7 of the true rms value of the 0 dB Standard Record Level as described in subparagraph 6.8.2, chapter 6. Noise must be limited by a low-pass filter just above the UBE.

9.3 Record with zero input (input terminated in 75 ohms). The three record steps above can consist of 10 seconds each. The spectra can be obtained with three manually initiated sweeps of less than a second each, since no great frequency resolution is required. All of the spectrum analyzer parameters can be standardized and set in prior to running the mission tape.

10.0 Signature Playback and Analysis

Before analyzing the signature, the reproducer azimuth should be adjusted. With the short signature, it is probably more convenient to use the data part of the recording for this purpose. If predetection recording is used, the azimuth can be adjusted to maximize the output as observed on the spectrum analyzer or on a voltmeter connected to the output. If baseband recording is used, the azimuth can be adjusted to maximize the spectrum at the upper end of the band. Using a spectrum analyzer, reproduce, store and photograph the spectra obtained from subparagraphs 9.1, 9.2 and 9.3 in paragraph 9.0. Store and photograph the spectrum analyzer input level of zero.

10.1 It is evident that any maladjustment of the recorder and reproducer or magnetization of the heads will result in the decrease of SNR across the band and will be seen from the stored spectra or photograph.

10.2 By having a photograph of the spectra, amplitude equalization can be accomplished without shuttling the mission tape as follows:

10.2.1 Use an auxiliary tape (not the mission tape, but preferably the same type tape). With a white-noise input signal band limited (see paragraph 9.0), adjust the amplitude equalization of the recorder and reproducer at the tape dubbing or data reduction site and photograph the output spectrum.

10.2.2 Compare this photo with the photo made from the signature. Note the difference at several points across the band.

10.2.3 Using the auxiliary tape, adjust the amplitude equalization to compensate for the differences noted.

10.2.4 Recheck with the mission tape to verify that the desired amplitude equalization has been achieved.

10.3 If the phase equalization is to be checked, a square-wave signal can be added to the signature in accordance with the manufacturer's specification (see subparagraph 4.9.2.3.3 of volume III, IRIG Document 118-79). The same procedure as that recommended for amplitude equalization can be used, except based on oscillograms.

APPENDIX E

AVAILABLE TRANSDUCER DOCUMENTATION

APPENDIX E

AVAILABLE TRANSDUCER DOCUMENTATION

Transducer Characteristics and Performance

A number of documents dealing with specific transducer types have been published. Additional documents are being prepared by various organizations. Because such published documents are subject to continuing review, users are urged to contact the responsible organization for the most up-to-date edition. The following documents published to date pertaining to transducers with electrical output are

Accelerometers and Vibration

ANSI S2.2 - 1959, "USA Standard Methods for the Calibration of Shock and Vibration Pickups."

ANSI S2.11 - 1969, "American National Standard for the Selection of Calibrations and Tests for Electrical Transducers Used for Measuring Shock and Vibration."

ANSI Z24.21 - 1957, "American Standard Method for Specifying the Characteristics of Pickups for Shock and Vibration Measurement."

IEEE Std 337 - 1972, "IEEE Standard Specification Format Guide and Test Procedure for Linear, Single-Axis, Pendulous, Analog Torque Balance Accelerometers."

ISA - RP 37.2 - 1982, "Guide for Specifications and Tests for Piezoelectric Acceleration Transducers for Aerospace Testing."

ISA - S37.5 - 1975 (ANSI MC 6.3 - 1975), "Specifications and Tests for Strain Gage Linear Acceleration Transducers."

Fluid Velocity

ASME PTC 19.5.3 - 1965, "Fluid Velocity Measurement."

Microphones and Sound Power

ANSI S1.1 - 1960, "USA Standard Acoustical Terminology (Including Mechanical Shock and Vibration)."

ANSI S1.4 - 1983, "American National Standard Specification for Sound Level Meters."

ANSI S1.8 - 1969, "American National Standard Preferred Reference Quantities for Acoustical Levels."

ANSI S1.10 - 1966, "USA Standard Method for the Calibration of Microphones."

ANSI S1.12 - 1967, "USA Standard Specifications for Laboratory Standard Microphones."

ANSI S1.13 - 1971, "Methods for Measurement of Sound Pressure Levels" (R.1976).

ANSI S1.30 - 1979, "Guidelines for Use of Sound Power Standards and for the Preparation of Noise Test Codes" (see ASA 10-79).

ANSI S1.31 - 1980, "Precision Methods for the Determination of Sound Power Levels of Broad-Band Noise Sources in Reverberation Rooms" (see ASA 11-80).

ANSI S1.32 - 1980, "Precision Methods for Determination of Sound Power Levels of Discrete-Frequency and Narrow-Band Noise Sources in Reverberation Rooms" (see ASA 12-80).

ANSI S1.33 - 1982, "Engineering Methods for Determination of Sound Power Levels of Noise Sources in a Special Reverberation Test Room" (see ASA 13-82).

ANSI S1.34 - 1980, "Engineering Methods for Determination of Sound Power Levels of Noise Sources for Essentially Free-Field Conditions over a Reflecting Plane" (see ASA 14-80).

ANSI S1.35 - 1979, "Precision Methods for Determination of Sound Power Levels of Noise Sources in Anechoic and Hemi-Anechoic Rooms" (see ASA 15-79).

ANSI S1.36 - 1979, "Survey Methods for Determination of Sound Power Levels of Noise Sources" (R.1985) (see ASA 16-79).

<u>Pressure Transducers</u>

ASME PTC 19.2 - 1964, "Pressure Measurements."

ANSI MC88.1 - 1972, "A Guide for the Dynamic Calibration of Pressure Transducers."

ISA - S37.3 - 1975 (ANSI MC 6.2 - 1975), "Specifications and Tests for Strain Gage Pressure Transducers."

ISA S37.6 - 1976 (ANSI MC 6.5 - 1976), "Specifications and Tests of Potentiometric Pressure Transducers."

ISA - S37.10 - 1975 (ANSI MC 6.4 - 1975), "Specifications and Tests for Piezoelectric Pressure and Sound-Pressure Transducers."

<u>Rate Gyros</u>

IEEE No. 292 - July 1969, "IEEE Specification Format for Single-Degree-of-Freedom Spring-Restrained Rate Gyros."

IEEE No. 293 - July 1969, "IEEE Test Procedure for Single-Degree-Of-Freedom Spring-Restrained Gyros."

Thermocouples

ASTM E 220-80, "Standard Method for Calibration of Thermocouples by Comparison Techniques."

ASTM E 230-83, "Standard Temperature-Electromotive Force (EMF) Tables for Thermocouples."

ASTM E 344-84, "Standard Definitions of Terms Relating to Temperature Measurement."

SAMA Standard RC21-4 - 1966, "Temperature-Resistance Values for Resistance Thermometer Elements of Platinum, Nickel and Copper."

Miscellaneous

ISA Book - 1974, "Standards and Practices for Instrumentation."

ISA - S37.8 - 1977, "Specifications and Tests for Strain Gage Force Transducers."

SAMA Standard PMC 20.1 - 1973, "Process Measurement and Control Terminology."

APPENDIX F

CONSTANT BANDWIDTH FM SUBCARRIER CHANNEL NOMENCLATURE

APPENDIX F

CONSTANT BANDWIDTH FM SUBCARRIER CHANNEL NOMENCLATURE

1.0 The constant bandwidth FM subcarrier channels have been renamed in conjunction with the expansion of the number of available channels and wider bandwidths. The relationship between the previous designations and the new designations are given.

2.0 The "A" channels are related as follows:

Old Designation	New Designation
1A	16A
2A	24A
3A	32A
4A	40A
5A	48A
6A	56A
7A	64A
8A	72A
9A	80A
10A	88A
11A	96A
12A	104A
13A	112A
14A	120A
15A	128A
16A	136A
17A	144A
18A	152A
19A	160A
20A	168A
21A	176A

3.0 The "B" channels are related as follows:

Old Designation	New Designation
3B	32B
5B	48B
7B	64B
9B	80B
11B	96B
13B	112B
15B	128B
17B	144B
19B	160B
21B	176B

4.0 The "C" channels are related as follows:

Old Designation	New Designation
3C	32C
7C	64C
11C	96C
15C	128C
19C	160C