IRIG

IRIG STANDARD 106-80

TELEMETRY STANDARDS

TELEMETRY GROUP
INTER-RANGE INSTRUMENTATION GROUP
RANGE COMMANDERS COUNCIL

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IRIG STANDARD 106-80

TELEMETRY STANDARDS

Containing International (SI) Units
and Conventional Units

TELEMETRY GROUP
INTER-RANGE INSTRUMENTATION GROUP
RANGE COMMANDERS COUNCIL

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CHAPTER 1

INTRODUCTION

1.1 General

The Telemetry Group of the Range Commanders Council (RCC) has prepared this document of standards to foster the compatibility of telemetry transmitting, receiving, and signal processing equipment at all 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 utilized by the range user 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 careful consideration of tradeoffs. Guidance concerning these tradeoffs is provided in the text.

1.3 Purpose

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

1.3.1 A companion document (now in four volumes), 118-79, *Test Methods for Telemetry Systems and Subsystems*, has been published in conjunction with this standard.

1.3.2 It is the policy of the Telemetry Group to update the Telemetry Standards and Test Procedures approximately every 2 years. As a result, IRIG 106-80 supersedes IRIG 106-77 and IRIG 118-79 (Volumes I, II, III, and IV) supersedes IRIG 118-73 (Revised July 1975).

1.3.3 Metric conversions are included in this edition and are shown preceding the conventional units.

1.4 Reference Documents

Reference documents are identified at the point of reference.

1.5 Definitions

Commonly used terms are as 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.

1.7 Deletion of Standards

The Pulse Duration Modulation (PDM) Standard and the Amplitude Modulation (AM) Subcarrier Standard have been deleted due to lack of use. Ranges which have an established capability are encouraged to maintain it as long as current needs exist; however, application of other standards is recommended for new programs. It is recommended that the ranges not buy new equipment related to these standards.

CHAPTER 2

TRANSMITTER AND RECEIVER SYSTEMS

2.1 Radio Frequency Standards for Telemetry

The purpose of these standards is to provide development and coordination agencies with criteria on which to base equipment requirements and capabilities. The intent is to ensure efficient utilization of equipment and interchange of operations and data for radio link telemetry systems at member ranges of the Range Commanders Council (RCC). 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 ranges of the RCC, and recommended for all telemetry service.

2.2 225 to 260 MHz Frequency Band

This frequency band was reallocated to fixed and mobile communications services effective 1 January 1970. The Military Communications Electronics Board will consider temporary VHF telemetry waivers on an individual basis subject to the following limitations (See Appendix A, Paragraph 3.0)

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

2.2.2 Available facts must clearly support the contention that the use of telemetry equipment in the 1435-1535 MHz or 2200-2300 MHz bands would be prohibitively expensive or impractical, or that significant test program slippage would occur if conversion/retrofit is required.

2.2.3 Ranges and test sites selected to support the proposed operations can provide VHF telemetry support without installation of additional equipment.

2.2.4 Operations will be limited to the frequency bands listed in Table 2-1 below.

TABLE 2-1

RADIO FREQUENCY TELEMETRY ASSIGNMENTS

226.7 MHz	237.0 MHz	246.3 MHz	258.5 MHz*
230.4 MHz	239.4 MHz	248.6 MHz	259.7 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	

**Not available for telemetry waiver beyond 1 January 1975 due to conflict with planned satellite communications.*

2.2.5 The use of VHF telemetry on the foregoing frequencies beyond 1 January 1975 will not be a bar to satisfying communications needs for which the 225-400 MHz band is primarily allocated.

2.2.6 Frequency allocation applications proposing development or procurement of new telemetry equipment designed to operate in the 225-260 MHz band will not be approved.[1]

[1] Certain short-term waivers that have been granted to DOD components will permit some flexibility in effecting full conversion to UHF telemetry. Users with waivers which permit continued operations in the 225-260 MHz band will adhere to telemetry standards contained in this chapter and in Appendix A, paragraph 3.0.

2.2.7 225-260 MHz Transmitter Systems

2.2.7.1 Frequency Tolerance. The transmitter RF carrier (modulated or unmodulated) shall be within ±0.01 percent of the assigned frequency under all operating conditions and environments. The specified frequency tolerance is applicable for any or 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 ±0.01 percent frequency tolerance shall apply when a field intensity of greater than 150 μV per meter for 1 or more seconds is experienced at any radial distance of 30.48 meters (100 feet) from the transmitter antenna systems.

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

2.2.7.3 Spurious Emission and Interference Requirements Using Test Methods and Equipment in Accordance with Applicable Military Standard or Specification.

2.2.7.3.1 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; i.e., measured in the antenna transmission line, or antenna-radiated; i.e., measured in free space, shall be limited to the values derived from the formula:

dB (down from unmodulated carrier) = $55 + 10 \log P_t$
where P_t is the measured output power in watts.[2]

[2]For radiated measurements, this value will be the equivalent of -25 dBm as referenced to the unmodulated carrier power.

NOTE

This limits all conducted spurious and harmonic emissions to a maximum power level of -25 dBm.

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.

2.2.7.3.2 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 Standard or Specification.

2.2.7.4 Bandwdith (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 $\pm$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.

2.2.8 225-260 MHz Receiver Systems

2.2.8.1 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.

2.2.8.2 Interference Protection. RF interference protection shall be provided only for systems using receivers which meet the following criteria:

2.2.8.2.1 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.

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

2.2.8.2.3 Flexibility of Operation. The system shall operate on any of the frequencies in Table 2-1, without design modification.

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

2.3 1435-1535 MHz and 2200-2300 MHz 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 and beginning with the frequency 2200.5 MHz in the 2200 to 2300 MHz band. Wideband channels are permitted. They will be centered 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 1435-1535 MHz band. This band is nationally allocated to government and nongovernment telemetry use on a shared basis. Telemetry assignments will be made therein for flight testing[3] of manned and unmanned aircraft, missiles, space vehicles or major components thereof, as described below.

2.3.1.1 1435-1485 MHz. Use of these channels is primarily for flight testing of manned aircraft, and secondarily for flight testing of unmanned aircraft and missiles or major components thereof.

2.3.1.2 1485-1535 MHz. Use of these channels is primarily for flight testing of unmanned aircraft and missiles or major components thereof, and secondarily for flight testing of manned aircraft.

2.3.2 Allocation of 2200-2300 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 2200-2290 MHz. Use of these channels is on a co-equal shared basis with government fixed and mobile communications. Use of these channels includes telemetry associated with launch vehicles, missiles, upper atmosphere research rockets, and space vehicles, regardless of their trajectories.

2.3.2.2 2290-2300 MHz. Channels in this band are for space research telemetry on a shared basis with fixed and mobile services.

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

2.3.3 1435-1535 and 2200-2300 MHz Transmitter Systems

2.3.3.1 Frequency Tolerance. The transmitter RF carrier, (modulated or unmodulated) shall be within ±0.003 percent of the assigned radio frequency under all operating conditions and environments.

NOTE

Between 1 and 5 seconds after initial turn-on, the transmitter radio frequency shall remain within ±0.005 percent of 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 ±0.003 percent frequency tolerance shall apply when a field intensity of greater than 500 μV per meter is experienced at any radial distance of 30.48 meters (100 feet) from the transmitter system.

2.3.3.2 Power. The power shall be as directed by the intended use, and never more than absolutely necessary for reliable telemetry reception.

2.3.3.3 Spurious Emission and Interference Requirements Using Test Methods and Equipment in Accordance with Applicable Military Standard or Specification (Antenna Conducted or Antenna Radiated 0.150 to 10,000 MHz).

2.3.3.3.1 Emissions from the transmitter-antenna system are of primary importance. Spurious and harmonic outputs, antenna-conducted; i.e., measured in the antenna transmission line, or antenna-radiated; i.e., measured in free space, shall be limited to the values derived from the formula:

dB (down unmodulated carrier)=55 + 10 log P_t
where P_t is the measured output power in watts.

NOTE

This limits all conducted spurious and harmonic emissions to a maximum power level of -25 dBm.

Radiated tests will only be used when the transmission line is inaccessible for conducted measurements.

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

2.3.3.3.2 Interference (Conducted and 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 Standard or Specification.

2.3.3.4 Flexibility of Operation. The transmitter shall be capable of operating throughout the entire frequency band from 1435 to 1535 MHz and/or 2200-2300 MHz, without design modifications.

2.3.3.5 Bandwidth (Transmitter Modulated). Refer to Appendix A for channel bandwidth definitions, spacing allocations, and for stanards for the level of undesired emissions outside the authorized bandwidth for telemetering stations excluding those for space radio communication in the 1435-1535 and 2200-2300 MHz bands.

2.3.4 1435-1535 and 2200-2300 MHz Receiver Systems

2.3.4.1 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.

2.3.4.2 Interference Protection. RF interference protection will be provided only for systems using receivers which meet the following criteria:

2.3.4.2.1 Frequency Tolerance. The combined errors of all local oscillators of the receivers shall not exceed ±0.001 percent of the assigned frequency under operating conditions during mission support.

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

2.3.4.2.3 Flexibility of Operation. The system shall be operable over the entire 1435 to 1535 MHz band and/or 2200 to 2300 MHz band, without design modification, and will have variable bandwidth selection.

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 utilized. The data bandwidth of one type of format is proportional to the center frequency of the subcarrier, while the data bandwidth of the other type is constant, regardless of subcarrier frequency.

3.2 Scope

The following paragraphs set forth the standards for utilization of FM frequency division multiplexing.

3.3 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.

3.3.1 Each of the subcarriers convey 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).

3.3.2 The selection and grouping of subcarrier channels depends upon the data bandwidth requirements of the application at hand and upon the necessity to ensure adequate guard bands between channels. Combinations of both proportional-bandwidth channels and constant-bandwidth channels may be used.

3.4 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 twelve highest numbered channels. The channels shall be used within the limits of maximum subcarrier deviation. (See Appendix B for expected performance tradeoffs at selected combinations of deviation and modulating frequency.)

NOTE

Table 3-2 lists the standard FM constant-bandwidth FM subcarrier channels. The letters A, B and C identify the channels for use with maximum subcarrier deviations of ±2 kHz, ±4 kHz and ±8 kHz, along with maximum frequency responses of 2, 4, and 8 kHz, respectively. The channels shall be used within the limits of maximum subcarrier deviation. (See Appendix B for expected performance tradeoffs at selected combinations of deviation and modulating frequency.)

3.5 Tape Speed Control and Flutter Compensation

Tape speed control and flutter compensation for FM/FM formats may be accomplished as indicated in subparagraph 6.3.8. Use of the standard reference frequency shall be in accordance with the criteria of Table 3-3, when the reference signal is mixed with data.

TABLE 3-1. PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS

±7.5% CHANNELS

Channel	Center Frequencies (Hz)	Lower Deviation Limit[1] (Hz)	Upper Deviation Limit[1] (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	7,350	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
16	40,000	37,000	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]

Channel	Center Frequencies (Hz)	Lower Deviation Limit[1] (Hz)	Upper Deviation Limit[1] (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response[1,2] (Hz)	Minimum Rise Time[2] (ms)
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, 3 } *See footnotes at end of table, page 3-4.*

TABLE 3-1. PROPORTIONAL-BANDWIDTH FM SUBCARRIER CHANNELS CONTINUED

Channel	Center Frequencies (Hz)	Lower Deviation Limit[1] (Hz)	Upper Deviation Limit[1] (Hz)	Nominal Frequency Response (Hz)	Nominal Rise Time (ms)	Maximum Frequency Response[1,2] (Hz)	Minimum Rise Time[2] (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	79,050	106,950	2,790	.13	13,950	.025
G	124,000	105,400	142,600	3,720	.09	18,600	.018
H	165,000	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	255,000	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
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] *Rounded 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.*

TABLE 3-2. CONSTANT-BANDWIDTH FM SUBCARRIER CHANNELS

A CHANNELS		B CHANNELS		C CHANNELS	
Deviation limits=±2 kHz Nominal frequency response=0.4 kHz Maximum frequency response=2 kHz[1]		Deviation limits=±4 kHz Nominal frequency response=0.8 kHz Maximum frequency response=4 kHz[1]		Deviation limits=±8 kHz Nominal frequency response=1.6 kHz Maximum frequency response=8 kHz[1]	
Channel	Center Frequency (kHz)	Channel	Center Frequency (kHz)	Channel	Center Frequency (kHz)
1A	16				
2A	24				
3A	32	3B	32	3C	32
4A	40				
5A	48	5B	48		
6A	56				
7A	64	7B	64	7C	64
8A	72				
9A	80	9B	80		
10A	88				
11A	96	11B	96	11C	96
12A	104				
13A	112	13B	112		
14A	120				
15A	128	15B	128	15C	128
16A	136				
17A	144	17B	144		
18A	152				
19A	160	19B	160	19C	160
20A	168				
21A	176	21B	176		

[1] *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 response tradeoffs.)*

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

Pulse Code Modulation (PCM) data, the characteristics of which are specified herein, shall be 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. These standards define recommended pulse train structure and design characteristics for the implementation of PCM telemetry systems.

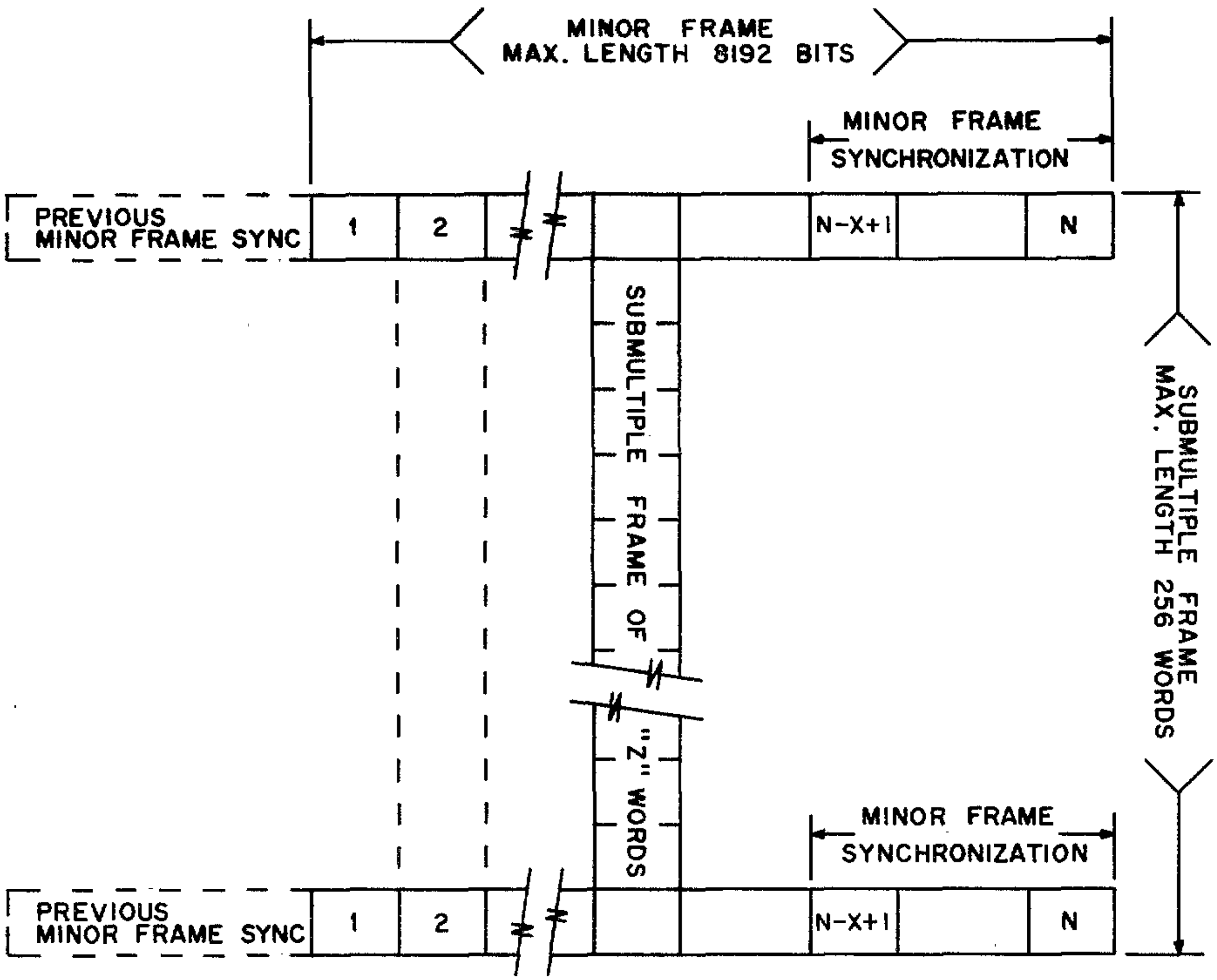
4.2 Word and Frame Structure

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:

NOTE

In PCM formats, the minor frame is defined as that period between synchronization words which includes one complete cycle of the commutator having the highest rate. The major frame, which includes one or more minor frames, is defined as that period in which all data is sampled once.

A submultiple frame is defined as that period which includes one cycle of a commutator whose rate is a submultiple of the minor frame rate.



- 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.

4.2.1 Major Frame Length. The length of the major frame shall have a maximum of 8192 bits/minor frame times 256 words/submultiple frame equalling 2,097,152 bits/major frame.

4.2.2 Minor Frame Length. The length of a minor frame shall not exceed 8192-bit intervals, including the intervals devoted to synchronization.

4.2.3 Minor Frame Synchronization. The minor frame synchronization information shall consist of a digital word not longer than 33 bits in consecutive bit intervals. Recommendations concerning synchronization patterns are shown in Appendix C.

4.2.4 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.

4.2.5 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.

4.2.6 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.

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

NRZ-L	DM-M	BIØ-L
NRZ-M	DM-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.

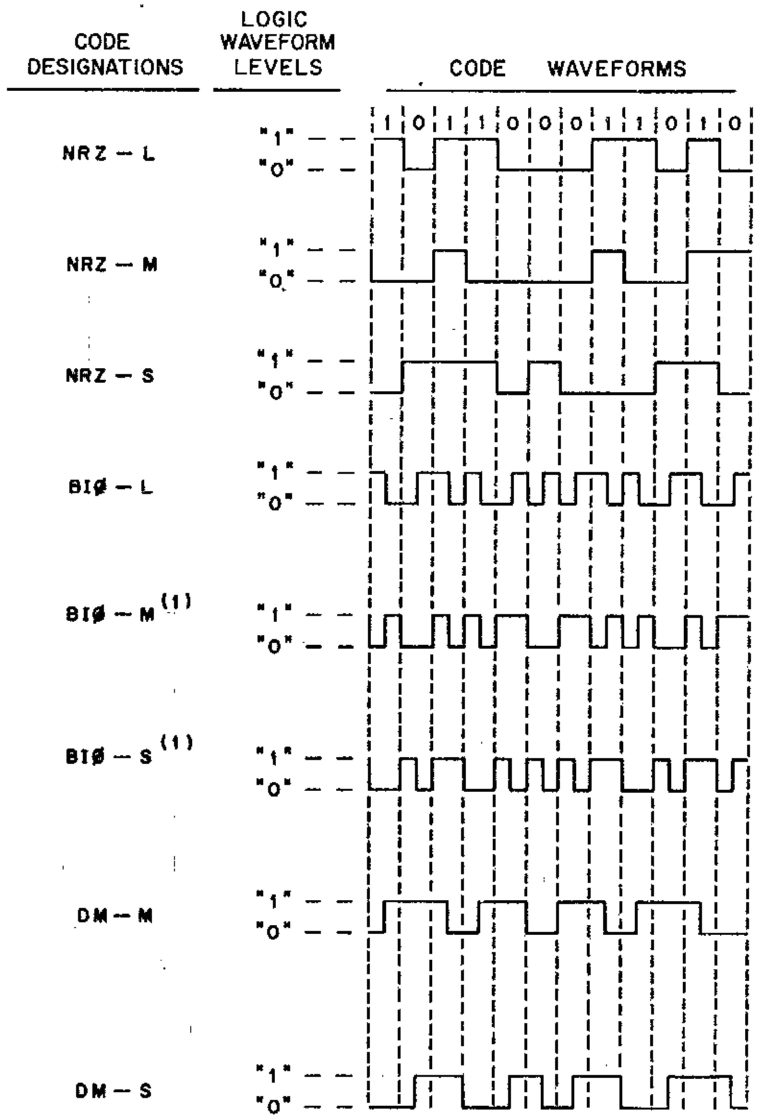
4.3 Bit Rate

The maximum bit rate is limited only by the requirements in Table 4-1 and in Chapter 2. Receiver intermediate-frequency (IF) bandwidths should be selected from Table 4-1. 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 shall 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 shall occur within 0.1 bit period of the time at which such transition is expected to occur based upon 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.

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



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 period.
"One" is represented by a "one" level with the transition to the "zero" level.
"Zero" is represented by a "zero" level with the 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.

DELAY MODULATION-MARK (MILLER CODE)
"One" is represented by a level change midbit time.
"Zero" followed by a "zero" is represented by a level change at the end of the first "zero" bit. No level change occurs when a "zero" is preceded by a "one".

DELAY MODULATION-SPACE (MILLER CODE)
"Zero" is represented by a level change at midbit time.
"One" followed by a "one" is represented by a transition at the end of the first "one" bit. No level change occurs when a "one" is preceded by a "zero".

(1) These definitions for BIØ-M and BIØ-S represent the accepted standard as previously defined in RCC documents 106-66 and 106-73 (Revised NOV 1975). These codes were erroneously defined in RCC documents 106-69, 106-71 and 106-73.

Figure 4-2. PCM Code Definition.

TABLE 4-1

RECEIVER INTERMEDIATE FREQUENCY BANDWIDTH (3 dB)

12,500 Hz[1]
25,000 Hz[1]
50,000 Hz[1]
100,000 Hz
300,000 Hz
500,000 Hz
750,000 Hz
1,000,000 Hz
1,500,000 Hz
3,300,000 Hz

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 4.2.2) and bit jitter (subparagraph 4.3.2) are applicable to the submultiple frame.

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 shall have a fixed and known relationship to the submultiple frame identification word.

[1] *System instabilities may limit the use of these bandwidths.*

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 sync word within the submultiple frame may contain identifiction 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

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

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

4.5.3 PCM/FM/FM. The subcarrier channel shall be chosen such 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 as required in Chapter 2, subparagraphs 2.2.7.4 and 2.3.3.5.

CHAPTER 5

PULSE AMPLITUDE MODULATION (PAM) STANDARDS

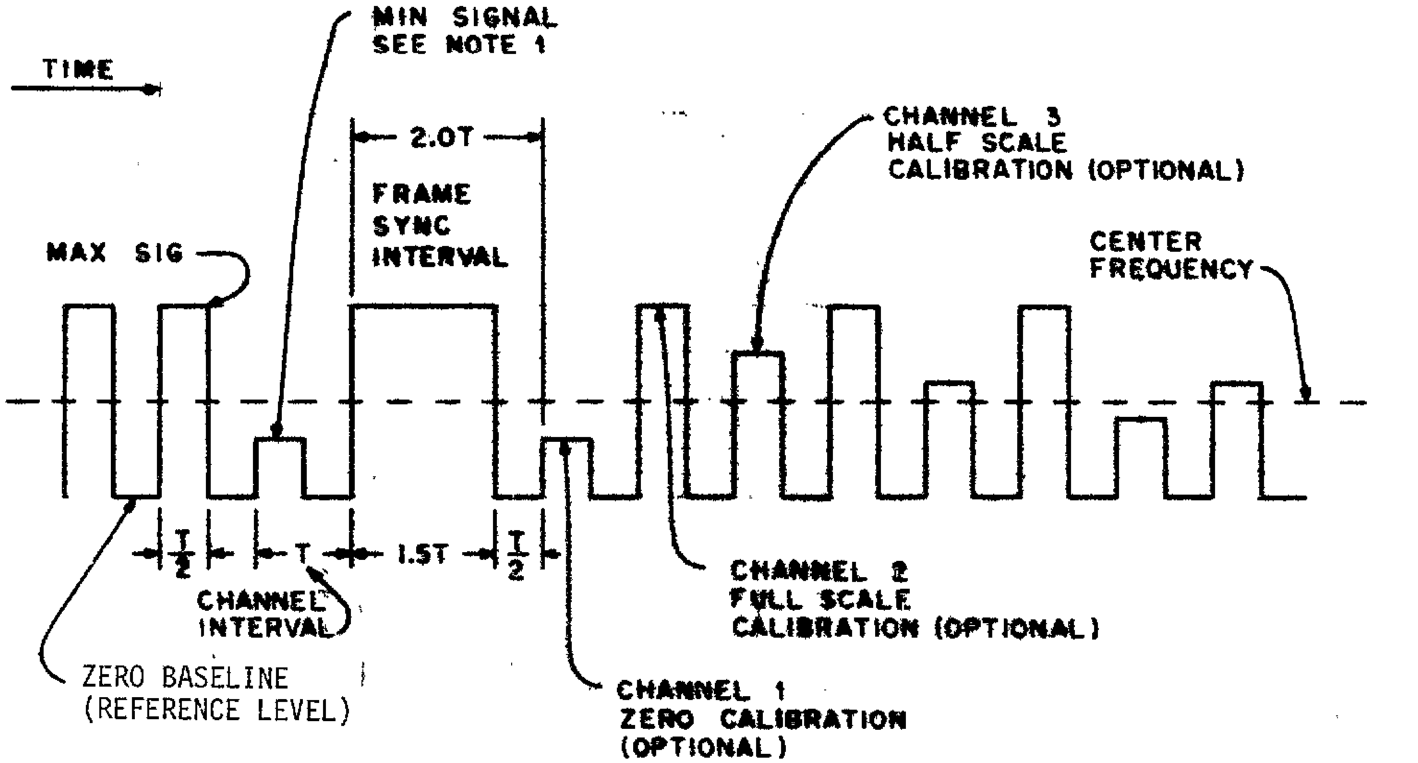
5.1 General

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

5.2 Frame and Pulse Structure

Each frame shall consist 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 commencing 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 percent to 25 percent of full amplitude level as shown in Figure 5-1. The pulse width shall be the



NOTE 1 20 to 25 percent deviation reserved for pulse synchronization is recommended.

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

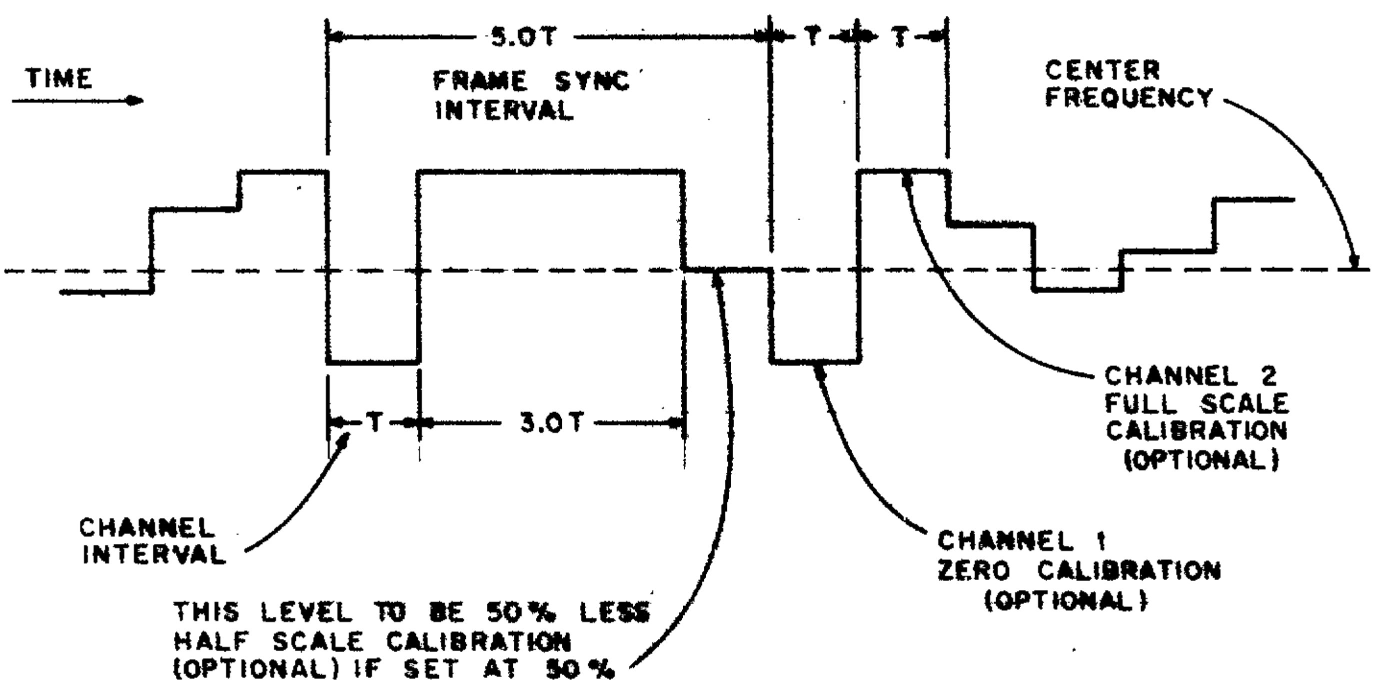


Figure 5-2. 100 Percent Duty Cycle PAM with Amplitude Synchronization.

same in all time intervals (the intervals devoted to synchronization excepted). 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 shall be 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 shall be, in the order given: zero level for a period T; full-scale amplitude for a period 3T; and a level not exceeding 50 percent full-scale amplitude for a period T (see Figure 5-2).

5.2.4 Maximum Pulse Rate. The maximum pulse rate shall 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 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 listed in Table 4-1.

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 the period of desired data, the time between the occurrence of corresponding points in any two successive frame synchronization intervals shall 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) shall not differ from the average channel interval established by the formula $T_{avg} = \frac{P}{1000}$ 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 shall be identified by the transmission of a synchronization pattern. All other submultiple frames shall have a fixed and known relationship to the identified submultiple frames.

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

5.4.1.2 One-hundred Percent Duty Cycle (NRZ). The synchronization pattern shall have 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 shall be 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, shall be equal and opposite with respect to the assigned carrier or subcarrier frequency. The deviation shall be the same for all occurrences of the same level.

5.6 Premodulation Filtering

Premodulation filtering is recommended to restrict the radiated spectrum as specififed in Chapter 2, subparagraphs 2.2.7.4 and 2.3.3.5.

CHAPTER 6

MAGNETIC TAPE RECORDER/REPRODUCER STANDARDS

6.1 Introduction

6.1.1 These standards define terminology and standardize the recorder/reproducer configuration required to assure crossplay 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.

6.1.2 Wherever feasible, quantitative performance levels which must be met or exceeded to comply with these standards are given. In all cases, including those in which quantitative limits for requirements falling within the scope of these standards are not stated but are left to agreement between interchange parties, standard test methods and measurement procedures, including those contained in Volume III of RCC Document 118-79, *Test Methods for Recorder/Reproducer Systems and Magnetic Tape,* shall be used to determine such quantities.

6.1.3 U. S. engineering units are the original dimension in these standards. Conversions of toleranced dimensions from customary U. S. engineering units (similar to British Imperial Units) to System International d' Unites (SI) units have been done according to American National Standards Institute (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 Fixed Head Recorder/Reproducer Capability Requirements

To allow maximum interchange of telemetry magnetic tape records and recording equipment between the test ranges, standard recording techniques and tape configurations are required. Any one of the several methods of information storage set forth here; i.e., direct recording, predetection recording, FM recording or PCM recording, may be used, or any compatible combination may be used simultaneously.

6.2.1 Tape Speeds[1]. The standard tape speeds for instrumentation magnetic tape recorders are 47.6 mm/s (1-7/8 ips), 95.3 mm/s (3-3/4 ips), 190.5 mm/s (7-1/2 ips), 381 mm/s (15 ips), 762 mm/s (30 ips), 1524 mm/s (60 ips), 3048 mm/s (120 ips), and 6096 mm/s (240 ips)*.

6.2.2 Record/Reproduce Bandwidths. For the purpose of these standards, two bandwidth classes, Intermediate Band and Wideband, are designated (see Table 6-4). Interchange of tapes between wideband and intermediate-band machines is NOT recommended.

6.2.2.1 Intermediate Band. Direct record response is to 300,000 Hz at 1524 mm/s (60 ips) or 600,000 Hz at 3048 mm/s (120 ips).

6.2.2.2 Wideband. Direct record response is to 4.0 MHz at 6096 mm/s (240 ips) for wideband.

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[1] *Tape speeds are based on integral binary multiples and submultiples of 15 ips. Metric speed ratios may not be exactly binary due to converison tolerances.*

**6096 mm/s (240 ips) represents an extension from IRIG 106-77 and previous issues.*

6.3 Direct Recording

Direct recording is a method of recording on magnetic tape by which the electrical input signal is added to a high frequency bias signal and converted to an analog current in the recording-head winding.

6.3.1 Magnetic Tape and Reel Characteristics. Magnetic tape and reel characteristics are specified in Chapter 7. It is recommended that all recorder/reproducer systems at a particular range be calibrated for operational use against a manufacturer's centerline tape of the type used by the range for each bandwidth class of recorder/reproducer system. Additional supplementary procurement specifications may be required to meet a particular operational requirement of the ranges.[2]

6.3.1.1 Tape Widths. The standard nominal tape widths for direct recording are 12.7 mm (1/2 in) and 25.4 mm (1 in). See Table 7-1, Tape Dimensions.

6.3.1.2 Track Geometry. Refer to Figure 6-1 (Analog Tape Geometry) and Tables 6-1, 6-2, and 6-3 for information. (Refer to Appendix E for several configurations not now included in these standards.)

6.3.1.2.1 The track width shall be 1.27 ±0.13 mm (0.050 ±0.005 in) for the 7- and 14-track configurations and 0.64 ±0.03 mm (0.025 ±0.001 in) for the 28-track configuration.

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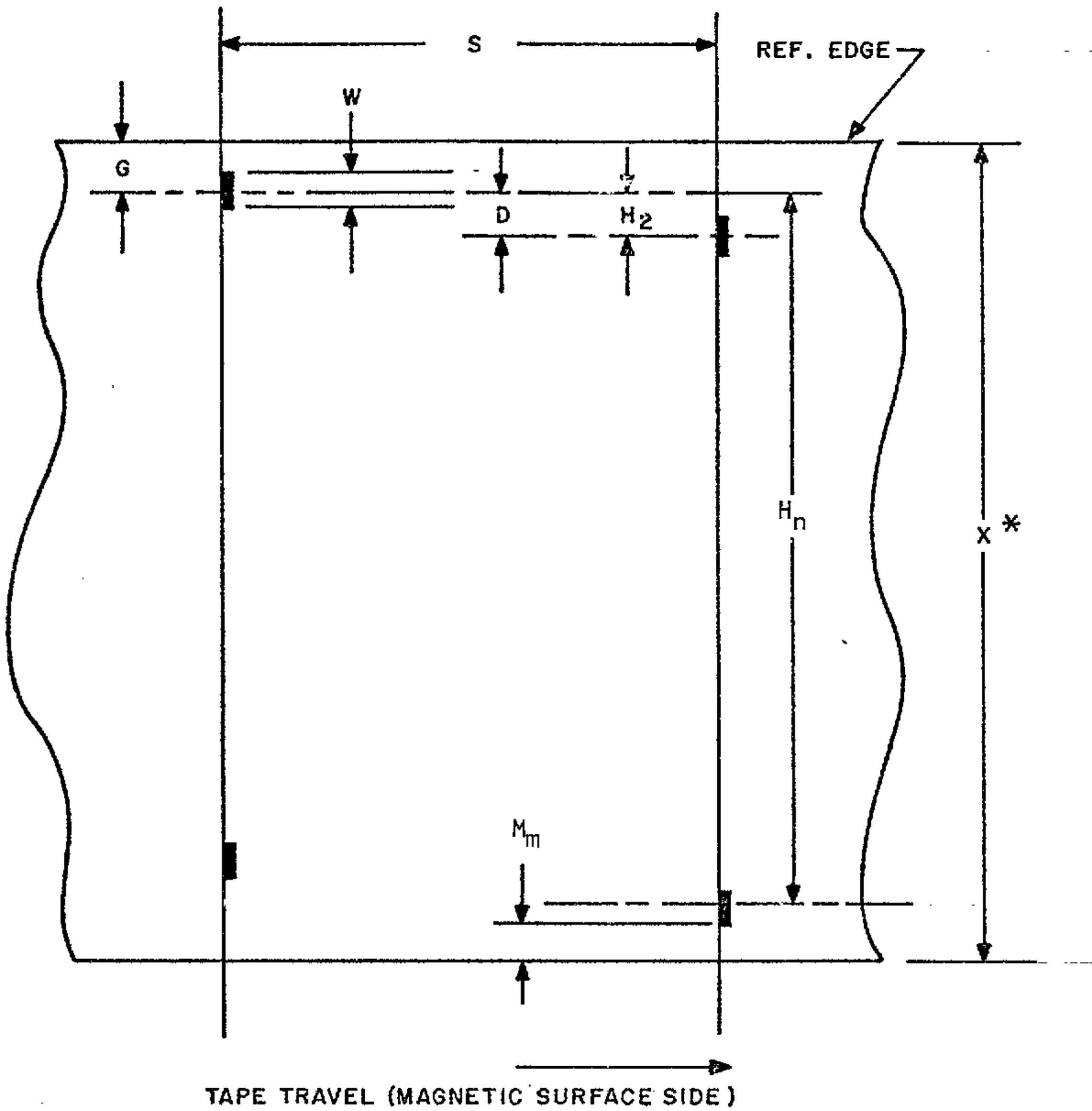
[2] *Federal Specification (FS) W-T-001553, "Tape, Recording, Instrumentation, Magnetic Oxide-Coated"; FS W-R-175C, "Reels and Hubs for Magnetic Recording Tape, General Specification for"; FS W-R-175/4C, "Reel, Precision, Aluminum and Magnesium, 3-Inch Center Hole"; FS W-R-175/6T, "Reels, Precision, Glass Flange with Aluminum Hub, 3-Inch Center Hole."*



* VALUES OF X FOR DIFFERENT TAPE WIDTHS:
25.35 ± 0.05 mm (0.998 ± 0.002 in)
12.65 ± 0.05 mm (0.498 ± 0.002 in)

LEGEND:

W — TRACK WIDTH
D — TRACK SPACING
S — HEAD STACK PLACEMENT (DATA SPACING)
M_m — EDGE MARGIN, MINIMUM
G — TRACK LOCATION (REFERENCE EDGE TO TRACK 1 CENTERLINE)
H_n — CENTERLINE DIMENSION FOR nth TRACK

8-29-77

Figure 6-1. Analog Tape Geometry.

6.3.1.2.2 Tracks shall be spaced 1.78 mm (0.070 in) across the 7- and 14-track configuration and 0.89 mm (0.035 in) across the 28-track configuration. Track location shall be as shown in Tables 6-1, 6-2, and 6-3.

TABLE 6-1

7 TRACKS ON 12.7-MM (½-IN) WIDE TAPE

	mm*	(in)
Track Width (W)	1.27±0.13	(0.050±0.005)
Track Spacing (D)	1.78	(0.070)
Head Stack Placement (Data Spacing) (S)	38.10±0.03	(1.500±0.001)
Edge Margin, Minimum (M_m)	0.14	(0.005)
Track Location (Reference Edge to Track 1 Centerline) (G)	1.02±0.05	(0.040±0.002)
Track Spacing Tolerance (ΔH_n)	±0.05	(±0.002)
Centerline Dimension for nth Track (H_n)		
H_1	0	(0)
H_2	1.78	(0.070)
H_3	3.56	(0.140)
H_4	5.34	(0.210)
H_5	7.12	(0.280)
H_6	8.90	(0.350)
H_7	10.68	(0.420)

**Although the metric equivalents in this table may not be exact, they conform to those currently accepted by industry.*

TABLE 6-2

14 TRACKS ON 25.4-MM (1-IN) WIDE TAPE

	mm*	(in)
Track Width (W)	1.27±0.13	(0.050±0.005)
Track Spacing (D)	1.78	(0.070)
Head Stack Placement (Data Spacing)(S)	38.10±0.03	(1.500±0.001)
Edge Margin, Minimum (M_m)	0.28	(0.011)
Track Location (Reference Edge to Track 1 Centerline) (G)	1.12±0.05	(0.044±0.002)
Track Spacing Tolerance (ΔH_n)	±0.05	(±0.002)
Centerline Dimension for nth Track		
H_1	0	(0)
H_2	1.78	(0.070)
H_3	3.56	(0.140)
H_4	5.34	(0.210)
H_5	7.12	(0.280)
H_6	8.90	(0.350)
H_7	10.68	(0.420)
H_8	12.46	(0.490)
H_9	14.24	(0.560)
H_{10}	16.02	(0.630)
H_{11}	17.80	(0.700)
H_{12}	19.58	(0.770)
H_{13}	21.36	(0.840)
H_{14}	23.14	(0.910)

**Although the metric equivalents in this table may not be exact, they conform to those currently accepted by industry.*

TABLE 6-3

28 TRACKS ON 25.4-MM (1-IN) WIDE TAPE

	mm*	(in)
Track Width (W)	0.64±0.03	(0.025±0.001)
Track Spacing (D)	0.89	(0.035)
Head Stack Placement		
(Data Spacing) (S)	38.10±0.03	(1.500±0.001)
Edge Margin, Minimum (M_m)	0.22	(0.009)
Track Location (Reference Edge to		
Track 1 Centerline) (G)	0.66±0.04	(0.0260±0.0015)
Track Spacing Tolerance (ΔH_n)	±0.04	(±0.0015)
Centerline Dimension for nth Track		
H_1	0	(0)
H_2	0.89	(0.035)
H_3	1.78	(0.070)
H_4	2.67	(0.105)
H_5	3.56	(0.140)
H_6	4.45	(0.175)
H_7	5.34	(0.210)
H_8	6.23	(0.245)
H_9	7.12	(0.280)
H_{10}	8.01	(0.315)
H_{11}	8.90	(0.350)
H_{12}	9.79	(0.385)
H_{13}	10.68	(0.420)
H_{14}	11.57	(0.455)
H_{15}	12.46	(0.490)
H_{16}	13.35	(0.525)
H_{17}	14.24	(0.560)
H_{18}	15.13	(0.595)
H_{19}	16.02	(0.630)
H_{20}	16.91	(0.665)
H_{21}	17.80	(0.700)
H_{22}	18.69	(0.735)
H_{23}	19.58	(0.770)
H_{24}	20.47	(0.805)
H_{25}	21.36	(0.840)
H_{26}	22.25	(0.875)
H_{27}	23.14	(0.910)
H_{28}	24.03	(0.945)

**Although the metric equivalents in this table may not be exact, they conform to those currently accepted by industry.*

6.3.1.2.3 The tracks on a tape shall be numbered consecutively, starting with track number 1, from top to bottom when viewing the oxide-coated side of a tape with the earlier portion of the recorded signal to the observer's right.

6.3.2 Head and Head-Stack Configuration (see Figure 6-2).

In Figure 6-2, head and head-stack parameters important to tape interchangeability are shown. Some of the parameters are defined where they appear in the standards. The following definitions apply to other parameters:

a. <u>Head Reference Surface.</u> The plane which is parallel to the reference edge of the tape and perpendicular to the plane of the tape (for some head designs, also the head mounting surface).

b. <u>Head Stack Azimuth</u>. The angle, in the plane of the tape, between a line perpendicular to the Head Reference Surface and a line passing through the centerlines of the gaps of the two outside heads of a head stack.

c. <u>Gap Scatter</u>. The distance between two parallel lines, in the plane of the tape and perpendicular to the Head Reference Surface, between which all gap trailing edges of a record head stack or all gap centerlines of a reproduce head stack shall fall.

6.3.2.1 Head Placement. The standard placement is to locate the heads (both record and playback) for alternate tracks in separate head stacks. Thus, to record on all tracks of a standard-width tape, two record head stacks will be used; to reproduce all tracks of a standard-width tape, two playback head stacks will be used.

6.3.2.2 Head Stack Placement. The two stacks of a head pair (record or reproduce) shall be mounted in such a manner that the centerlines through the head gaps of each stack are parallel and spaced 38.10 ±0.03 mm (1.500 ±0.001 in) apart for fixed head stacks. Where azimuth adjustment of the reproduce-head stacks is required, the stack spacing shall be 38.10 ±0.05 mm (1.500 ±0.002 in) between gap centerlines including maximum azimuth adjustment required to meet system performance requirements.

6.3.2.3 Head-Stack Numbering. Head-stack number 1 of a pair of stacks (record or reproduce) is the first stack over which an element of tape passes when moving in the normal record or reproduce direction.

6.3.2.4 Head and Stack Numbering. Numbering of a record or reproduce head shall correspond to the track number of the magnetic tape which that head normally records or reproduces. Stack number 1 of a pair will contain all odd-numbered heads, while stack number 2 will contain all even-numbered heads.

6.3.2.5 Head Location. Any head in a stack shall be located within ±0.05 mm (±0.002 in) of the nominal position required to match the track location as shown in Figure 6-1 and Tables 6-1, 6-2 and 6-3.

6.3.2.6 Head-Stack Tilt. The plane tangent to the front surface of the head stack at the centerline of the head gaps shall be perpendicular to the head reference surface within ±0.87 mrad (±3 minutes of arc) for intermediate-band recorders and ±0.29 mrad (±1 minute of arc) for wideband recorders (see Figure 6-2).

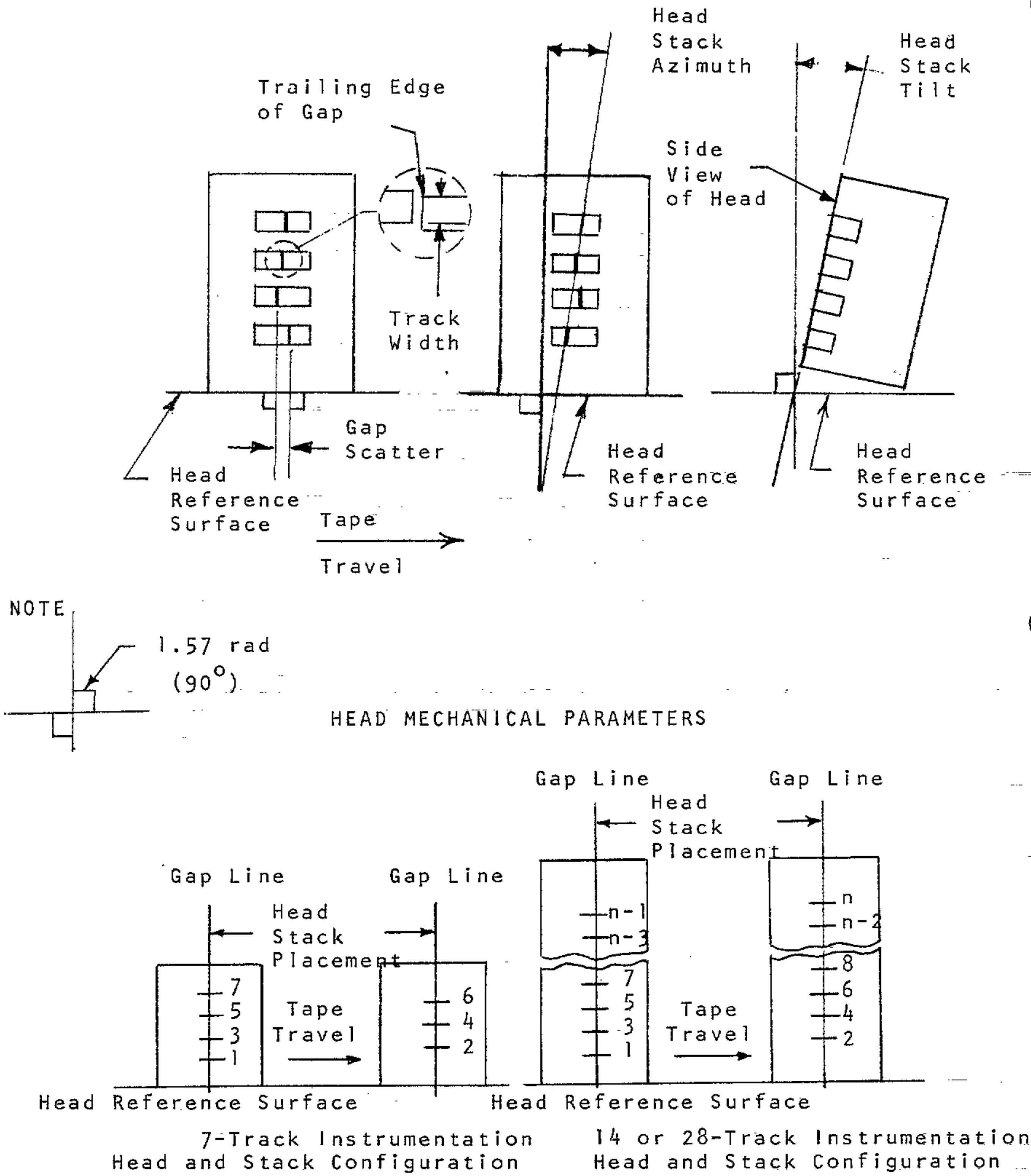


Figure 6-2. Head Configuration for Instrumentation Tape Units.

6.3.2.7 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 6-2 and Appendix E).

6.3.2.8 Record Gap Parameters

6.3.2.8.1 Record Gap Length. For wideband recorders, the record gap length (the perpendicular dimension from the leading edge to the trailing edge of the gap) shall be 2.16 μm ±0.5 μm (85 ±20 μin). See Appendix E, paragraph 5.

6.3.2.8.2 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 of Volume III, RCC Document 118-79 for suggested test procedure.)

6.3.2.9 Reproduce Head Stack Gap Azimuth Alignment. The reproduce head stack azimuth alignment shall match that of the record head stack as indicated by reproducing an upper band edge (UBE) frequency signal on a selected track and setting or adjusting the reproduce head stack azimuth for maximum output. At this azimuth setting, the output of any other track in the reproduce head stack shall be within 2 dB of the output at its own optimum azimuth setting (see paragraph 1.3 of Volume III, RCC Document 118-79).

6.3.3 Head Polarity. See Chapter 1, Volume III, of RCC Document 118-79 and Appendix E of this document for information.

6.3.3.1 Record Head. Each record-head winding shall be connected to its respective amplifier in such a manner that a positive-going pulse, with respect 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.

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

6.3.4 Tape Guiding. The tape guidance system shall restrict the tape angular motion to ±0.15 mrad (±30 seconds of arc) as measured by the interchannel time displacement error (ITDE) of outer tracks on the same head stack and shall not damage the tape.

6.3.5 Record/Reproduce Parameters. The high frequency bias signal for intermediate-band recorders shall have a wavelength on tape of less than 1.524 μm (60 μin). For wideband recorders, the bias frequency shall be greater than 3.5 times the highest direct record frequency for which the recorder/reproducer system is designed (see Appendix E).

NOTE

The frequency response or passband of direct-recorded data as a function of tape speed is given in Table 6-4. In measuring this response, signals throughout the specified passband with amplitudes equal to the Standard Record Level are recorded and the reproduce output signal levels are referenced to the playback output at the Record Level Set Frequency (see Appendix E).

6.3.6 Record Parameters

6.3.6.1 The input impedance at all frequencies in the intermediate band shall be 75 ohms nominal, while the input impedance for wideband recorders shall be 75 ohms or 50 ohms nominal across the specified band.

6.3.6.2 Input sine wave signals of 0.35 to 3.5 V rms shall be adjustable to produce Standard Record Level.

6.3.6.3 The record amplifier shall provide a transfer characteristic which is basically a constant current versus frequency characteristic upon which is superimposed a compensation characteristic to correct only for loss of record-head efficiency with frequency. For the test described in paragraph 4.8 of Volume III, RCC Document 118-79, the difference in the response curves normalized to the 0.02 UBE frequency shall be no greater than the figures given below:

Fraction of Upper-Band-Edge Frequency	dB Difference
0.1	0.5
0.5	1.0
0.8	1.6
1.0	2.0

6.3.6.4 Record bias setting information is contained in Table 6-4.

6.3.6.5 Standard Record Level

The Standard Record Level (synonomous with the term "Normal Record Level" used in RCC Document 118-79) for

TABLE 6-4

DIRECT-RECORD PARAMETERS

mm/s	(ips)	±3 dB Pass Band kHz[1]	Record Bias Set Frequency (UBE) kHz	Record Level Set Frequency (0.1 UBE) kHz
INTERMEDIATE BAND			(OVERBIAS 3 dB)[2]	
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 2 dB)[2]	
*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

**These speeds are an extended range of operation for wideband systems which may be supported at the option of the individual ranges.*

[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 subparagraph 4.1.3.3 of Volume III, RCC Document 118-79).*

direct record systems is the input level of the Record Level Set Frequency which produces an output signal containing 1.0 percent 3rd 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 6-4 and proper reproduce amplifier termination as defined in Figure 4.1-1, Volume III, RCC Document 118-79. A 1.0 percent 3rd harmonic distortion content is achieved when the level of the 3rd harmonic of the Record Level Set Frequency is 40 ±1 dB below the level of a sinusoidal signal of 0.3 UBE which is recorded at the Standard Record Level. Refer to Appendix E, paragraph 4.0, Record Level, for information regarding standard test and operating practices. The Standard Record Level is seldom optimum for telemetry data recording because crest factors, expected amplitude variation range, and modulation type must be considered when selecting the Operating Record Level (see Appendix E, paragraph 4.0).

6.3.7 Reproduce Parameters

6.3.7.1 The output impedance for intermediate-band recorders shall be 75 ohms nominal across the passbands specified in Table 6-4. For wideband recorders, the output impedance shall be 75 ohms nominal across the specified passband (50 ohms nominal output impedance is preferred at some installations and is an acceptable alternative).

6.3.7.2 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 V rms with a 3rd harmonic distortion of 1.0 percent and a maximum 2nd harmonic distortion of 1/2 percent when measured across a resistive load of 75 ohms (50 ohms for 50-ohm systems). Lack of proper output termination shall not cause the reproduce amplifier to oscillate.

6.3.8 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-reproduce 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:

6.3.8.1 The effective tape speed throughout the reel or any portion of the reel (in the 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 of RCC Document 118-79.

6.3.8.2 Sinusoidal 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 ±0.5 dB below Standard Record Level when mixed with other signals, or Standard Record Level when recorded on a separate track.

6.3.8.2.1 The constant-amplitude speed-control signal should 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 6-5 lists speed-control signal frequencies. The speed-control signal may also be used as a flutter correction signal.

6.3.8.2.2 Signals to be used for discriminator flutter correction systems are listed in Tables 3-3 and 6-5. See subparagraph 6.3.8.2.1 above and Table 3-3 for restrictions on use of flutter correction signals.

6.3.9 Timing Signal Recording. Modulated-carrier time code signals, IRIG-A and IRIG-B, are in wide use, and other formats are available. When recording IRIG-B time code signals, care must be taken to assure 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, it is recommended that IRIG-B time-code signals be recorded on an FM track or on an FM subcarrier. The highest subcarrier available should be employed to minimize time delay.[3]

6.3.10 Predetection Recording. Predection signals consist of FM or PM IF carriers which have been translated in frequency to be compatible with wideband recorder frequency response. These signals will be recorded by direct (high frequency bias) recording. Parameters for these signals are in Table 6-6.

6.3.11 Tape Signature Recording. For data processing using wideband recorders and reproducers, a tape signature recorded

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[3] *Timing Code formats are found in IRIG 104-70, IRIG Standard Time Formats, and IRIG Standard 128-77, IRIG Standard Parallel Binary Time Code Formats.*

TABLE 6-5

CONSTANT-AMPLITUDE SPEED-CONTROL SIGNALS[1]

Tape Speed mm/s	(ips)	Frequency[2] kHz			
6096	(240)	400	±0.01%	800	±0.01%
3048	(120)	200	±0.01%	400	±0.01%
1525	(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%
95.2	(3 3/4)	6.25	±0.01%	12.5	±0.01%
47.6	(1 7/8)	3.125	±0.01%	6.25	±0.01%

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.

[1]*May also serve as descriminator 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. When interchanging tapes, care should be taken to assure that the recorded speed-control signal is compatible with the reproduce system's speed-control electronics.*

TABLE 6-6

PREDETECTION CARRIER PARAMETERS

Tape Speed mm/s	(ips)	Predetection Carrier Center Frequency [1, 2] kHz A	B
6096	(240)	1800	2400
3048	(120)	900	1200
1524	(60)	450.0	600
762	(30)	225.0	300
381	(15)	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.*

before and/or after the data provides a method of adjusting the reproducer head azimuth and reproduce equalization. It also provides a means of verifying the proper operation of equipment such as playback receivers and bit synchronizers used to retrieve the recorded data. A PCM signature is recommended where primarily PCM data is recorded. A swept-frequency 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 6 of Appendix E.

6.4 FM Record Systems

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

6.4.1 Tape and Reel Characteristics. Subparagraph 6.3.1 and all related subparagraphs shall apply.

6.4.2 Head and Head-Stack Configuration. Subparagraph 6.3.2 and all related subparagraphs shall apply.

6.4.3 Tape Guiding. Subparagraph 6.3.4 shall apply.

6.4.4 Tape Speeds and Corresponding FM Carrier Frequencies. See Table 6-7.

6.4.5 FM Record/Reproduce Parameters. See Table 6-7.

6.4.6 Speed Control and Compensation. Subparagraph 6.3.8 shall apply. Note that a separate track is always required

TABLE 6-7

INTERMEDIATE AND WIDEBAND 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	d.c. to 0.625	±1
95.2 (3-3/4)	47.6 (1-7/8)	6.750	9.450	4.050	d.c. to 1.250	±1
190.5 (7-1/2)	95.2 (3-3/4)	13.500	18.900	8.100	d.c. to 2.500	±1
381.0 (15)	190.5 (7-1/2)	27.000	37.800	16.200	d.c. to 5.000	±1
762.0 (30)	381.0 (15)	54.000	75.600	32.400	d.c. to 10.000	±1
1524.0 (60)	762.0 (30)	108.000	151.200	64.800	d.c. to 20.000	±1
3048.0 (120)	1524.0 (60)	216.000	302.400	129.600	d.c. to 40.000	±1
	3048.0 (120)	432.000	604.800	259.200	d.c. to 80.000	±1
	Wideband FM					
	GROUP II					
	47.6 (1-7/8)	14.062	18.281	9.844	d.c. to 7.810	+1, -3
	95.2 (3-3/4)	28.125	36.562	19.688	d.c. to 15.620	+1, -3
	190.5 (7-1/2)	56.250	73.125	39.375	d.c. to 31.250	+1, -3
	381.0 (15)	112.500	146.250	78.750	d.c. to 62.500	+1, -3
	762.0 (30)	225.000	292.500	157.500	d.c. to 125.000	+1, -3
	1524.0 (60)	450.000	585.000	315.000	d.c. to 250.000	+1, -3
	3048.0 (120)	900.000	1170.000	630.000	d.c. to 500.000	+1, -3
	6096.0 (240)	1800.000	2340.000	1260.000	d.c. to 1000.000	+1, -3

[1] *Input voltage levels per subparagraph 6.4.2.*

[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.*

for speed-control and flutter-compensation signals with a single-carrier FM system.

6.4.7 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.

6.4.7.1 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.

6.4.7.2 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.

6.4.7.3 Wideband FM Record Systems. Input impedance is 75 ohms ±10 percent at all frequencies in the specified passband.

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

6.4.8.1 Intermediate Band FM Systems. Output of these systems is 3 V peak-to-peak minimum across a resistance of 75 ohms minimum, from d.c. to the maximum specified frequency. A signal of increasing frequency on the input of the reproduce system shall give 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 resistances should be coordinated with the ranges.)

6.4.8.2 Wideband FM Systems. Output of wideband FM systems 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.

6.5 PCM Recording

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

6.5.1 Predetection PCM Recording

a. This method employs direct recording of the signal obtained by heterodyning the receiver IF bandpass to one of the center frequencies listed in Table 6-6, without demodulating the serial PCM signal (see Figure 6-3).

b. The maximum recommended bit rate for predetection recording of NRZ data is equal to the predetection carrier frequency; e.g., 900 kb/s for a 900-kHz predetection carrier. The maximum recommended bit rate for predetection recording of Bi-Phase (Biϕ) 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.

6.5.2 Postdetection PCM Recording

The serial PCM signal (plus noise) at the video output of the receiver demodulator is recorded by direct or wide-

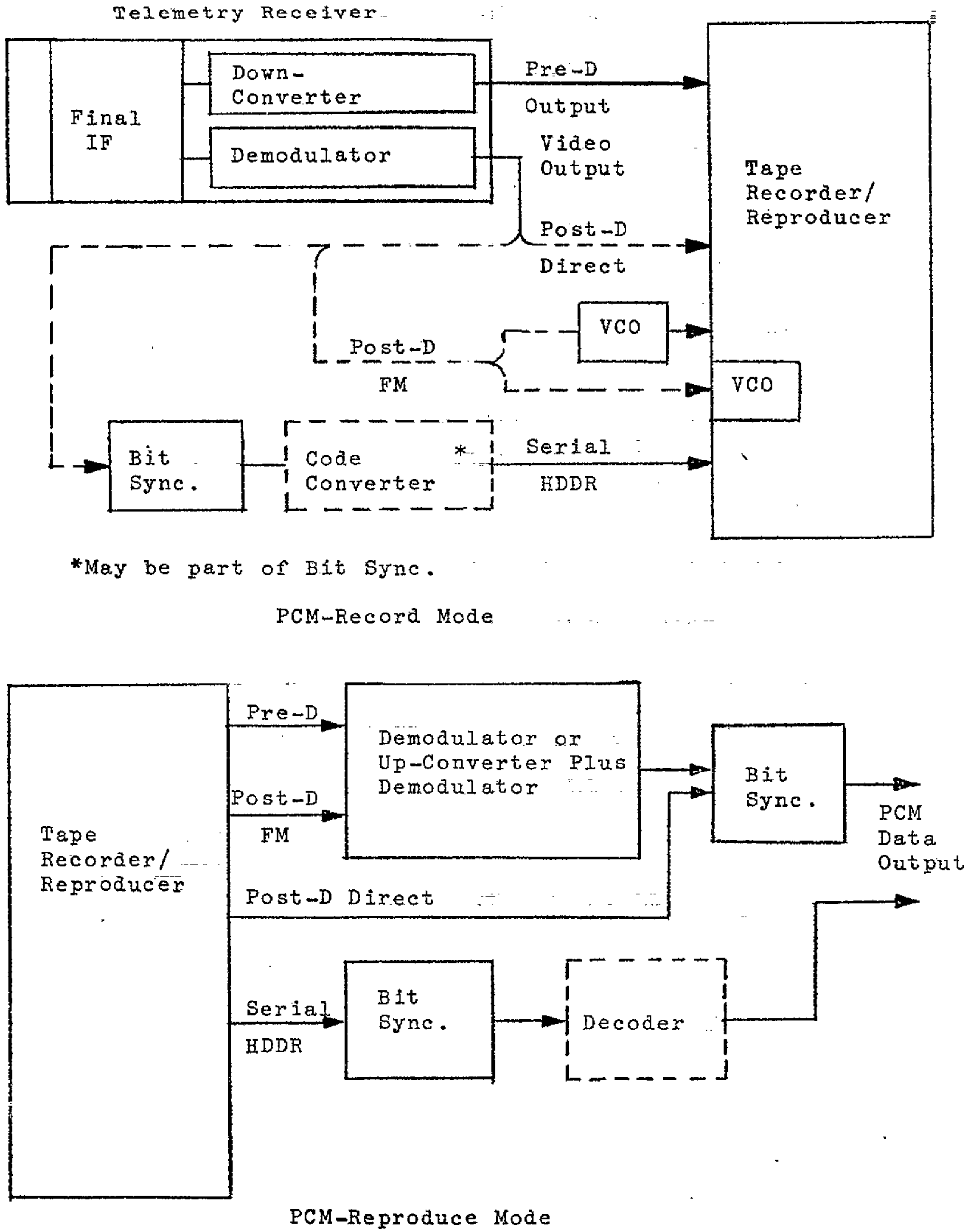


Figure 6-3. PCM Record/Reproduce Configurations.

band FM recording methods without first converting the PCM signal to bi-level form (see Figure 6-3). Table 6-8 lists maximum bit rates versus tape speed for these recording methods. The minimum recommended reproduce bit rates are 10 kb/s for Postdetection Direct Biϕ and 10 bits per second for Postdetection FM (see paragraph 4.3, Chapter 4, Pulse Code Modulation (PCM) Standards).

6.5.3 Serial High Density Digital Recording (HDDR)

a. 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.

TABLE 6-8

MAXIMUM RECOMMENDED BIT RATES, POSTDETECTION RECORDING

Tape Speed mm/s	(ips)	Post-D Direct* Biϕ (kb/s)	Post-D FM Biϕ (kb/s)	Post-D FM NRZ (kb/s)
6096	(240)	1800	900	1800
3048	(120)	900	450	900
1525	(60)	450	225	450
762	(30)	225	112	225
381	(15)	112	56	112
190.5	(7-1/2)	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.*

b. This paragraph deals with standards for direct recording of PCM telemetry data using a wideband analog instrumentation recorder/reproducer system (direct recording is described in paragraph 6.3). The recommended PCM codes, maximum bit rates, record and reproduce parameters, and the magnetic tape requirements are also described.

6.5.3.1 PCM Codes

The recommended codes for serial high density PCM recording are Bi-Phase Level (Biϕ-L) and Randomized Non-Return-to-Zero Level (RNRZ-L). The maximum recommended bit packing densities are 590 b/mm (15 kb/in) for Biϕ-L and 980 b/mm (25 kb/in) for RNRZ-L. Refer to Table 6-9 for maximum recommended bit rates versus standard tape speeds. The minimum recommended reproduce bit rates are 5 kb/s for Biϕ-L and 200 kb/s for RNRZ-L.

6.5.3.1.1 Biϕ-L Code

The Biϕ-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 Biϕ-L (see Table 6-9) and the amount of tape required for mission recording by this method is not a severe operational constraint.

6.5.3.1.2 RNRZ-L Code

a. The RNRZ-L code is recommended for direct recording under any of the following conditions:

TABLE 6-9

MAXIMUM RECOMMENDED BIT RATES

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

NOTE

When using recorder/reproducers with a 1.5 MHz bandwidth at 3048 mm/s (120 ips), the maximum recommended data rates are 75 percent of the data rates shown in Table 6-9.

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

(1) The bit rate of the data to be recorded exceeds the maximum recommended bit rates for Biϕ-L (see Table 6-9), or,

(2) Maximum tape recording time is needed.

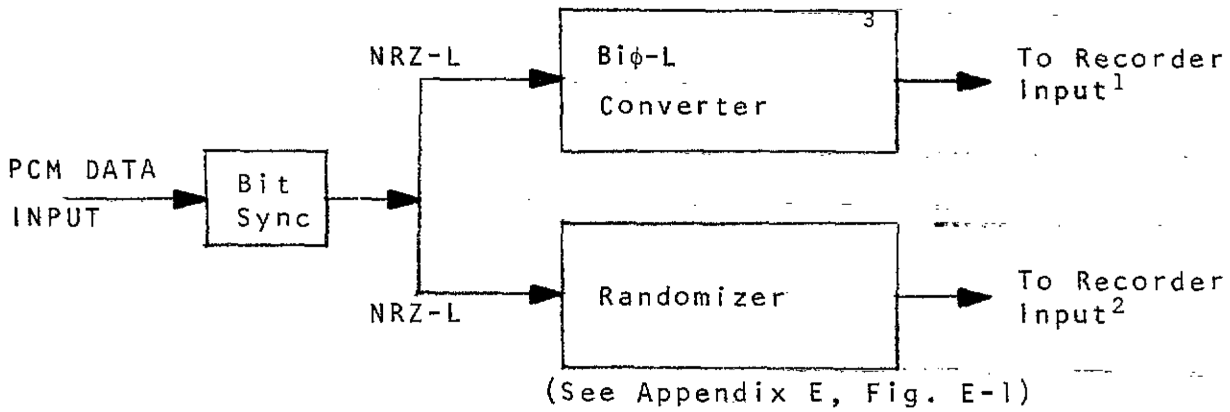
b. To minimize baseline wander anomalies, RNRZ-L is NOT recommended if the reproduced bit rate will be less than 200 kb/s.

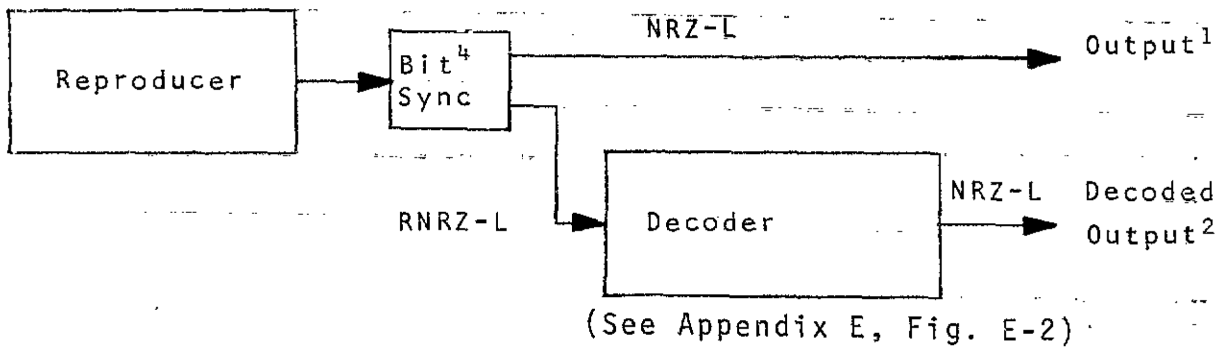
c. RNRZ-L shall be implemented using a 15-stage shift register and modulo-2 adders (Figure 6-4). The randomized bit stream to be recorded is generated by adding (modulo-2) the input bit stream to the modulo-2 sum of the outputs of the 14th and 15th stages of a shift register. The randomized bit stream is also the input to the shift register. Decoding of the randomized bit stream is accomplished by adding (modulo-2) the bit synchronized/reconstructed 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 (Figure 6-4).

6.5.3.2 Record Parameters

6.5.3.2.1 High density PCM data shall be recorded in compliance with the direct record parameters detailed in subparagraph 6.3.6, including the use of an a.c. bias signal level which produces the required 2-dB overbias condition.

6.5.3.2.2 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 (refer to subparagraph 6.3.6.5).





[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 6-4. Serial High Density Digital Record and Reproduce.

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

6.5.3.2.4 Serial high density digital data should be recorded on the center tracks of the tape to minimize the effects of tape dropouts.

6.5.3.3 Reproduce Parameters

All reproduce parameters in subparagraph 6.3.7 shall apply.

6.5.3.3.1 PCM Signature

It is recommended that a PCM signature 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 (refer to subparagraph 6.3.11 for tape signature recording).

6.5.3.3.2 Phase Equalization

Correct phase equalization is very important to the reconstruction of the serial high density digital data. Adjustable phase equalizers are desirable but not mandatory.

6.5.3.4 Magnetic Tape

High density PCM magnetic tapes are recommended; however, wideband instrumentation tapes can be used on recorder/reproducer systems with 1.27-mm (0.050-in) track widths.

6.5.3.5 Tape Copying

The following are recommended practices to be observed when making copies of original data tapes:

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

b. Align reproduce head azimuth to original tape

c. Correctly adjust reproducer equalizers

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

<u>*NOTE*</u>

If an appropriate PCM bit synchronizer (subparagraph 6.5.3.6) is not available, the tape can be copied directly; however, the SNR will be decreased.

6.5.3.6 PCM Bit Synchronizer

a. The PCM bit synchronizer should contain circuitry to reestablish the baseline reference of the PCM signal (a d.c. restorer circuit). This circuit is essential when reproducing RNRZ at reproduced bit rates less than 1 Mb/s.

b. The PCM bit synchronizer loop bandwidth should be selected for optimum performance between 0.1 percent and 3 percent of the bit rate.

CHAPTER 7

MAGNETIC TAPE STANDARDS

7.1 General

These standards define terminology, establish key performance criteria and reference test procedures for instrumentation magnetic tape which is used for telemetry data storage.[1]

7.2 Reference Tape System

In order to establish, where practical, a set of test procedures which can be carried out independently and repeatedly on different manufacturers' tape transports with as little special equipment as possible, a centerline reference tape system should be established by the tape user. This reference tape system can be used to provide a centerline standard for aligning operational recorders for mission support, using the applicable setup procedures contained in Chapter 6 or when initiating a tape procurement, as outlined below.

7.3 Manufacturer's Centerline Tape

A Manufacturer's Centerline Tape (MCT) is a tape provided by a manufacturer, at the request of the tape user, on which all magnetic/electrical characteristics of the tape specified by the tape user duplicate the manufacturer's true average (mean) production centerline within ± 0.5 dB. These magnetic/electrical characteristics shall include, but not be limited

[1]*Federal Specifications W-T-001553, W-R-175C, W-R-175/4B and W-R-1756T replace any of the paragraphs contained in this chapter.*

to, bias level, record level, wavelength response and output at 254 μm (10 mils) wavelength. The physical characteristics of the MCT shall also represent the manufacturer's average (mean) production centerline. The MCT shall be representative of all manufacturer's production tape delivered during any resultant contractual period. The manufacturer may incorporate any desired changes in the MCT and production tape at the conclusion of any contract or as specified by the tape user. Any such change will, however, necessitate the requalification of all centerline values as outlined in paragraph 7.5.

NOTE

The MCT shall be a full length tape of either 12.7 mm (1/2 inch) or 25.4 mm (1 inch) width, wound on a 266.7 mm (10-1/2 inch) or 355.6 mm (14 inch) 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.

7.4 Manufacturer's Secondary Centerline Tape

A manufacturer's secondary centerline tape (MSCT) is a tape provided by the manufacturer in lieu of an MCT. On the MSCT, one or more of the specified magnetic/electrical characteristics may depart from the centerline average by more than 0.5 dB. All of the specified magnetic/electrical characteristics of the MSCT shall be calibrated to the MCT or to the manufacturer's true average (mean) production centerline. Any departure from these centerline values shall be specified within ±0.5 dB. The physical characteristics of the MSCT shall, however, represent the manufacturer's average (mean) production centerline. All additional MCT requirements shall apply to the MSCT.

7.5 Centerline Performance Requirements

The tape user procuring magnetic tape shall establish, to the greatest extent possible, the operational support requirements which the magnetic tape must satisfy. A tape recorder which meets both the requirements of Chapter 6 and the above determined operational requirements shall also be selected for use as a test recorder/reproducer. The tape user will then request, from each appropriate tape manufacturer, two or more MCT's which meet the requirements of paragraph 7.3. If these MCT's cannot be obtained, an MSCT which meets the requirements of paragraph 7.4 will be an acceptable, but less desirable, alternate.

7.6 MCT/MSCT Use

Using the MCT or MSCT, the tape user will perform all tests necessary to determine if the manufacturer's centerline performance values meet operational/recorder requirements. All acceptable MCT's or MSCT's will be retained by the tape user for use as a reference in any subsequent acceptance test procedures performed in support of resultant contracts or contractual periods. A working reference tape (WRT), which has been calibrated to the MCT or MSCT, will be used as the actual working reference in the applicable testing procedures outlined in Volume III, Appendix B, IRIG 118-79.

7.7 Test Recorder/Reproducer

A test recorder shall be designated for use in conjunction with the reference tape system during any magnetic tape procurement/testing program. The recorder or recorders selected shall meet the requirements of Chapter 6 and the operational requirements imposed upon the tape. For operating convenience, the test recorder/reproducer selected should be equipped with adjustable bias and record level monitor meters with readout in dB units used in the applicable test procedures.

7.8 Test Recorder/Reproducer Requirements

This standard describes the key requirements applicable to high resolution (HR) and standard resolution (SR) instrumentation magnetic tape. Limits are specified, where necessary, to standardize configurations and to establish the basic handling characteristics of the tape. The limits placed upon the remaining requirements must be determined by the tape user in light of the intended application and interchangeability requirements imposed on the tape. Table 7-5 contains IRIG Recommended Requirement Limits, which have been selected on the basis of having provided satisfactory performance in existing telemetry applications.

7.9 General Requirements

7.9.1 Marking and Identification. Identification markings shall appear on the reel flange and individual carton, or can, of each delivered tape. Tape reel and production information, as specified below, shall be on a removable gummed label on the outer reel flange and on a permanently affixed label on the carton or can. Shipping containers shall be marked with the tape and reel identification and such production information as specified by the tape user.

7.9.1.1 Tape and Reel. The magnetic tape shall be identified in the following format:

Basic Indicator	Base Thickness Indicator µm (mils)	Width Indicator µm (mils)	Reel Indicator	Length Indicator m (ft)
HR	25.4 (1.0)	12700 (500)		
SR	38.1 (1.5)	25400 (1000)	SCP-I	2804 (9200)

7.9.1.1.1 Basic Indicator. The basic indicator defines the general application of the specified tape. HR tape is for recording wavelengths of 1.52 µm (0.06 mil) or greater and SR tape is for recording wavelengths of 5.08 µm (0.2 mil) or greater.

7.9.1.1.2 Base Thickness Indicator. The base thickness indicator is the nominal thickness of the polyester base material measured in micrometers (mils).

7.9.1.1.3 Width Indicator. The width indicator is the nominal width of the tape measured in micrometers (mils) as specified in Table 7-1.

7.9.1.1.4 Reel and Reel Type Indicator. The reel or reel type is identified in accordance with Federal Specification W-R-175.

7.9.1.1.5 Length Indicator. The length indicator is the designated minimum length of tape in meters (feet) as specified in Table 7-1.

7.9.1.2 Production Identification. Production identification of the magnetic tape will be in the following format:

Vendor - Tape Type - Production Date - Production Code

7.9.1.2.1 Vendor. The vendor is the company that manufactures and markets the tape.

7.9.1.2.2 Tape Type. Tape type is the vendor's identifying tape name.

7.9.1.2.3 Production Date. The production date is a five-digit number; the first two digits indicate the year of production and last three digits indicate the day of production completion. For example, 70048 indicates production completed on the 48th day of 1970.

7.9.1.2.4 Production Code. This is a unique code by which the vendor identifies, where applicable, the production batch, coater, slitter, and web position of the tape.

TABLE 7-1
TAPE DIMENSIONS
TAPE LENGTH/BASE THICKNESS

Designated/Minimum Length		Nominal Base Thickness		Nominal Reel Diameter		Nominal Hub Diameter	
m	(ft)	μm	(mils)	mm	(in)	mm	(in)
762	(2500)	38.1	(1.5)	266.7	(10½)	114	(4½)
1097	(3600)	25.4	(1.0)	266.7	(10½)	114	(4½)
1402	(4600)	25.4	(1.0)	266.7	(10½)	114	(4½)
1524	(5000)	38.1	(1.5)	355.6	(14.0)	114	(4½)
2195	(7200)	25.4	(1.0)	355.6	(14.0)	114	(4½)
2804	(9200)	25.4	(1.0)	355.6	(14.0)	114	(4½)
3292	(10800)	25.4	(1.0)	381.0	(15.0)	114	(4½)

TAPE WIDTH

Designated Width mm (in)	Dimension mm (in)	Tolerance mm (in)
12.7 (½)	12.65 (0.498)	±0.05 (±0.002)
25.4 (1)	25.35 (0.998)	±0.05 (±0.002)

7.9.2 Packaging. Each reel of magnetic tape shall be enclosed, as a minimum, by an individually sealed polyethylene wrapper packaged in an appropriate carton or can which provides support of the enclosed reel at the hub.

7.9.3 Wind. The tape shall be wound on the reel or hub with the oxide surface facing toward the hub unless otherwise specified by the tape user. When wound in this fashion, the front of the wound reel is defined as that flange which is visible when viewing the reel of tape with the loose end hanging from the viewer's right.

7.9.4 Reels and Hubs. Reels and hubs shall conform to the tape-user specified requirements of Federal Specification W-R-175.

7.9.5 Radial Clearance. The minimum radial clearance for all tape lengths shall be not less than 3.175 mm (1/8 inch). Radial clearance is defined as the difference in millimeters in radii between the outside layer of tape and the edge of the reel when the tape is wound at a tension of 1.67 N to 2.78 N (6 to 10 ounces) per 12.7 mm (½ inch) of tape width on a reel that meets the requirements of Federal Specification W-R-175.

7.9.6 Inflammable Materials. Inflammable materials, which will ignite from a match flame and when so ignited will continue to burn in a still carbon dioxide atmosphere, shall not be a part of the magnetic tape.

7.9.7 Toxic Compounds. Compounds which produce toxic effects in the environmental conditions normally encountered under operating and storage conditions defined in subparagraph 7.10.2 shall not be part of the magnetic tape. Toxicity is defined as the property of a material which has the ability to do chemical damage to the human body. Highly toxic or corrosive compounds which are produced under conditions of extreme heat shall be identified and described by the manufacturer.

7.10 General Characteristics

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

7.10.2 Environmental Conditions. The tape shall withstand, with no physical damage or performance degradation, any natural combination of operating or nonoperating conditions defined in subparagraphs 7.10.2.1 and 7.10.2.2. The test procedure outlined in Volume III, Appendix B, subparagraph 3-57 a. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.10.2.1 Operating Environmental Conditions.

Condition	Range
Temperature:	277.6 K to 313.8 K (+40° to +105°F)
Humidity:	25 to 95% RH
Barometric Pressure:	4.6 km (105 kN/m^2 (sea level) to 84 kN/m^2) or 1050 millibars (sea level) to 840 millibars (15,000 ft.)

7.10.2.2 Nonoperating Environmental Conditions

Condition	Range
Temperature:	244.3 K to 324.9 K (-20^{o} to $+125^{o}F$)
Humidity:	5 to 100% noncondensing
Barometric Pressure:	15.2 km (105 kN/m^2 (sea level) to 40 kN/m^2) or 1050 millibars (sea level) to 400 millibars (50,000 ft)

7.10.3 Storage Life. The tape shall be sufficiently durable such that storage up to 12 months (31.56 Ms), in conditions not exceeding those specified in subparagraph 7.10.2.2 above, shall result in no detrimental effects to the tape. The test procedure outlined in Volume III, Appendix B, paragraph 3-58 of IRIG 118-79 shall be used to determine compliance with this requirement.

7.10.4 Bi-Directional Performance. The magnetic/electrical performance of the tape shall remain constant, regardless of the longitudinal direction of tape movement, during a record/reproduce process. The test procedure outlined in Volume III, Appendix B, paragraph 3-59 of IRIG 118-79 shall be used to determine compliance with this requirement.

7.10.5 Frictional Vibration. The tape shall not exhibit frictional vibration which manifests itself in an audible squeal at any standard IRIG speed as the tape passes over the guides and heads of the test recorder/reproducer. Frictional vibration is defined as the random frequency and amplitude modulation which results when the tape passes over the guides and heads of a magnetic tape recorder.

7.10.6 Scatterwind. The tape shall be smoothly centerwound on the reel and hub to form an integral mass. There shall be no visible folds, shifts, spoking, or gaps between the tape layers. The edges of the wound tape shall be in a single plane with a minimum of roughness and with no protruding tape layers or groups of layers.

7.11 Physical Characteristics

7.11.1 Yield Strength. The 1 percent offset yield point, the force at 3 percent elogation and the breaking force of the tape, when conditioned according to the procedures described in Volume III, Appendix B, subparagraph 3-60 a. (1) of IRIG 118-79 shall not be less than the minimum values specified in Table 7-2. The test procedure outlined in Volume III, Appendix B, subparagraph 3-60 a. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.11.2 Shock Tensile Strength. A sample of tape, 12.7 mm (½ inch) in width, when conditioned according to the procedures described in Volume III, Appendix B, subparagraph 3-60 b. (1) of IRIG 118-79 shall possess, as a minimum, the shock tensile strength specified in Table 7-2. Shock tensile strength is defined as the ability of the magnetic tape to resist, without breaking, a suddenly applied stress. The test procedure outlined in Volume III, Appendix B, subparagraph 3-60 b. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.11.3 Permanent Elongation. A sample of tape, 12.7 mm (½ inch) in width, when conditioned according to the procedures described in Volume III, Appendix B, subparagraph 3-60 b. (3) (a) of IRIG 118-79, and stressed as described below, shall not exceed the percentage limits of permanent elongation specified in Table 7-2. Permanent elongation is defined as the difference between an initially measured unstressed tape length and a final tape length, expressed as a percentage of the unstressed tape length. The unstressed tape length is the measured distance between a point of clamping and a mark on the tape while the tape is under an applied tension of 490 mN (50 grams). The final length is the measured distance between the point of clamping and the same mark on the tape under an applied tension of 490 mN (50 grams) after the tape has undergone an applied tension of 22 N (5 pounds) for a period of 10.8 ks (180 minutes), and thereafter a period of zero tension for 10.8 ks (180 minutes). The test procedure outlined in Volume III, Appendix B, subparagraph 3-60 b. (3) of IRIG 118-79 shall be used to determine compliance with this requirement.

TABLE 7-2

TAPE STRENGTH*

Base Thickness μm (mils)	Yield Strength N (pounds)	Shock Tensile Strength J (foot-pounds)	Permanent Elongation (percent)
38.1 (1.5)	43.6 (9.8)	1.570 (1.16)	0.30
25.4 (1.0)	28.5 (6.4)	1.570 (1.16)	0.50

**Based on 12.7 mm (½ inch) tape width.*

7.11.4 Humidity Stability (Cupping). A sample of tape 12.7 mm (½ inch) in width, when conditioned according to the procedures described in Volume III, Appendix B, subparagrah 3-60 c. (1) of IRIG 118-79 shall show no cupping in excess of 0.175 rad (10 degrees). Cupping is defined as the transverse curvature of a strip of tape viewed "end-on." The test procedure outlined in Volume III, Appendix B, subparagraph 3-60 c. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.11.5 Flexibility. The flexibility of the tape, when conditioned according to the procedures described in Volume III, Appendix B, subparagraph 3-61 a. of IRIG 118-79, shall not be less than the values specified in Table 7-3. Flexibility is defined as the ability of the tape to conform to a minimum radius of curvature when subjected to a force normal to the surface of the tape. The test procedure outlined in Volume III, Appendix B, paragraph 3-61 of IRIG 118-79 shall be used to determine compliance with this requirement.

TABLE 7-3
FLEXIBILITY

Nominal Width mm (in)	Base Thickness µm (mils)	Deflection rad (degrees)
12.7 (½)	38.1 (1.5)	0.611 (35°)
12.7 (½)	25.4 (1.0)	0.785 (45°)

7.11.6 Layer-to-Layer Adhesion. A sample of tape 12.7 mm (½ inch) in width, when conditioned according to the procedures described in Volume III, Appendix B, subparagraph 3-62 a. of IRIG 118-79, shall exhibit no sticking or layer-to-layer adhesion when being unwound from a tape pack. Layer-to-layer adhesion is defined as the tendency for one layer of tape to adhere to an adjacent layer in the same pack. The test procedure outlined in Volume III, Appendix B, paragraph 3-62 of IRIG 118-79 shall be used to determine compliance with this requirement.

7.11.7 Fungus Resistance. The tape shall be sufficiently fungus resistant so that at least two out of three test specimens are rated 0 to 1 as defined in MIL-I-631D. Each reel or hub of tape shall be tested completely wound. The test procedures outlined in MIL-I-631D shall be used to determine compliance with this requirement.

7.11.8 Electrical Resistance. The oxide coating of the tape shall be conductive, allowing minimum static charge build-up. When conditioned according to the procedures outlined in Volume III, Appendix B, subparagraph 3-63 a. of IRIG 118-79, the electrical resistance of the oxide coating shall not exceed 100 megohms per square unit of area. The test procedure outlined in Volume III, Appendix B, paragraph 3-63 of IRIG 118-79 shall be used to determine compliance with this requirement.

7.11.9 Tape Abrasivity. The abrasivity of the oxide side of the magnetic tape determines the rapidity with which head wear takes place on a recorder/reproducer. Although no absolute method of determining tape abrasivity has been developed, a means exists for accurately comparing the relative abrasivity of two test samples. It is therefore recommended that the tape user select a specific centerline tape that has exhibited satisfactory abrasive characteristics in normal operational use and employ this tape as an abrasivity reference in conjunction with the test procedure outlined in Volume III, Appendix B, paragraph 3-64 of IRIG 118-79.

7.12 Magnetic/Electrical Characteristics

7.12.1 Bias Level. The bias level required by the magnetic tape shall not differ from the bias level requirements of the MCT by more than the amount specified by the tape user. The bias level of the tape is defined as the amount of high frequency record head input required to achieve IRIG specified, upper-band-edge, signal suppression. The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 a. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.2 Record Level. The record level required by the magnetic tape shall not differ from the record level requirements of the MCT by more than the amount specified by the tape user. The record level of the tape is defined as the amount of record head input signal at 1/10 upper-band-edge frequency required to achieve the IRIG specified normal record level. The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 b. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.3 Wavelength Response. The output of the magnetic tape, measured at the wavelength values listed in Table 7-4, shall not differ from the output of the MCT 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 254 µm (10 mils) wavelength.

TABLE 7-4
MEASUREMENT WAVELENGTHS

High Resolution Tape		Standard Resolution Tape	
µm	(mils)	µm	(mils)
3810	(150)	7620	(300)
254	(10)	1524	(60)
25.4	(1)	254	(10)
12.7	(0.5)	25.4	(1)
6.35	(0.25)	12.7	(0.5)
3.18	(0.125)	6.35	(0.25)
2.59	(0.10)	5.08	(0.2)
2.03	(0.08)		
1.52	(0.06)		

The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 c. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.4 Output at 254 μm (10 mils) Wavelength. The wavelength output of the magnetic tape shall not differ from the 254 μm (10 mils) wavelength output of the MCT by more than the amount specified by the tape user. The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 c. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.5 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. Short wavelength output uniformity is defined as the ratio of the peak value of the highest amplitude signal recovered in the working tape length to the peak value of the lowest amplitude signal recovered in the working tape length. The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 d. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.6 Short Wavelength Instantaneous Nonuniformity (Dropout). The instantaneous nonuniformity (dropout) output of a recorded signal, which is 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 feet) 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 feet) intervals tested.

NOTE

Due to the natural tendency of the edge track to contain more dropouts than the center tracks, it is recommended that center tracks be used for critical data requirements and that more dropouts be allowed on the edge tracks. Refer to Table 7-5.

7.12.6.1 An alternate method of specifying the allowable dropout count is to specify the maximum number per track for each 30.48 m (100 feet) interval tested. This method may be desired if critical data is recorded in specific areas of the working tape length.

7.12.6.2 A dropout is defined as a 6.0 dB reduction in output signal amplitude for a period of 10 microseconds when recording and reproducing a short wavelength signal. Signal losses of 6.0 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. Center tracks are defined as those which are more than one track distant from either edge of the tape; i.e., tracks 2 through 6 of a 7-track system. Edge tracks are defined as those which are nearest to either edge of the tape; i.e., tracks 1 and 7 of a 7-track system. The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 e. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.7 Durability. The magnetic tape shall resist deterioration in magnetic/electrical performance due to wear of the coating surface. Signal losses caused by surface wear shall not occur in excess of the per-pass limits specified in Table 7-6 for the first 35 passes.

TABLE 7-5

SUGGESTED TAPE REQUIREMENT LIMITS

Para. No.	Tape Requirement	Suggested Limit
7.11.9	Tape Abrasivity	No more than 2 times centerline reference tape
7.12.1	Bias Level	±2.0 dB
7.12.2	Record Level	±2.0 dB
7.12.3	Wavelength Response	See below

Measurement Wavelength µm	(mils)	HR Tape (dB)	SR Tape (dB)
7620	(300)	N/A	±1.5
3810	(150)	±1.0	N/A
1524	(60)	N/A	±1.0
254	(10)	0	0
25.4	(1)	±1.0	±1.0
12.7	(0.5)	±1.0	±1.0
6.35	(0.25)	±1.5	±1.5
5.08	(0.20)	N/A	±2.0
3.18	(0.125)	±2.0	N/A
2.54	(0.10)	±2.5	N/A
2.03	(0.08)	±2.5	N/A
1.52	(0.06)	±3.0	N/A

7.12.4	Output at 254 µm (10 mil) Wavelength	±1.5 dB	
7.12.5	Short Wavelength Output Uniformity	HR Tape 4.5 dB	SR Tape 3.0 dB
7.12.6	Dropouts per 30.48 m (100 ft.)	HR Tape 1 MHz Carrier at 3048 mm/s (120 ips)	SR Tape 400 kHz Carrier at 3048 mm/s (120 ips)

HR Center Track	HR Edge Track	SR Center Track	SR Edge Track
10	40	20	25

7.12.7	Modulation Noise	1 dB maximum

TABLE 7-6

DURABILITY SIGNAL LOSSES

Designated Tape Length m	(ft)	Allowable Signal Losses (per pass) dB
762	(2500)	2
1097	(3600)	2
1402	(4600)	2
1524	(5000)	2
2195	(7200)	3
2804	(9200)	3
3292	(10800)	4

Signal losses in excess of those limits specified above shall not occur during either a record, record/reproduce, or uninterrupted reproduce pass of the working tape length. A signal loss is defined as 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 Volume III, Appendix B, subparagraph 3-65 f. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.8 Modulation Noise. The high frequency amplitude modulation superimposed 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 Volume III, Appendix B, subparagraph 3-65 g. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.9 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 µm (1.0 mil) tape and 46 dB for 38.1 µm (1.5 mils) tape. Layer-to-layer signal transfer is defined as the transfer of recording information from a layer of tape in a wound reel, which has been prerecorded to saturation, to an adjacent unrecorded layer of tape in the same reel. The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 h. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.10 Ease of Erasure. 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 µm (1.0 mil) wavelength signal. The test procedure outlined in Volume III, Appendix B, subparagraph 3-65 i. of IRIG 118-79 shall be used to determine compliance with this requirement.

7.12.11 Suggested Tape Requirement Limits. Table 7-5 lists the suggested tape limits to be used for instrumentation tape.

CHAPTER 8

TRANSDUCER STANDARDS

8.1 General

The vast variety of transducers currently available for use in telemetry systems make it impractical to develop a standard which is universally applicable to all transducers, except in the areas of terminology and definition. Professional societies and similar groups have promulgated a number of standards and recommended practices pertaining to particular classes of transducers. These documents, which are listed in Appendix F, have been reviewed and it is recommended that they be used to the maximum extent possible in order to achieve the goal of uniformity in the field of telemetry.

8.2 Terminology and Definitions

Terminology and definitions pertaining to transducers are contained in:

8.2.1 "A Glossary of Range Terminology," RCC Document 104-64, (Revised 1968) Secretariat, Range Commanders Council.

8.2.2 ISA Standard S37.1 (ANSI MC 6.1-1975), "Electrical Transducer Nomenclature and Terminology," (1969), Instrument Society of America, 530 William Penn Place, Pittsburgh, PA.

APPENDIX A

FREQUENCY MANAGEMENT PLAN FOR UHF TELEMETRY BANDS

1.0 Purpose

This plan was prepared by the Frequency Management Group (FMG) to provide guidelines for the most effective use of allocated UHF telemetry bands 1435-1535 MHz and 2200-2300 MHz.

2.0 Scope

This plan is intended to be utilized as a guide by all managers and users of telemetry frequencies in the above bands at national, service or other DOD test ranges/facilities.

3.0 General

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 225-260 MHz portion of the military communications band, 225-400 MHz. Telemetering for manned and unmanned aircraft was also authorized in this band on a secondary basis. The Military Communications-Electronics Board (MCEB) had directed DOD agencies to remove all telemetering operations from this band by 1 January 1970. However, budgetary limitations and technical constraints have prevented certain operations from being converted to the 1435-1535 MHz and 2200-2300 MHz bands which have been allocated to satisfy displaced and/or future telemetry needs.[1] Current frequency management policy provides that continued use of frequencies

[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.*

for telemetering operations in the 225-260 MHz band beyond 1 January 1975, will not be a bar to satisfying communications needs for which the 225-400 MHz band is primarily allocated.

This plan is based primarily on information obtained as a result of empirical and theoretical analysis, judgements formulated on past experience, and on expectations of future requirements and equipment characteristics. The plan has been devised for application where congestion of the allocated telemetry spectrum is expected to be a problem; i.e., at the national and service ranges and adjacent areas.

4.0 UHF Telemetry Radio Frequency Assignments

4.1 Air/space-ground telemetering must be accommodated in the appropriate allocated UHF bands, 1435-1535 MHz and 2200-2300 MHz, to enhance unrestricted use of the 225-400 MHz military communications band for communications.

4.2 The band 1435-1535 MHz is nationally allocated for government/non-government telemetry use for flight testing of manned and unmanned aircraft, missiles, and space vehicles or major components thereof on a shared basis. The 2200-2300 MHz band is allocated for government fixed and mobile communications and telemetry on a co-equal basis.

4.3 Narrowband telemetry channel spacing will be in increments of 1 MHz beginning with frequencies 1435.5 and 2200.5 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 1435-1535 MHz or 2200-2300 MHz band, without infringing upon 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 necessary bandwidth of 1 MHz or less.

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

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

NOTE

Necessary bandwidth is defined as the minimum value of the occupied bandwidth sufficient to insure the transmission of information at the rate and with the quality required for the system employed, under specified conditions.

5.4 For the purpose of designating channels to satisfy the varying necessary bandwidths, the following normally will prevail. However, it is recognized that for certain requirements, operational flexibility may necessitate the use of channels centered on any narrowband center frequency within the allocated bands. Further, the necessary bandwidth used on any particular channel will be contained within the allocated telemetry band concerned.

5.4.1 1435-1535 MHz Band

5.4.1.1 Narrowband Channel (Center Frequency). 1435.5-1534.5 MHz; in 1 MHz increments, e.g., 1435.5, 1436.5, 1436.5, etc.

5.4.1.2 Mediumband Channel (Center Frequency). 1436.5-1532.5 MHz; in 3 MHz increments, e.g., 1436.5, 1439.5, 1442.5, etc.[2]

5.4.1.3 Wideband Channel (Center Frequency). 1440.5-1520.5 MHz, in 10 MHz increments, e.g., 1440.5, 1450.5, 1460.5, etc.[3]

5.4.2 2200-2300 MHz band

5.4.2.1 Narrowband Channel (Center Frequency). 2200.5-2299.5 MHz; in 1 MHz increments, e.g., 2200.5, 2201.5, 2202.5, etc.

5.4.2.2 Mediumband Channel (Center Frequency). 2201.5-2297.5 MHz; in 3 MHz increments, e.g., 2201.5, 2204.5, 2207.5, etc.[2]

5.4.2.3 Wideband Channel (Center Frequency). 2205.5-2285.5 MHz; in 10 MHz increments, e.g., 2205.5, 2215.5, 2225.5, etc.[3]

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

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

6.0 Telemetry Frequency Assignment Guidance

The following information, which is based on the results of tests, theoretical analyses, and judgements based on past experience, should be used for the guidance of all concerned:

6.1 Geographical Separation. Two or more telemetry transmitters operating simultaneously on the same narrowband channel center frequency must be sufficiently separated geographically; otherwise degradation of data is likely to occur.

6.2 Simultaneous Operations. Two or more narrowband telemetry transmitters operating simultaneously on the same vehicle or in the same geographical area must be separated by a minimum of 1 MHz, to preclude degradation of data.

6.3 Multicarrier Operations. If interference is to be precluded or minimized to the maximum extent possible, frequency selection must be made judiciously. Various systematic methods have been developed for selecting frequencies to accomplish this aim.[4]

7.0 Standards for the Level of Undesired Emissions Outside the Authorized Bandwidth for Telemetering Stations.

NOTE

(Material in paragraph 7.0 was taken from OTP Manual of Regulations and Procedures for Radio Frequency Management - September 1976.)

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[4] *Pacific Missile Test Center Technical Publication PMTC-TP-77-16, Methods for Assgning Frequencies to Avoid Intermodulation Interference, 11 Jul 77.*

7.1 General

These standards are applicable to telemetering stations authorized for operation in the bands 1435-1535 and 2200-2290 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.

7.2 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 in dB, 55 + 10 log P_t

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

7.3.1 On each side of F_o:

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

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.

7.3.2 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, the minimum attenuation for all emissions must be in accordance with the following formula:

X = -60 dB or to -25 dBm, whichever is greater

Y (in dB) = $-(55 + 10 \log P_t)$

NOTE

This limits the maximum power level outside B to -25 dBm.

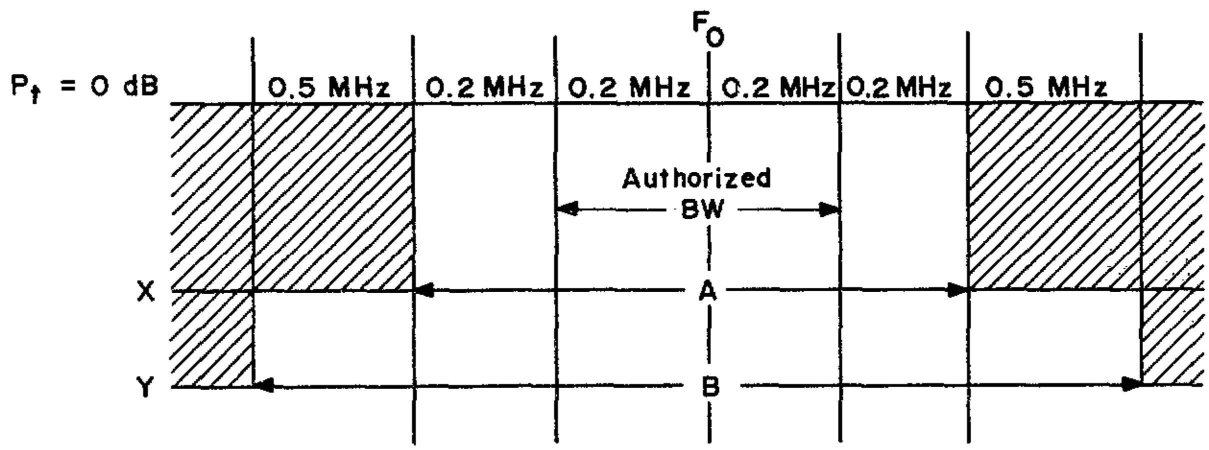
EXAMPLE

Assume an Authorized BW of 0.4 MHz centered on F_o:

A = 2 x Authorized BW
= 2 x 0.4
= 0.8 MHz

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

The illustration below shows the power level limit:



7.4 Standard for Authorized Bandwidth Greater than 1 MHz

7.4.1 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 necssary in any case to attenuate below a level of -25 dBm.

7.4.2 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', the minimum attenuation for all emissions must be in accordance with the following formula:

X = -60 dB or to -25 dBm, whichever is greater

Y (in dB) = $-(55 + 10 \log P_t)$

NOTE

This limits the maximum power level outside B' to -25 dBm.

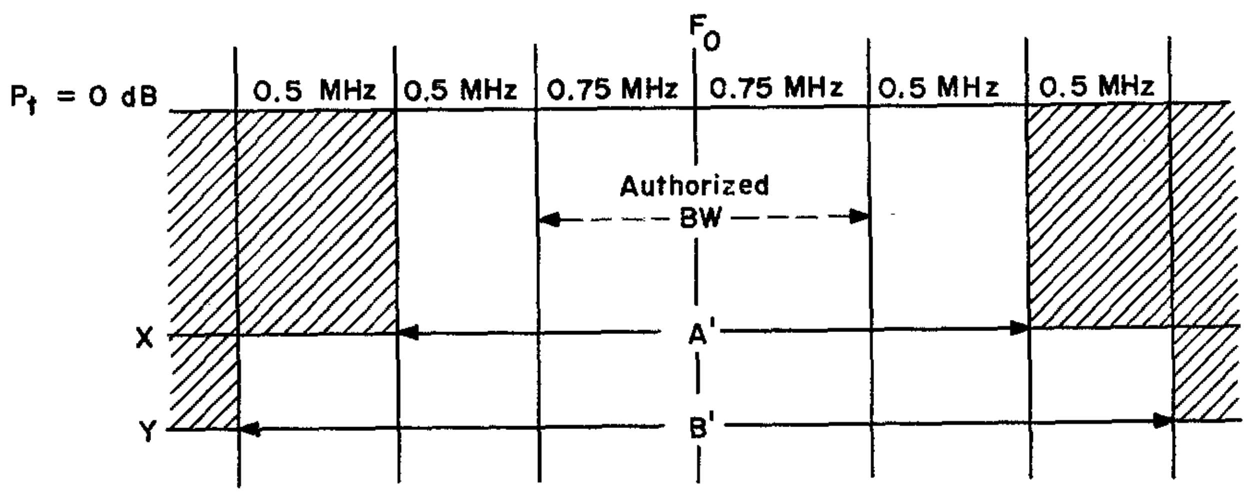
EXAMPLE

Assume an Authorized BW of 1.5 MHz centered on F_o:

A' = Authorized BW + 1.0 MHz
= 1.5 + 1.0
= 2.5 MHz

B' = Authorized BW + 2.0 MHz
= 1.5 + 2.0
= 3.5 MHz

The illustration below shows the power level limit:



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.

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.

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 the 10 to 90 percent rise time for a step function of the channel input signal. However, deviations from these values may be encountered due to 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 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.

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, and DDC Documents AD-621139 and AD-621140, which were completed under a contract administered by the Telemetry Working Group of IRIG. 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 SNR's 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.

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 upon 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.

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.

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

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

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

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)

[1] *K.M. Uglow, "Noise and Bandwidth in FM/FM Radio Telemetry," IRE Transactions on Telemetry and Remote Control, pp. 19-22 (May 1957).*

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

f_s = subcarrier center frequency

f_{dc} = carrier peak deviation due to 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.

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.

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

Intermodulation of the subcarriers in a system is due to 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 pre-emphasis of the upper subcarriers, the lower subcarriers may experience intermodulation interference due to difference frequencies of the high-frequency (and high-amplitude) channels.

The use of magnetic tape recorders for recording a subcarrier multiplex may degrade the data channel accuracy due primarily to tape speed differences or variations between recording 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

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

1.0 Bit Rate Versus Receiver Intermediate-Frequency (IF) Bandwidth (3 dB Points)

1.1 The receiver IF bandwidth should be selected from those values listed in Table 4-1. Only those discrete receiver IF bandwidths listed should be used for data channel selection (optional below 12,500 Hz). The selections in Table 4-1 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 system, a receiver IF SNR (power) of approximately 15 dB will result in a bit error probability (BEP) of about 1 bit in 10^6. 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.

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

2.0 Suggested PCM Synchronization Patterns.

2.1 Table C-1 contains optimum frame synchronization patterns for general use in PCM telemetry.

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			
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	010	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

2.2 The technique used in the determination of these patterns was essentially that of examining all 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]

3.0 Spectral Comparisons for NRZ, BIØ, and DM

Plotted in Figure C-1 are the power spectral densities of NRZ, BIØ, and DM coding. Plotted in Figure C-2 are the theoretical BER vs SNR curves for NRZ, BIØ, and DM coding. The spectral properties of DM coding include[2]:

3.1 The majority of the signaling energy lies in frequencies less than one half the bit rate.

3.2 The spectrum is small at f=0. This spectral minimum eases the problem of bit synchronization.

3.3 A reduced power spectral density in the vicinity of f=0 is important in tape recording because tape response is poor at low frequencies when the Direct Recording Method is used.

3.4 As a result of subparagraphs 3.1 and 3.2 above, higher bit packing density can be used in tape recording.

---

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

[2] *Material presented in paragraph 3.0 is taken from the Naval Missile Center Technical Publication TP-73-18, "Bit Synchronization System Performance Characterization, Modeling and Tradeoff Study," by W. C. Lindsey, University of Southern California.*

3.5 DM is insensitive to 180° phase ambiguity in the bit stream.

3.6 RF transmission of DM formats must consider an approximate 3.5 dB SNR penality[1].

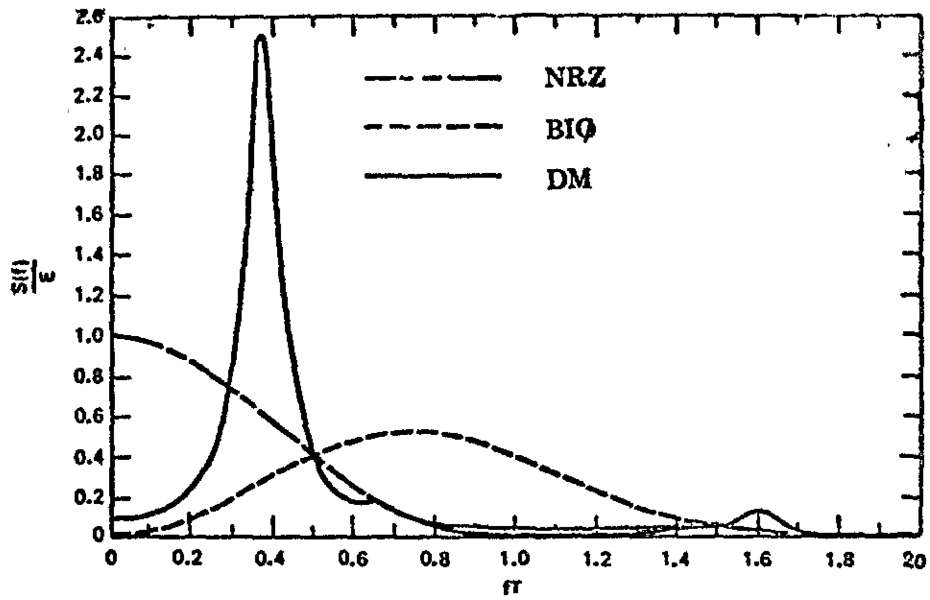


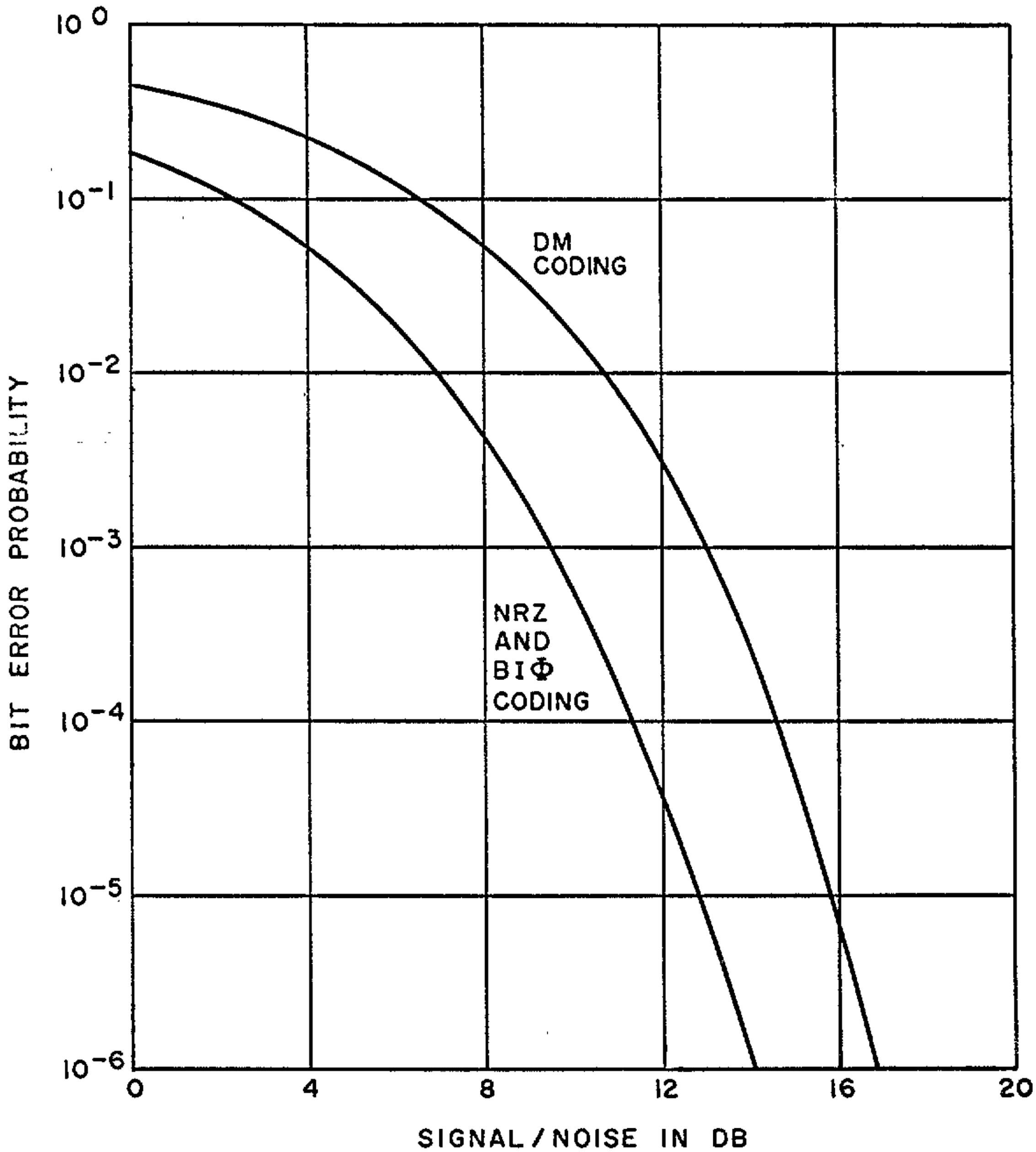
Figure C-1. Spectral Density of Random NRZ, BIØ and DM Coding.

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

f is frequency.

T is bit period.

[1] *See footnote page C-3.*



(Peak Signal to RMS Noise Measured in a Bandwidth Equal to One-Half the Bit Rate.)

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

APPENDIX D

PAM STANDARDS
ADDITIONAL INFORMATION AND RECOMMENDATIONS

1.0 IF Bandwidth and Transmitter Deviation

The appropriate receiver final IF bandwidth and transmitter deviation depends primarily on the total pulse rate, system noise, and distortion tolerance.

2.0 Premodulation Filtering

The premodulation filter recommended in Chapter 5, paragraph 5.6 exhibits a final attenuation slope of 36 dB per octave and shall have a maximally linear phase response.

APPENDIX E

MAGNETIC TAPE RECORDER/REPRODUCER INFORMATION AND USE CRITERIA

1.0 Configurations Not Included in IRIG Standards

Special applications of recorder/reproducer equipment have resulted in many configurations not included in IRIG standards. Among those which may improve recording and tape-use efficiency are double-density wideband systems and high-density track configurations.

1.1 Double Longitudinal Density Recording

Systems using special heads, modified electronics and special high-output magnetic tape have been produced. These systems allow direct recording to 2.0 MHz at 1524 mm/s (60 ips) without serious degradation of output signal-to-noise ratio (SNR). These systems have not been included in IRIG standards because of special tape requirements, the need for equipment modification to provide increased bias power for the high-output tapes, the need for critical azimuth adjustment during reproduce, and susceptibility to tape dropouts.

1.2 Higher Track Density Configurations

American National Standards Institute (ANSI) and International Standards Organization (ISO) standards include tape track configurations resulting in 14 and 21 tracks on 12.7-mm (1/2-in) magnetic tape and 42 tracks on 25.4-mm (1-in) magnetic tape. The ISO track configurations are shown in Tables E-1 through E-3. The track dimensions contain

TABLE E-1

DIMENSIONS - RECORDED TAPE FORMAT

14 Tracks on 12.7-mm (1/2-in) Wide Tape
(Refer to Figure 6-1)

	mm*	(in)	
Track Width (W)	0.64±0.03	(0.025±0.001)	
Track Spacing (D)	0.89	(0.035)	
Data Spacing (S)	38.10±0.03	(1.500±0.001)	Fixed
	38.10±0.05	(1.500±0.002)	Adjustable
Edge Margin, Minimum (M_m)	0.13	(0.005)	
Track Location (Reference Edge to Track 1 Centerline) (G)	0.50±0.04	(0.020±0.0015)	
Track Spacing Tolerance (ΔH_n)	±0.04	(±0.0015)	
Track Number (H_n)			
1	0.00	(0.000)	
2	0.89	(0.035)	
3	1.78	(0.070)	
4	2.67	(0.105)	
5	3.56	(0.140)	
6	4.45	(0.175)	
7	5.34	(0.210)	
8	6.23	(0.245)	
9	7.12	(0.280)	
10	8.01	(0.315)	
11	8.90	(0.350)	
12	9.79	(0.385)	
13	10.68	(0.420)	
14	11.57	(0.455)	

**Although the metric equivalents in this table may not be exact, they conform to those currently accepted by industry.*

TABLE E-2

DIMENSIONS - RECORDED TAPE FORMAT

21 Tracks on 12.7-mm (1/2-in) Wide Tape
(Refer to Figure 6-1)

	mm*	(in)
Track Width (W)	0.46±0.03	(0.018±0.001)
Track Spacing (D)	0.584	(0.023)
Data Spacing (S)	38.10±0.03 38.10±0.05	(1.500±0.001) Fixed (1.500±0.002) Adjustable
Edge Margin, Minimum (M_m)	0.17	(0.007)
Track Location (Reference Edge to Track 1 Centerline) (G)	0.44±0.04	(0.07±0.0015)
Track Spacing Tolerance (ΔH_n)	±0.03	(±0.001)
Track Number (H_n)		
1	0.000	(0.000)
2	0.584	(0.023)
3	1.168	(0.046)
4	1.753	(0.069)
5	2.337	(0.092)
6	2.921	(0.115)
7	3.505	(0.138)
8	4.089	(0.161)
9	4.674	(0.184)
10	5.258	(0.207)
11	5.842	(0.230)
12	6.426	(0.253)
13	7.010	(0.276)
14	7.595	(0.299)
15	8.179	(0.322)
16	8.763	(0.346)
17	9.347	(0.368)
18	9.931	(0.391)
19	10.516	(0.414)
20	11.100	(0.437)
21	11.684	(0.460)

**Although the metric equivalents in this table may not be exact, they conform to those currently accepted by industry.*

TABLE E-3

DIMENSIONS - RECORDED TAPE FORMAT

42 Tracks on 25.4-mm (1-in) Wide Tape
(Refer to Figure 6-1)

	mm*	(in)
Track Width (W)	0.46±0.03	(0.018±0.001)
Track Spacing (D)	0.584	(0.023)
Data Spacing (S)	38.10±0.03 38.10±0.05	(1.500±0.001) Fixed (1.500±0.002) Adjustable
Edge Margin, Minimum (M_m)	0.32	(0.012)
Track Location (Reference Edge to Track 1 Centerline) (G)	0.70±0.04	(0.0275±0.0015)
Track Spacing Tolerance (ΔH_n)	±0.03	(±0.001)

Track Number (H_n)

Track Number	mm*	(in)	Track Number	mm*	(in)
1	0.000	(0.000)	22	12.268	(0.483)
2	0.584	(0.023)	23	12.852	(0.506)
3	1.168	(0.046)	24	13.437	(0.529)
4	1.753	(0.069)	25	14.021	(0.552)
5	2.337	(0.092)	26	14.605	(0.575)
6	2.921	(0.115)	27	15.189	(0.598)
7	3.505	(0.138)	28	15.773	(0.621)
8	4.089	(0.161)	29	16.358	(0.644)
9	4.674	(0.184)	30	16.942	(0.667)
10	5.258	(0.207)	31	17.526	(0.690)
11	5.842	(0.230)	32	18.110	(0.713)
12	6.426	(0.253)	33	18.694	(0.736)
13	7.010	(0.276)	34	19.279	(0.759)
14	7.595	(0.299)	35	19.863	(0.782)
15	8.179	(0.322)	36	20.447	(0.805)
16	8.763	(0.345)	37	21.031	(0.828)
17	9.347	(0.368)	38	21.615	(0.851)
18	9.931	(0.391)	39	22.200	(0.871)
19	10.516	(0.414)	40	22.784	(0.897)
20	11.100	(0.437)	41	23.368	(0.920)
21	11.684	(0.460)	42	23.952	(0.943)

**Although the metric equivalents in this table may not be exact, they conform to those currently accepted by industry.*

conversions between inches and millimeters in which the metric equivalents have been slightly adjusted to rounded metric numbers while retaining sufficient accuracy for most interchange purposes (the original dimensions are inches).

1.3 High Density PCM Recording

Several manufacturers are offering systems for recording PCM signals at bit packing densities of 33,000 bits per inch per track and above, which may also utilize nonbias recording techniques (see paragraph 2.0 below). Each system employs special coding and/or electronics to minimize the effect of low frequency components obtained during reproduce due to long strings of "ones" or "zeros". The ANSI X3B6 Committee is developing standards for parallel (multitrack) high density digital recording (HDDR) systems as well as serial HDDR standards. In addition to Biϕ and RNRZ, several other codes will be included.

2.0 Serial HDDR

a. Serial HDDR is a method of recording digital data on a magnetic tape whereby 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 Biϕ-L and randomized NRZ-L (RNRZ-L) (refer to paragraph 6.5 of Chapter 6).

b. In preparing paragraph 6.5 of Chapter 6, the following codes, which are not recommended for interchange applications at the bit rates given in paragraph 6.5, were considered: Delay Modulation (Miller Code), Miller Squared, Enhanced NRZ, NRZ Level, NRZ Mark, and NRZ Space.

c. If user bit rate requirements increase beyond those now accommodated, codes other than Biϕ 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 advanced techniques, which might become applicable, would also have to be reviewed.

d. The properties of the Biϕ-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.

e. The Biϕ-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.

f. Some characteristics of the Biϕ-L code favorable to serial HDDR are:

(1) Only a small proportion of the total signal energy occurs near d.c.

(2) The maximum time between transitions is one bit period.

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

(4) Biϕ-L can be decoded using existing bit synchronizers.

(5) Biϕ-L is less sensitive to misadjustments of bias and reproducer equalizers than most other codes.

(6) Biϕ-L performs well at low tape speeds and low bit rates.

g. The most unfavorable characteristic of the Biϕ-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.

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

(1) RNRZ-L requires approximately one-half the bandwidth of Biϕ-L.

(2) The symbols for a "one" and a "zero" are antipodal. Therefore, the bit error probability versus SNR performance is optimum.

(3) The RNRZ-L decoder is self-synchronizing.

(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.

(5) The RNRZ-L code is easily generated and decoded.

(6) RNRZ-L data can be easily decoded in the reverse mode of tape playback.

(7) RNRZ-L data is 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.

(8) The RNRZ-L code does not require overhead bits.

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

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

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

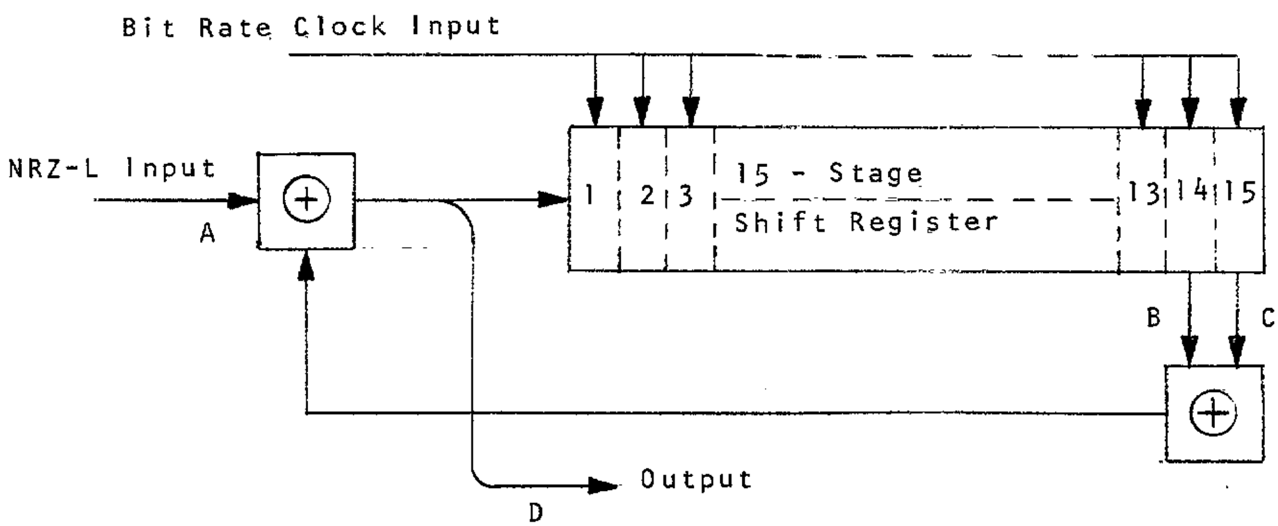
(3) The decoder requires 15 consecutive error-free bits to establish/reestablish error-free operation.

(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 specially designed d.c. and low frequency restoration circuitry is available.

j. Randomizer for RNRZ-L

(1) 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 bit stream is also the input to the shift register (refer to Figure E-1).

(2) 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



Boolean Expression:

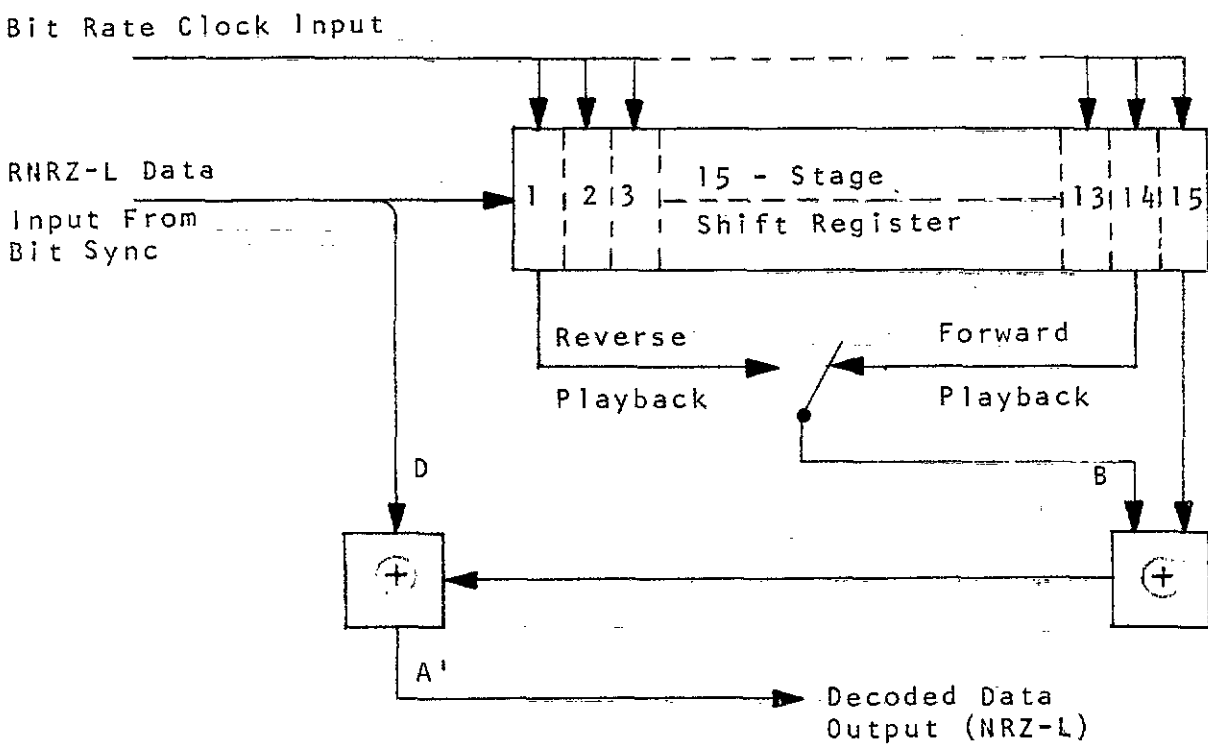
$$D = A \oplus B \oplus C$$

Figure E-1. Randomizer Block Diagram.

a change in the input data 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 $(2^{-15} \cdot p(X))$ of having a run length of (X+15) bits. Therefore, the output can contain long runs of bits without a transition, but the probability of occurrence is low.

(3) 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 E-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 E-2). The net effect is that the decoding shift register runs "backwards" with respect to the randomizing shift register.

(4) 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, though 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.



Boolean Expression:

With input data A into randomizer,

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

(see Fig. E-1)

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

$= A \oplus B \oplus B \oplus C \oplus C$ But $B \oplus B = 0$

$C \oplus C = 0$

Therefore:

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

Figure E-2. Randomized NRZ-L Decoder Block Diagram.

(5) 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 at 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.

(6) Input data containing frequent long runs of bits without transitions create potential d.c. and low frequency restoration problems in PCM bit synchronizers due to the low frequency cutoff of direct recorder/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 μs. Additional methods of minimizing these effects include selecting bit synchronizers which contain special d.c. and low frequency restoration circuitry or recording data using the Biϕ-L code.

(7) The power spectra of the RNRZ-L and Biϕ-L codes are shown in Figure E-3. The power spectral density of RNRZ-L is concentrated at frequencies which are less than one-half the bit rate. The power spectral density of Biϕ-L

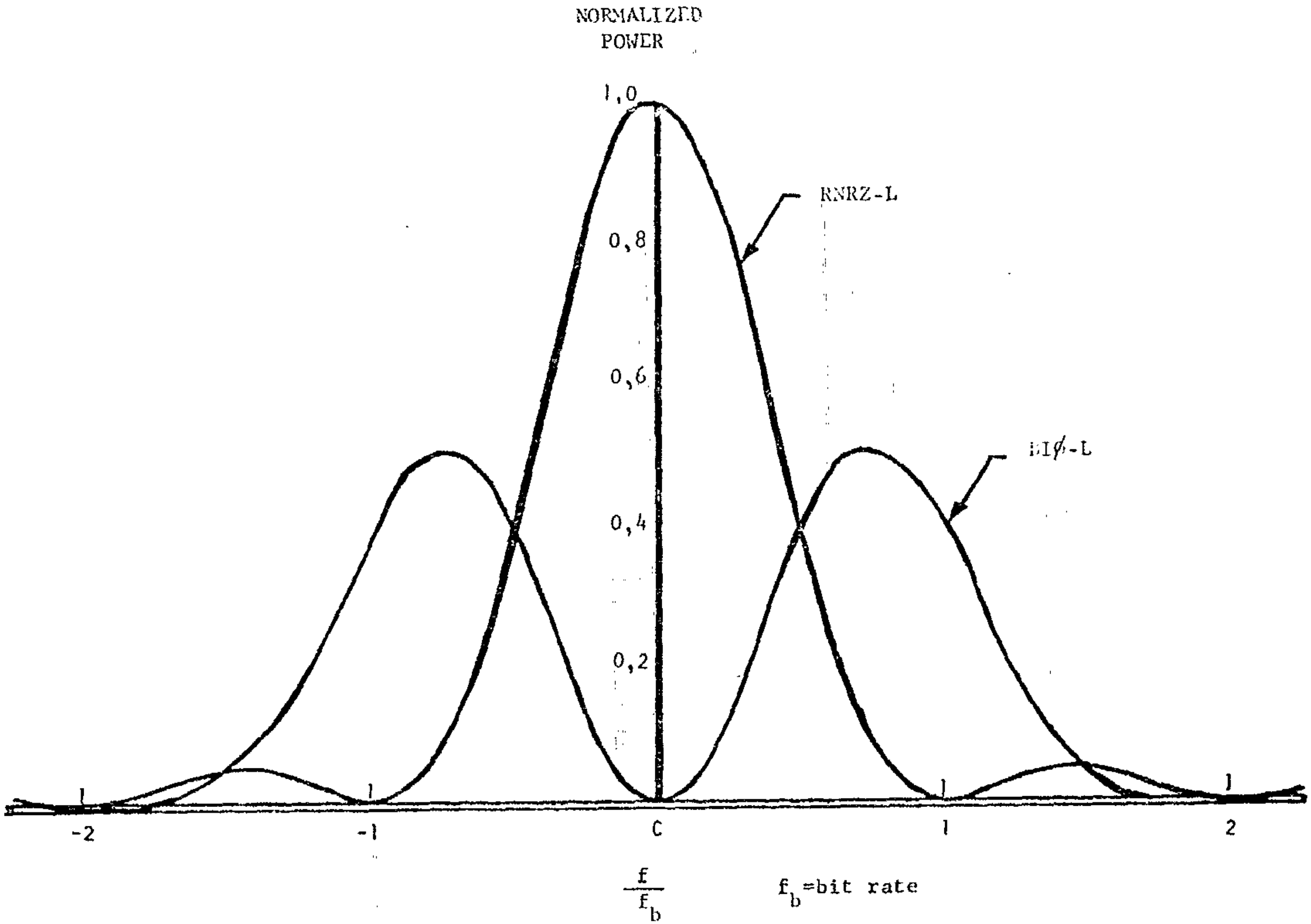
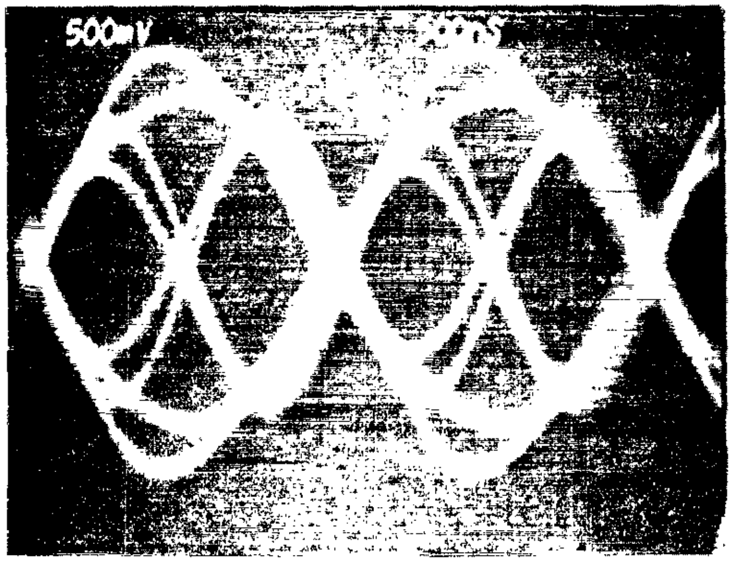


Figure E-3. Random PCM Power Spectra.

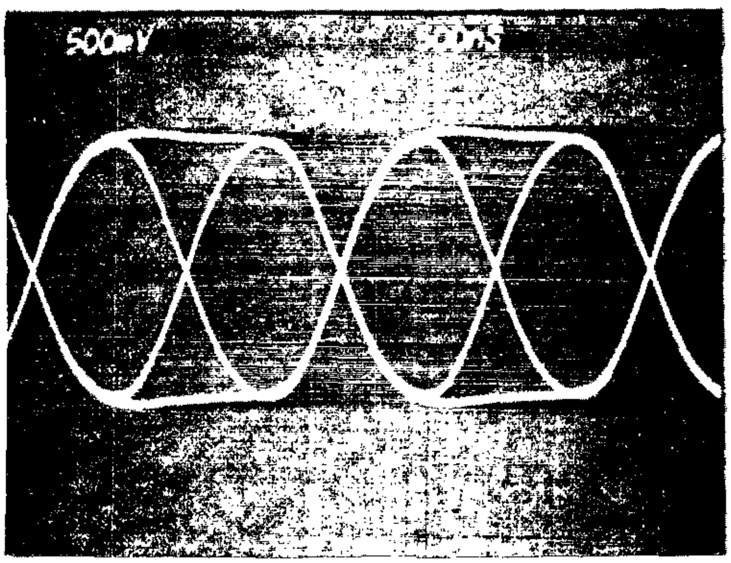
is concentrated at frequencies in a region around 0.75 times the bit rate. The concentration of energy in the low frequency region (when using the RNRZ-L code) has the effect of reducing the SNR as well as creating baseline wander which the bit synchronizer must follow. Therefore, reproducing data at 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 d.c. and low frequency restoration circuitry is available.

(8) Alignment of the reproducer system is very important to reproducing high quality PCM data; i.e., data with the lowest possible bit error probability. A PCM signature utilizing the standard 2047-bit pseudo-random pattern, recorded on the leader and/or trailer of the 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 superpositioning 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.

(9) Sample eye patterns are shown in Figures E-4 and E-5. Figure E-4A shows a typical Biϕ-L eye pattern at a recorded bit packing density of 15 kb/in (450 kb/s at 30 ips). Figure E-4B shows the Biϕ-L eye pattern at the output

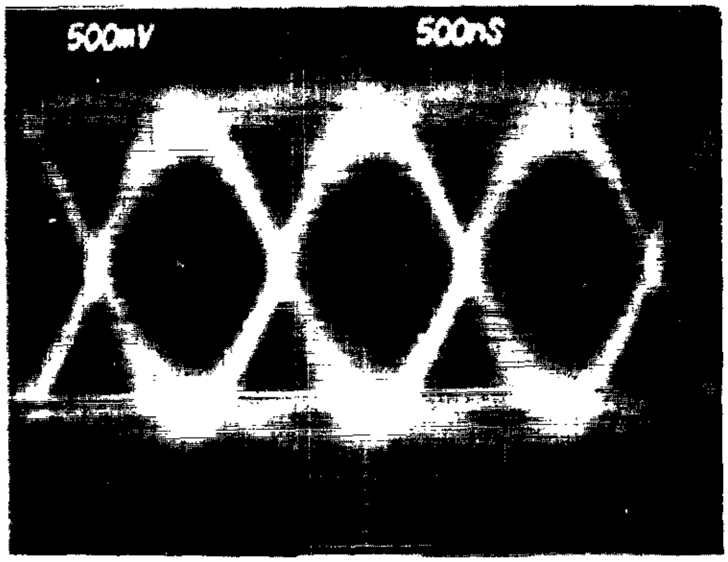


A. Typical recorder/reproducer output,
30 ips, 15 kb/in.

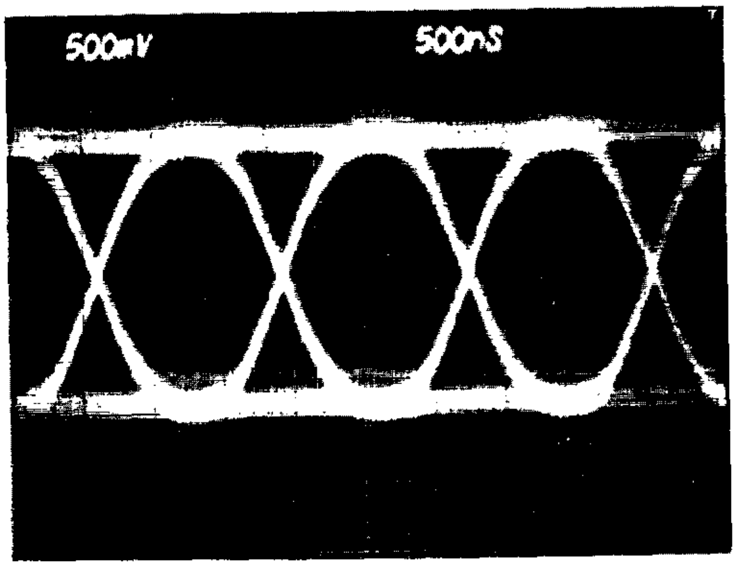


B. Linear phase bandpass filter output,
400 Hz to 500 kHz filter.

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



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



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

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

of a linear phase 400-Hz to 500-kHz bandpass filter with a bit rate of 450 kb/s. Figure E-5A shows a typical RNRZ-L eye pattern at a recorded bit packing density of 25 kb/in (750 kb/s at 30 ips). Figure E-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 E-5 were caused by baseline wander in the RNRZ-L bit stream.

3.0 Head Parameters

3.1 Gap Scatter (Refer to the definition in subparagraph 6.3.2 of 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-μm (0.0002-in) gap scatter is allowed for such recorder/reproducers. A 2.54-μm (0.0001-in) gap scatter is recommended for fixed-head systems (see upper illustration in Figure 6-2).

3.2 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 produce a positive pulse at the reproduce amplifier output still leaves two interdependent parameters unspecified. These are: (1) polarity inversion or noninversion in record and/or 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.

4.0 Record Level

a. The Standard Record Level (synonomous with the term "Normal Record Level" used in RCC 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 3rd harmonic distortion at the output of a properly terminated reproduce amplifier (see subparagraph 4.1.3.3 of Volume III, RCC Document 118-79). A 1.0 percent harmonic distortion content is achieved when the level of the 3rd harmonic component of the Record Level Set Frequency is 40 ±1 dB below the level of a sinusoidal signal of 0.3 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 be within ±1.0 dB of the output at 0.1 UBE. Then a 1 V rms 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 3rd harmonic distortion at a level of 1.0 V rms.

b. 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, RCC 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.

5.0 Tape Crossplay Considerations (Wideband)

a. Crossplay of tapes from intermediate-band machines on wideband machines will exhibit bias signal output due to the higher resolution of the wideband reproduce heads and the relatively low bias frequencies employed. Care should also be taken to assure that intermediate-band tapes will not damage wideband reproduce heads.

b. Figure E-6 illustrates the typical departure from optimum frequency response that may result when crossplaying 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-μm (120-μin) record-head gap length and a 1.02-μm (40-μin) reproduce-head gap length. Lines BB and CC represent the output response curves of the same tapes recorded on machines with 5.08-μm (200-μin) and 1.27-μm (50-μin) record-head gap lengths, respectively. Each of these recorders was set up individually per IRIG requirements. The tapes were then reproduced on the machine having a 1.02-μm (40-μin) reproduce-head gap length without readjusting its reproduce equalization.

c. The output curves have been normalized to 0 dB at the one-tenth 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 gap-length heads will provide the greatest relative output at the UBE.

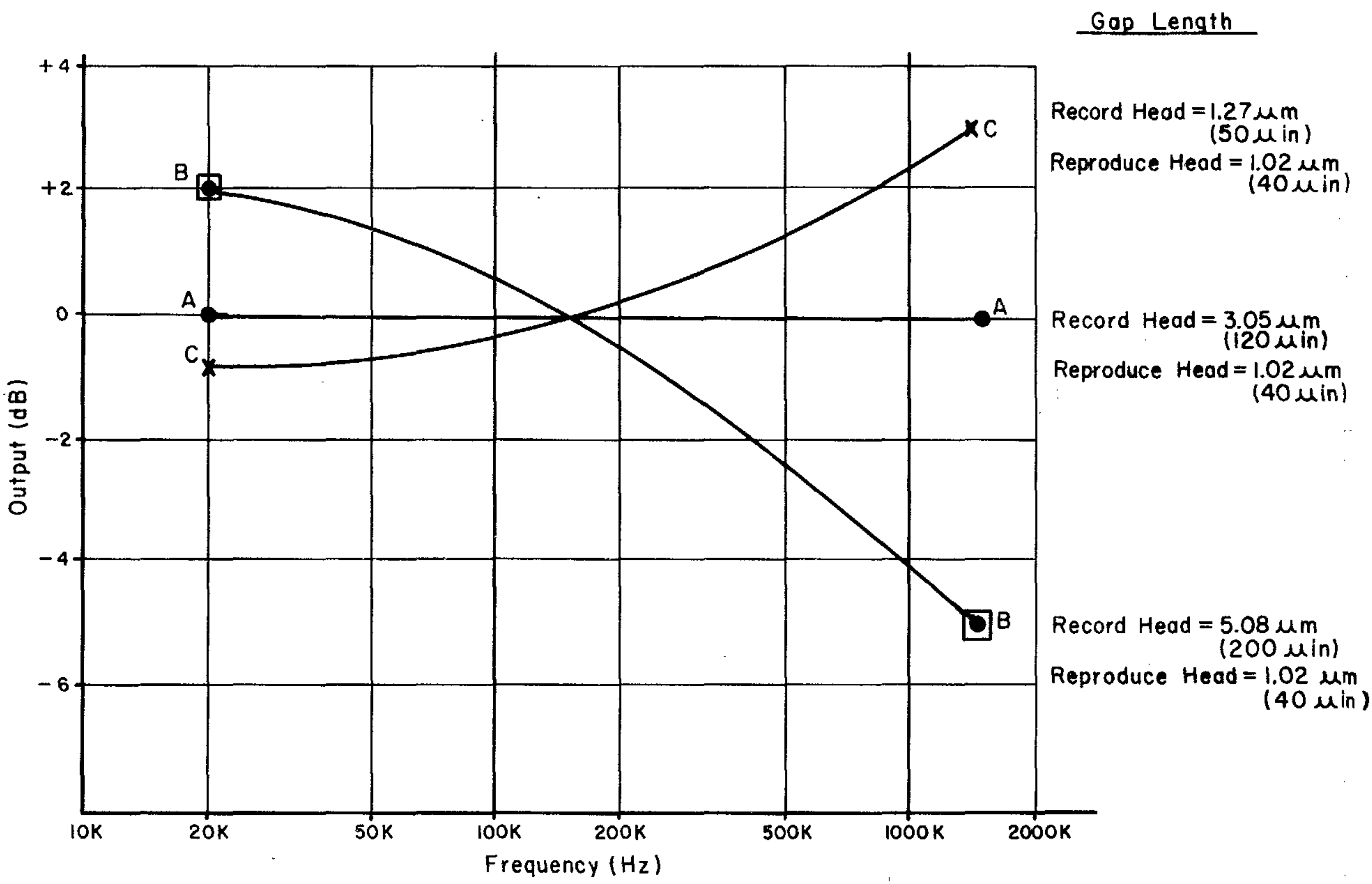


Figure E-6. Tape Crossplay.

d. While the examples shown are from older equipment with record gap lengths outside the limits recommended in subparagraph 6.3.2.8.1 in Chapter 6, they illustrate the importance of the record gap length in tape interchange applications.

6.0 Standard Tape Signature Procedures

6.1 PCM Signature

6.1.1 PCM Signature Recording Procedure

a. Configure test equipment as described in subparagraph 2.1, Volume IV, RCC Document 118-79. The configuration should simulate the operational link as closely as possible; i.e., same RF frequency, deviation, bit rate, code type, predetection frequency, receiver bandwidth, and recorder speed.

b. 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.

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

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

6.1.2 PCM Signature Playback Procedure

a. Optimize playback equipment (receiver tuning, bit synchronizer setup, etc.) for data being reproduced.

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

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

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

e. Repeat for each data track.

6.2 Swept-Frequency Signature

6.2.1 Swept-Frequency Signature Recording Procedure

a. 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 RCC Document 118-79. As a minimum, patch the sweep oscillator to one odd and one even track.

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

c. Record the signature signals for a minimum of 30 seconds at Standard Record Level.

NOTE

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

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

6.2.2 Swept-Frequency Signature Playback Procedure

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

b. 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).

c. 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.

d. Repeat the playback procedure in steps b. and c. above for azimuth and equalization adjustments of an even-numbered tape track.

e. Repeat the procedure in step c. for equalization only of other selected prime data tracks, as required.

6.2.3 Equipment Required for Swept-Frequency Procedures

6.2.3.1 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 as the bandwidth of the recorder/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 assure 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.

6.2.3.2 A stepped-frequency oscillator could be substituted for the sweep-frequency generator at the recording location. Recommended oscillator wavelengths at the mission tape speed would be: 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).

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

6.3 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 6.3.6.5 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, and so on. The following signature procedure satisfies all the above requirements.

6.3.1 Signature Recording Procedure

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

(1) Equal to the Standard Record Level, Chapter 6, subparagraph 6.3.6.5, for direct recording of subcarrier multiplexes and HDDR.

(2) Equal to the carrier amplitude to be recorded for pre-detection recording of PCM/FM, PCM/PM, FM/FM, PAM/FM, etc.

b. Record flat band-limited white noise of amplitude seven-tenths of the true rms value of the 0-dB Standard Record Level as described in Chapter 6, subparagraph 6.3.6.5. Noise must be limited by a lowpass filter just above the UBE.

c. Record with zero input (input terminated in 75 ohms). It is suggested that the three record steps above can consist of ten 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.

6.3.2 Signature Playback and Analysis

a. 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.

(1) Using a spectrum analyzer, reproduce, store and photograph the spectra obtained from steps a., b. and c. in subparagraph 6.3.1 above.

(2) Store and photograph the spectrum obtained with a spectrum analyzer input level of zero.

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

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

(1) Use an auxiliary tape (not the mission tape, but preferably the same type tape). With a white-noise input signal band limited (see subparagraph 6.3.1 above), adjust amplitude equalization of the recorder/reproducer at the tape dubbing or data reduction site, and photograph the output spectrum.

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

(3) Using the auxiliary tape, adjust the amplitude equalization to compensate for the differences noted.

(4) Recheck with the mission tape to verify that the desired amplitude equalization has been achieved.

d. If it is desired that the phase equalization 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, RCC Document 118-79). The same procedure as that recommended for amplitude equalization can be used, except based on oscillograms.

APPENDIX F

AVAILABLE TRANSDUCER DOCUMENTATION

1.0 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. Documents published to date pertaining to transducers with electrical output are as follows:

1.1 Accelerometers/Vibration

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

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

1.1.3 ISA - RP 37-2 - 1964, "Guide for Specifications and Tests for Piezoelectric Acceleration Transducers for Aero-Space Testing."

1.1.4 ISA - S37.5 - 1971 (ANSI MC 6.3 - 1975), "Specifications and Tests for Strain Gage Linear Acceleration Transducers."

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

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

1.2 Fluid Velocity

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

1.3 Microphones

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

1.3.2 ANSI S1.4 - 1971, "American National Standard Specification for Sound Level Meters."

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

1.3.4 USAS S1.4 - 1961, "USA Standard Specification for General Purpose Sound Level Meters."

1.3.5 USAS S1.2 - 1962, "USA Standard Method for the Physical Measurement of Sound."

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

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

1.4 Pressure Transducers

1.4.1 ANSI B88.1 - 1972, "A Guide for the Dynamic Calibration of Pressure Transducers."

1.4.2 ISA - S37.10 - 1969 (ANSI MC 6.4 - 1975), "Specifications and Tests for Piezoelectric Pressure and Sound-Pressure Transducers."

1.4.3 ISA - S37.3 - 1970 (ANSI MC 6.2 - 1975), "Specifications and Tests for Strain Gage Pressure Transducers."

1.4.4 ISA S37.6 - 1975 (ANSI MC 6.5 - 1976), "Specifications and Tests of Potentiometric Pressure Transducers."

1.4.5 ASME PTC 19.2 - 1964, "Pressure Measurement."

1.5 Rate Gyros

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

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

1.6 Thermocouples

1.6.1 ASTM E 344 - 68, "Standard Definitions of Terms Relating to Temperature Measurement."

1.6.2 ASTM E 220 - 72, "Standard Method for Calibration of Thermocouples by Comparison Techniques."

1.6.3 ASTM E 230 - 72, "Standard Temperature - Electromotive Force (EMF) Tables for Thermocouples."

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

1.7 Miscellaneous

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

1.7.2 ISA - S37.8 - 1975, "Specifications and Tests for Strain Gage Force Transducers."

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