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TELEMETRY STANDARDS

Inter-Range Instrumentation Group
Of The
RANGE COMMANDERS' CONFERENCE

Air Force Flight Test Center
Air Proving Ground Center
Atlantic Missile Range
Naval Ordnance Test Station
Pacific Missile Range
White Sands Missile Range

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IRIG TELEMETRY STANDARDS

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of the
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NOTICE

This printing is released in response to a large number of requests for this document in spite of the knowledge that the Telemetry Working Group, IRIG, has under preparation a revision which will update several important sections. However, the forthcoming revision is not the result of any basic change in the standardization philosophy of the Working Group. Hence, the present document may be used in the interim without serious handicap.

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FOREWORD

A standard in the field of telemetry for guided missiles was established in 1948 by the Committee on Guided Missiles of the Research and Development Board (RDB), Department of Defense, and was thereafter revised and extended as necessary as a result of periodic reviews of the standard by the Committee's Working Group on Telemetering of the Panel on Test Range Instrumentation. The last official RDB revision of the standards was published as RDB report MTRI 204/6 dated 8 November 1951. Since the termination of the Research and Development Board, new standards have been prepared by the Inter-Range Instrumentation Group (IRIG). The Steering Committee representing IRIG and the Department of Defense test ranges, has assigned the task of promulgating new or revised telemetry standards to the Telemetry Working Group (TWG). This publication comprises the current Combined Standards and supersedes the following IRIG Standards.

IRIG Recommendation No. 101-55	Testing for Speed Errors in Instrumentation Type Magnetic Tape Recorders
IRIG Recommendation No. 101-57	Magnetic Recorder/Reproducer Standards
IRIG Recommendation No. 101-60	Magnetic Recorder/Reproducer Standards
IRIG Recommendation No. 102-55	Telemetry Standards for Guided Missiles
IRIG Recommendation No. 102-59	Standards for Pulse Code Modulation (PCM) Telemetry
IRIG Recommendation No. 103-56	Revised Telemetry Standards for Guided Missiles

Also included are a glossary of terms used in these standards and the Frequency Coordination Working Group (FCWG) "Telemetry Frequency Utilization Parameters and Criteria", IRIG Document # 101-59 revised.

The Standards have been generated to further compatibility of airborne transmitting equipments and ground receiving and data handling equipments at the test ranges. To this end, it is the recommendation of the Inter-Range Instrumentation Group Steering Committee that Telemetry equipment at the test ranges conform to these standards.

The quality of terminal equipment, generally, will be raised by concentration of development on a minimum number of system types. However, it is intended that research should be continued in telemetry systems that may offer substantial improvements over those described in these standards.

Agencies proposing to use equipment deviating from these standards shall be required to show that the use of such equipment is both technically required and economically feasible.

To insure current standards, they will be reviewed at every Telemetry Working Group (TWG) meeting and will be revised if necessary, annually from date of issue.

PART-1 RADIO FREQUENCIES

1.1 Detailed information on frequency usage is found in IRIG Recommendation No. 101-59 Revised, "Telemetry Frequency Utilization Parameters and Criteria", which is included in these standards as Appendix 1, page 56.

PART-2 FM/FM or FM/PM STANDARDS

2.1 General

These telemetry systems are of the frequency division multiplex type. That is, a radio frequency carrier is modulated by a group of subcarriers, each of a different frequency. The subcarriers are frequency modulated in a manner determined by the intelligence to be transmitted. One or more of the subcarriers may be modulated by a time division multiplex scheme (commutation) in order to increase considerably the number of individual data channels available in the system. The modulation of the radio frequency carrier may be by either of two methods: frequency modulation or phase modulation.

2.2 Sub-Carrier Bands

Eighteen standard sub-carrier band center frequencies with accompanying information on frequency deviation and nominal intelligence frequency response are specified in Table I. It is intended that the standard FM/FM receiving stations at the test ranges be capable of simultaneously demodulating a minimum of any twelve of these sub-carrier signals.

The nominal frequency response listed for each band is computed on a basis of maximum deviation and a deviation ratio of five, and it is intended that the standard receiving station be capable of demodulating data with these frequency responses. However, it should be remembered that the actual frequency response obtainable is dependent on many things, such as the actual deviation used, the characteristics of filters, etc. The primary reason for specifying a frequency response is to insure that elements in the receiving station such as filters and recording oscillographs provide the frequency responses shown in Table I.

2.2.1 While deviation ratios of 5 are recommended, deviation ratios as low as one or less may be used, but low signal-to-noise ratios, possible increased harmonic distortion and cross-talk must be expected.

2.2.2 The eighteen bands were chosen to make the best use of present equipment and the frequency spectrum. There is a ratio of approximately 1.3 : 1 between center frequencies of adjacent bands except between 14.5 kilocycles and 22 kilocycles, where a larger gap was left to provide for compensation tone for magnetic tape recording.

The deviation has been kept at ± 7.5 percent for all bands with the option of ± 15 percent deviation on the five higher bands to provide for transmission of higher frequency data. When this option is exercised on any of these five bands, certain adjacent bands cannot be used, as listed in the footnote to Table I.

2.2.3 It is likely that certain applications will make amplitude pre-emphasis of some subcarrier signals desirable, and it is recommended that the ground equipment be capable of accomodating this pre-emphasized signal. A de-emphasis capability of up to 9 db per octave may be required.

TABLE I SUBCARRIER BANDS

Band	Center Frequency (cps)	Lower Limit (cps)	Upper Limit (cps)	Maximum Deviation (percent)	Frequency* Response (cps)
1	400	370	430	± 7.5	6.0
2	560	518	602	"	8.4
3	730	675	785	"	11.
4	960	888	1,032	"	14.
5	1,300	1,202	1,398	"	20.
6	1,700	1,572	1,828	"	25.
7	2,300	2,127	2,473	"	35.
8	3,000	2,775	3,225	"	45
9	3,900	3,607	4,193	"	59.
10	5,400	4,995	5,805	"	81.
11	7,350	6,799	7,901	"	110.
12	10,500	9,712	11,288	"	160.
13	14,500	13,412	15,588	"	220
14	22,000	20,350	23,650	"	330
15	30,000	27,750	32,250	"	450
16	40,000	37,000	43,000	"	600
17	52,500	48,562	56,438	"	790
18	70,000	64,750	75,250	"	1,050
A.**	22,000	18,700	25,300	± 15.	660.
B.	30,000	25,500	34,500	"	900.
C.	40,000	34,000	46,000	"	1,200.
D.	52,500	44,625	60,375	"	1,600
E.	70,000	59,500	80,500	"	2,100

*Frequency response given is based on maximum deviation and deviation ratio of five (See text for discussion).

** Bands A through E are optional and may be used by omitting adjacent bands as follows:

Band Used	Omit Bands
A	13, 15 and B
B	14, 16, A and C
C	15, 17, B and D
D	16, 18, C and E
E	17 and D

NOTE:

In the process of magnetic tape recording of the above listed sub-carriers at a receiving station, provision may also be made to record a tape speed control tone and tape speed error compensation signals as specified in part (6) of these standards.

2.3 Automatic Correction of Subcarrier Zero and Sensitivity Drift

2 3.1 General

In some cases it is found necessary to automatically correct for subcarrier zero and sensitivity drift during the course of a test. To provide for such corrections calibration signals are applied to the subcarrier oscillators which must have such correction by an in-flight calibrator. In addition, a signal is required to arm and actuate the automatic correction equipment in the receiving or data playback station. Automatic correction command and calibration signals, when employed. shall conform to the following standards:

2.3.2 Automatic Correction Command

A standard IRIG subcarrier band multiplexed with the data subcarriers shall be employed to transmit the correction commands. Modulation of the command subcarrier shall be as follows:

2.3.2.1 Command Sequence

The command sequence shall be: "data," "correct for zero drift," "correct for sensitivity drift," "data."

2.3.2.2 Command Subcarrier Modulation

2.3.2.2.1 The "data" command is indicated by the command subcarrier operating at its nominal center frequency $\pm 0.75\%$ of f_c.

2.3.2.2.2 The "correct for zero drift" command is indicated by a displacement of the command subcarrier upward in frequency to f_c plus $(6.75\% \; f_c \pm 0.75\% \; f_c)$. This command shall occupy 50 percent of the total calibration time interval.

2.3.2.2.3 The "correct for sensitivity drift" command is indicated by a displacement of the command subcarrier downward in frequency to f_c minus $(6.75\% \; f_c \pm 0.75\% \; f_c)$. This command shall occupy 50 percent of the total calibration time interval.

2.3.3 Data Subcarrier Calibration

2.3.3.1 Calibration Sequence

The calibration sequence shall be; "data," "center frequency," "80 percent of full scale," "data."

2.3.3.2 Subcarrier Modulation (Ref. Fig. 1)

2.3.3.2.1 The "data" position is the subcarrier connected to its normal data source (transducer, commutator, etc.).

2.3.3.2.2 The "center frequency" position is the subcarrier connected to a signal source which would result in the nominal subcarrier center frequency if no zero or sensitivity drift has occurred. The subcarrier shall remain at this position for 50 percent of the calibration interval.

2.3.3.2.3 The "80 percent of full scale" position is the subcarrier connected to a signal source which would result in a frequency $f_c \pm 30\%$ of full scale bandwidth if no zero or sensitivity drift had occurred. The subcarrier shall remain at this position for 50 percent of the calibration interval.

2.3.3.3 Phasing of Calibration Signal

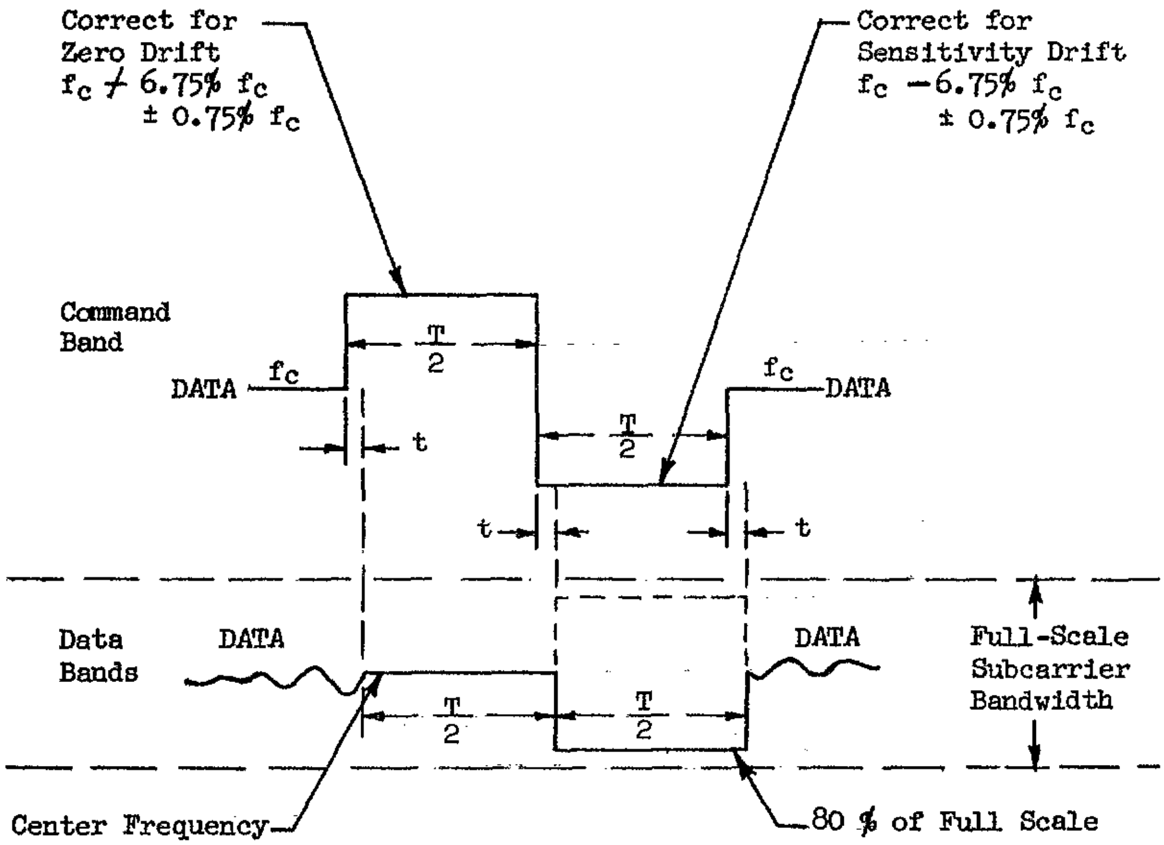
The data subcarrier calibration signals shall lag the command signals by 200 milliseconds minus zero, plus 50 milliseconds (Ref. Fig. 1).

2.3.4 Correction Capability

Automatic correction equipment shall be capable of correcting zero and sensitivity drift errors of up to ± 10 percent of full scale subcarrier bandwidth per calibrate cycle.

2.3.4.1 Calibration Duration

For maximum (± 10%) zero and sensitivity drift correction the calibrate interval shall be 5 seconds. Where maximum corrections per calibrate cycle are not required the calibration interval may be correspondingly reduced.



$t = 200$ milliseconds, $+ 50, \; - 0$ ms

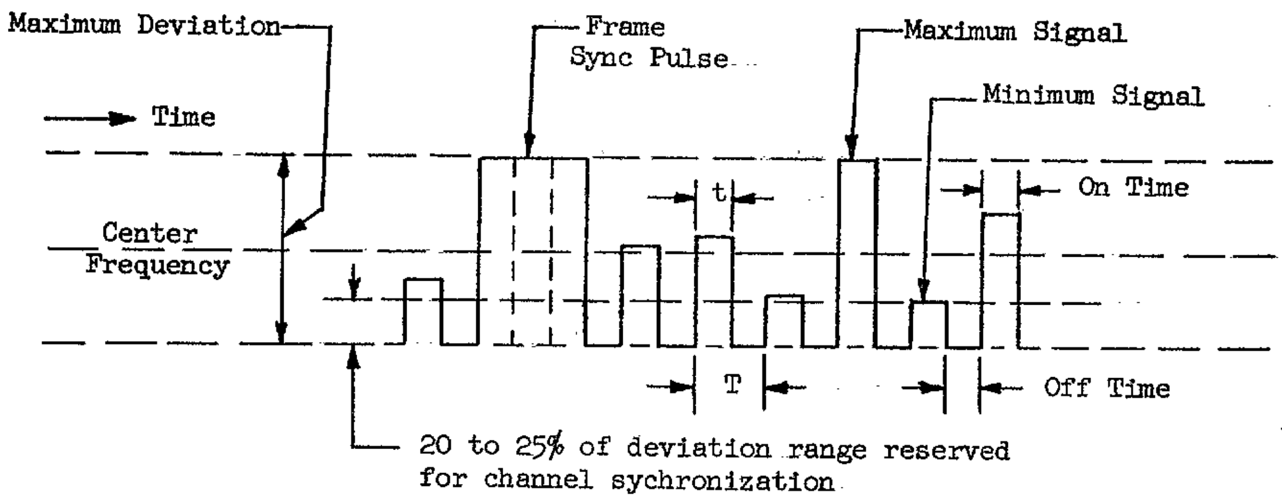
$T = 5$ seconds for ± 10% corrections per calibrate cycle

Fig. 1 - Automatic zero and sensitivity drift calibration command and data channel signals.

2.4 PAM/FM/FM Commutation

Commutation (time division multiplexing) may be used in one or more subcarrier bands. A nearly limitless variety of commutation schemes could be devised, but a few relatively simple methods will satisfy most telemetry needs. The specifications listed below for commutation were chosen to give a maximum flexibility consistent with presently available equipment and techniques, and it is intended that, in order to limit the varieties which must be handled at test ranges, the following restrictions on commutation be observed:

2.4.1 Commutation rates as listed in Table II shall not be exceeded on each subcarrier.



$\frac{t}{T}$ = Duty Cycle

PAM Pulse Train Waveform

Figure 2

TABLE II. COMMUTATION RATES - UNSEPARATED DATA

Band Number	Center Frequency (cps.)	Sample Duration (milliseconds) Recommended Values	Commutation Rate (samples per second) Recommended Values
1	400	170	6.0
2	560	120	8.4
3.	730	91	11
4	960	70	14
5	1,300	51	20
6	1,700	39	25
7	2,300	29	35
8	3,000	22	45
9	3,900	17	59
10	5,400	12	81
11	7,350	9.1	110
12	10,500	6.4	160
13	14,500	4.6	220
14	22,000	3.0	330
15	30,000	2.2	450
16	40,000	1.7	600
17	52,500	1.3	790
18	70,000	0.95	1,050
A	22,000	1.5	660
B	30,000	1.1	900
C	40,000	0.83	1,200
D	52,500	0.63	1,600
E	70,000	0.48	2,100

2.4.3 Recommended Sample Rates

Recommended commutation rates listed in Table II require the use of discriminator output low pass filters with cut off frequencies equal to 4 times the specified commutation rate.

2.4.4 Separated Data

Where required, automatic channel separation (decommutation) equipment shall be provided in the receiving station to process commutated signals that conform to the following characteristics: (See Fig. 2 and Table III).

2.4.4.1 The total number of samples per frame (number of segments of a mechanical commutator) and the frame rates shall be one of the combinations shown in Table III. If a higher commutation rate is required for certain information, two or more samples per frame (equally spaced in time) can be used to represent one telemetered function at the expense of the total number of information channels. This process is referred to as cross-strapping or super-commutation.

2.4.4.2 The commutation pattern in the subcarrier frequency vs. time domain, shall be as shown in Figure 2.

2.4.4.3 A frame synchronizing pulse of full scale amplitude and duration equal to two "on" periods plus one "off" period shall be provided once every frame, as shown in Figure 2.

2.4.4.4 The commutator speed (or frame rate) shall not vary more than plus 5.0 percent to minus 15 percent from the nominal values given in Table III.

2.4.4.5 The duty cycle shall be 40% to 65%.

2.4.4.6 A channel sychronization pedestal is required for automatic decommutation. (See Figure 2).

2.5 In Flight Zero and Full Scale Calibration

On all PAM commutators, channels one and two, following the synchronizing pulse are recommended for zero and full scale calibration respectively.

TABLE III. COMMUTATION SPECIFICATION FOR AUTOMATIC DECOMMUTATION

No. of Samples Per Frame*	Frame Rate Frames (Per Second)	Commutation Rate ** (Samples Per Second)	Lowest Recommended Subcarrier bands (cps)
18	5	90	14,500
18	10	180	22,000 (±15%) or 30,000 (±7.5%)
18	25	450	30,000 (±15%) or 70,000 (±7.5%)
30	2.5	75	10,500
30	5	150	22,000 (±7.5%)
30	10	300	22,000 (±15%) or 40,000 (±7.5%)
30	20	600	40,000 (±15%)
30	30	900	70,000 (±15%)

* The number of samples per frame available to carry information is two less than the number indicated, because the equivalent of two samples is used in generating the frame synchronizing pulse.

**Frame rate times number of samples per frame.

PART 3.0 PDM/FM or PDM/PM or PDM/FM/FM STANDARD

3.1 General

The pulse duration modulation (PDM) systems are intended for use where a strictly time division multiplex system can meet the bulk of the telemetry requirements of a given application. A relatively large number of information channels can be accommodated but a relatively low frequency response capability in comparison with the subcarrier channels of the FM/FM system.

3.2 PDM/FM or PDM/PM

The following are the specifications for the pulse duration modulated signal:

Number of samples per frame*	30	45	60	90
Frame rate (frames/sec.)	30	20	15	10
Commutation rate (Samples/sec.)**	900	900	900	900

The amplitude of the measurands being transmitted in each channel shall determine the duration of the corresponding pulses. The relation between measurands and pulse duration should, in general, be linear.

Minimum pulse duration (zero level information):	90 ± 30 microseconds
Maximum pulse duration (maximum level information):	700 ± 50 microseconds
Pulse rise and decay time (measured between 10% and 90% levels):	10 to 20 microseconds (constant to ± 1 microseconds for a given transmitting set).

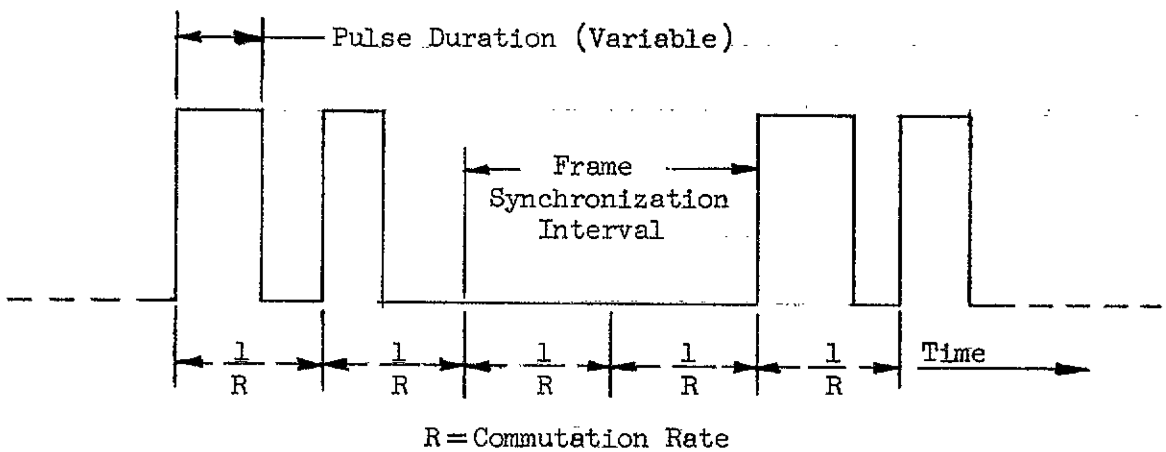
* The number of samples per frame available to carry information is two less than the number indicated because the equivalent of two samples is used in generating the frame synchronizing pulse.

**Commutation rate is equal to the frame rate multiplied by the number of samples per frame.

3.2.1 The time interval between the leading edges of successive pulses within a frame shall be uniform from interval to interval within plus or minus 25 microseconds. This time interval shall have a nominal period equal to one divided by the total sampling rate.

3.2.2 The commutator speed or frame rate shall not vary more than plus 5.0 percent to minus 15.0 percent from nominal.

A frame synchronizing interval equal to two successive pulse time intervals shall exist in the train of pulses transmitted, to be used for synchronization of the commutator and the decommutator. A representation of the pulse train waveform is shown in Figure 3.



PDM Pulse Train Waveform
FIGURE 3

3.3 PDM/FM/FM

Pulse duration modulation (PDM) systems may also be employed on the ± 15% deviation channels of the standard FM/FM multiplex systems. When so used they are designated as PDM/FM/FM Telemetry. It should be recognized that this application of PDM is wasteful of bandwidth and that it places three wide band modulation systems in cascade. Gaussian type output low pass filters should be used at the discriminator outputs for this application.

3.3.1 The recommended subcarrier channels for this application are bands B, C, D or E. Operating criteria for use of these specific bands are specified in Table IV.

TABLE IV PDM MODULATION OF FM/FM SUB-CARRIER CHANNELS

Samples Per Second	Channel Allocation	FM/FM Channel	Deviation Utilized	Recommended Value of Min. Pulse Length
900	B	30.0 kcps	± 7.5%	200 plus 30. Micro-seconds minus None
900	C	40.0 kcps	± 7.5%	170 plus 30. Micro-seconds minus None
900	D	52.5 kcps	± 7.5%	150 plus 30. Micro-seconds minus None
900	E	70.0 kcps	± 7.5%	110 plus 30. Micro-seconds minus None

Satisfactory performance is contingent upon use of optimum output low pass filters.

Reference: "The transmission of Pulse Width Modulated Signals over Restricted Bandwidth Systems." IRE Transactions on Telemetry and Remote Control. Volume TRC-3, No. 1 April 1957.

3.3.2 Time interval variation between leading edges of successive pulses. Section 3.2.1 shall apply.

3.3.3 Commutation Speed

Section 3.2.2 shall apply.

3.4 In-Flight Zero and Full Scale Calibration

On all PDM commutators, channels one and two, following the synchronizing pulse, are recommended for zero and full scale calibration respectively.

PART-4 PAM/FM or PAM/PM STANDARD

RESERVED FOR INCLUSION OF THE PAM/FM or PAM/PM STANDARDS AT A LATER DATE.

PART-5 PCM STANDARDS

5.1 General

Pulse code modulation (PCM) data specified in these standards shall be transmitted as serial binary coded, time division multiplexed samples.

5.2 Bit Rate Versus Receiver Intermediate Frequency (IF)[1] Bandwidth (3 db points)

Selections of bit rates and corresponding receiver IF bandwidth shall be made from those listed in Table VI below. Only those discrete receiver IF bandwidths listed shall be used (optional below 12,500 cps). The selections in Table VI have been chosen with the consideration that automatic tracking of radio frequency (RF) carrier drift or shift will be utilized in the receiver.

TABLE VI
Bit Rate and Receiver IF Bandwidth (3 db points)

SYSTEM TYPE	BIT RATE (bits per second)[2]	RECEIVER IF BANDWIDTH (cps)[3]
A	8,000 and lower	12,500 (and as required for lower bit rates)
B	8,000 to 65,000	25,000 - 50,000 - 100,000
C	50,000 to 330,000	100,000 - 300,000 - 500,000
D	320,000 to 800,000	500,000-1,000,000*-1,500,000*

*For use in 1435-1535 mcs and 2200-2300 mcs telemetry frequency bands only.

5.2.1 It is recommended that for practical design considerations a bit rate equal to the receiver IF bandwidth (3 db points) divided by a factor ranging from 1.5 to 3.0 be used. The bandwidth - bit rate relationships in Table VI were selected on this basis.

1. See Glossary of Terms.

2. See restrictions imposed by Part 6 "Magnetic Tape Recorder/Reproducer Standards".

3. See restrictions imposed by Appendix I "Telemetry Frequency Utilization Parameters and Criteria".

5.2.2 For reference purposes, a receiver IF signal-to-noise ratio (power) of approximately 15 db will result in a bit error probability of about one bit in 10^6. A two db change (increase or decrease) in this signal-to-noise ratio will result in an order of magnitude change (10^7 or 10^5, respectively) in the bit error probability.

5.2.3 It should be recognized that the range of factors 1.5 to 3.0 recommended in paragraph 5.2.1 may result in a compatibility problem when using current frequency modulation (FM) receivers for standard IRIG FM/FM and PDM/FM systems as well as PCM/FM systems designed in accordance with the standard herein. Modifications may be required to video amplifier stages and other circuitry as necessary.

5.3 Bit Rate Stability

The change in bit rate shall not exceed 1.0% of the nominal bit rate. It is recommended that rate of change of bit rate not exceed 0.1% of the nominal bit rate per second. (The above values are tentative and subject to change.)

5.4 Word and Frame Structure

The number of bits per frame shall not exceed 2048 including those used for frame synchronization. The frame length selected for a particular mission shall be kept constant. Word length for any given channel can range from 6 to 64 bits but shall be kept constant for any given channel for a particular mission. It is recommended that an odd parity bit be included where a higher order of confidence in bit transmission is desired.

5.5 Synchronization

5.5.1 Frames shall be identified by a unique frame synchronization word. The length of word should be proportional to the length of the frame, since longer frames require longer synchronization patterns in order to provide adequate probability of acquisition. It is recommended, that a repeated 11-bit Barker[4] code word be utilized with minimum length 11-bit plus (complement 11-bit), and maximum length 11-bit plus (complement 11-bit) plus (complement 11-bit). Patterns less than maximum length may be formed by progressively deleting the latter bits of the second complement 11-bit word. The 11-bit Barker code is 11100010010 and its complement is 00011101101.

4. See Glossary of Terms.

5.5.2 To facilitate rapid bit synchronization, it is recommended that, for a Non-Return-to-Zero (NRZ) code, a change in state occur at least once every 64 bits. Such change in state may be provided by odd parity, fixed programming, the guarantee that all data will not simultaneously go to zero or full-scale, etc.

5.6 Super-Commutation and Subcommutation

5.6.1 Super-commutation and subcommutation are acceptable methods for exchanging the number of measurands and sampling rate. A selected coded word shall be used to indicate the beginning of the subcommutator sequence. It is recommended that a repeated 7-bit Barker code word be utilized with minimum length 7-bit plus (complement 7-bit), and maximum length 7-bit plus (complement 7-bit) plus (complement 7-bit). Patterns less than maximum length may be formed by progressively deleting the latter bits of the second complement 7-bit word. The 7-bit Barker code is 1110010 and its complement is 0001101.

5.6.2 The number of bits per subcommutation frame shall not exceed 2048 including those used for subcommutation frame synchronization. The number of channels in a subcommutation frame shall not exceed 130 including that used for subcommutation frame synchronization.

5.7 Pre-Modulation Filtering

A low pass filter with cutoff frequency (3 db) equal to one-half the nominal bit rate shall be used before the transmitter modulator. The use of a maximally linear phase response type filter with a final slope of 36 db per octave is recommended.

5.8 RF Carrier Modulation

5.8.1 The Rf carrier modulation method shall be frequency modulation (FM). Since frequency-shift-keying (FSK), where modulation is accomplished by switching from one discrete frequency to another, is not compatible with pre-modulation filtering, it is not acceptable. Other modulation methods applicable to PCM (NRZ) transmission have not been proven and therefore are not included at this time.

5.8.2 Frequency modulation of the carrier shall be of the type where:

The carrier is deviated to the higher frequency deviation limit to transmit a "one" and to the lower frequency deviation limit to transmit a "zero". Once a frequency deviation limit is reached for either a "one" or a "zero", the resulting frequency remains constant for consecutive like bits.

PART-6 MAGNETIC TAPE RECORDER/REPRODUCER STANDARDS

6.1 Scope

These standards define terminology and specify the configuration and operating characteristics of magnetic tape recording/reproducing devices used for telemetry and airborne data collection applications at the various missile ranges. Also included are standards applying to magnetic tapes used by magnetic tape recording/reproducing devices.

Although intended primarily for telemetry data recording and reproducing purposes, it is intended that these standards also serve as a guide in the procurement of airborne magnetic tape recording equipment. Compatibility of airborne recording equipment is desirable in order to utilize standard reproducing equipment on the ground for playback purposes.

Because the magnetic tape is the only common element between the record and reproduce device, configuration of these devices is referenced, where applicable, to the magnetic tape.

6.2 Requirements

6.2.1 General

Magnetic tape recording and reproduction of telemetry signals is used throughout all of the various missile ranges. To provide the maximum utilization of the potential of the various activities doing the job of telemetry recording it is desirable that the maximum interchangeability of recording information and equipment should be obtained. These standards are to be used to obtain this result. It is quite possible that at any one establishment, or even during a single operation, one or more of the several methods of information storage set forth in this standard, may be used simultaneously.

6.3 Direct Recording

The method of direct recording is used for the recording of FM/FM derived telemetry data and also for such applications as airborne recording in which the data has not been telemetered, but is of the same general form as FM/FM telemetered data at the output of the ground receiver. Standards for this type of telemetry data are set forth in part 2 of these Standards.

6.3.1 Tape

6.3.1.1 Tape Widths

The standard tape widths are $\frac{1}{4}$ inch, $\frac{1}{2}$ inch and 1 inch, with tolerances on all widths being plus 0.000 inch, minus 0.004 inch. The preferred tape width for radio telemetry is $\frac{1}{2}$ inch and should be used whenever compatible with program requirements.

6.3.1.2 Tape Thickness

The over-all thickness (base plus coating) of the tape used for telemetry applications will be within the limits 1.0 to 2.2 mils, depending on the type of base and coating used. Federal specification MIL-T-21029 A (ships) sets forth the requirements for instrumentation quality magnetic tape as a function of tape thickness. A standard recorder/reproducer must be capable of handling or utilizing any of the tapes qualified under this specification without degradation of the specified recorder/reproducer system characteristics.

6.3.1.3 Track Geometry (see Figure 4)

6.3.1.3.1 Track Width

The track width for multiple track recording shall be 0.050 inch ± 0.005 inch. Track width is defined as the physical width of the head which would be used to record or reproduce any given track, although the actual width of the recorded track may be somewhat greater because of the magnetic fringing effect around each record head.

6.3.1.3.2 Track Spacing

Tracks shall be spaced 0.070 inch center-to-center across the tape and, as a group, shall be centered on the width of the tape. Therefore, the preferred width of tape ($\frac{1}{2}$ inch) would contain seven tracks with one track located at the center of the tape.

6.3.1.3.3 Track Numbering

The tracks on a tape shall be numbered consecutively, starting with track number "one", 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 5)

6.3.2.1 Head Placement

The standard head placement is to locate the heads (both record and playback) for alternate tracks in separate head stacks. Thus to record in <u>all</u> tracks of a standard width tape, two record head stacks will be used, and 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 pair (record or reproduce) shall be mounted in a manner such that the center lines through the head gaps of each stack are parallel and shall be spaced 1.500 inches, ±0.001 inch, apart as measured along the tape path.

6.3.2.3 Head Stack Numbering

Head stack number "one" 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

Heads, both record and reproduce, shall be numbered to correspond to the track on the magnetic tape which they normally record or reproduce. Stack number "one" of a pair will contain all odd number heads, while stack number "two" will contain all even numbered heads. Where only a single stack is needed, stack number "one" shall be used.

6.3.2.5 Individual Gap Azimuth Alignment

The alignment of individual gaps within a head stack shall be within ± 1 minute of arc referenced to a straight line which is perpendicular to the direction of tape travel and in the plane of the tape.

6.3.2.6 Head Stack Tilt

The plane tangent to the front surface of the head stack at the center line of the head gaps shall be perpendicular to the head mounting plate within ± 3 minutes of arc.

6.3.2.7 Gap Scatter

Shall be 0.0001 inch or less.

6.3.2.8 Head Location

The location of any head in a stack shall be within ± 0.002 inch of the nominal position required to match the track location set forth in paragraph 6.3.1.3.

6.3.2.9 Head Interchangeability

Where rapid interchangeability of heads is specified, the method of head mounting, locating and securing shall insure that all alignment and location requirements are satisfied without shimming or mechanical adjustment.

6.3.3 Head Polarity

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 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

6.3.4.1 Tape Guiding

The tape guiding which determines the position of the tape relative to the head stacks shall not in any way contribute to deterioration of machine performance and shall not permit vertical movement of the tape relative to the head mounting plate and/or misalignment of the tracks to exceed ± 0.003 inch.

6.3.5 Record/Reproduce Parameters

6.3.5.1 Bias

The high frequency bias signal shall be of a frequency greater than 3 times the highest data frequency for which the machine is designed and shall not be less than 50,000 cps.

6.3.5.2 Frequency Response

The nominal frequency response or pass band of direct recorded data is a function of tape speed as given in Table V.

6.3.5.3 Tape Speed

The nominal tape speeds shall be those listed in Table V.

6.3.5.4 Record Amplifier

6.3.5.4.1 Input Impedance

20,000 ohms minimum, with or without meter.

6.3.5.4.2 Nominal Input Level

1.0 volt rms.

6.3.5.4.3 Transfer Characteristics

The record amplifier shall provide a transfer characteristic (determined by a direct gap flux measurement) which is basically a constant current versus frequency characteristic upon which is superimposed a pre-emphasis characteristic to correct for loss of record head efficiency with frequency.

6.3.5.4.4 Record Bias Setting

For optimum record characteristics the amplitude of the bias current shall be adjusted for maximum reproduced signal while recording signals of the frequency set forth in Table V.

6.3.5.4.5 Record Level Setting

The level of recording shall be set at a value which yields 1% third harmonic signal content on playback. This level shall be set while recording a signal of Nominal Input Level and of the frequency indicated in Table V.

TABLE V
DIRECT RECORD PARAMETERS

Tape Speed (inches/second)	±3 db Pass Band (cycles/second)	Record Bias Set Frequency (cycles/second)	Record Level Set Frequency (cycles/second)
60	100 - 100,000	20,000 ± 10%	1000 ± 10%
30	100 - 50,000	10,000 ± 10%	1000 ± 10%
15	100 - 25,000	10,000 ± 10%	1000 ± 10%
7-1/2	50 - 12,000	500 ± 10%	500 ± 10%
3-3/4	50 - 6,000	500 ± 10%	500 ± 10%
1-7/8	50 - 3,000	500 ± 10%	500 ± 10%

6.3.6 Speed Control and Compensation

6.3.6.1 Speed Control

6.3.6.1.1 Speed Control Signal

The speed control signal is an amplitude modulated signal with the following characteristics:

Subcarrier Frequency	17.0 kc ±0.5%
Modulating Frequency	60 cps ±0.02%
Percentage Modulation	45 - 55
Operating Level	10 db, ± 0.5 db, below normal record level.

6.3.6.1.2 Record Speed

All tape shall be recorded at a tape speed within ±0.5% of the nominal standard speed.

6.3.6.1.3 Playback Speed

Tape playback speed without external speed control shall be within ±0.5% of the nominal standard speed. With external speed control the tape playback speed shall be within ±0.25% of the record speed.

6.3.6.2 Compensation

Compensation signals to be used for correction of tape speed error effects are a function of tape speed as follows:

Tape Speed	Compensation Tone Frequency
15 in/sec.	25 kc ± 0.01%
30 in/sec.	50 kc ± 0.01%
60 in/sec.	100 kc ± 0.01%

6.3.7 Reproduce Amplifier

6.3.7.1 Output Impedance

100 ohms maximum within the pass bands specified in Table V.

6.3.7.2 Nominal Output Level

1.0 volts rms.

6.3.7.3 Transfer Characteristic

The reproduce amplifier shall provide signal equalization as a function of frequency, considering the nature of the recorded signal as set forth in paragraph 6.3.5.4.3, head to tape, tape, and tape to head transfer characteristics, which will provide the overall recorder/reproducer system frequency response within the pass band requirements set forth in Table V.

6.4 PDM Recording

PDM recording is accomplished by differentiating the input, duration modulated, rectangular waveform and driving the record head with the resulting positive and negative spikes which correspond in time to the leading and trailing edges of the input pulses. The tape is thereby magnetically marked in such a manner that the pulses during the reproduce process may be used to trigger pulse reconstruction circuitry. Although recorded PDM data may be reproduced through a direct recorded data reproduce amplifier and pulse reconstruction performed later, the PDM reproduce amplifier reconstructs the original, duration modulated, rectangular waveform.

6.4.1 Tape

Standards for tape used in PDM Recording are the same as for Direct Recording (paragraph 6.3.1).

6.4.2 Head and Head Stack Configuration

Standards for PDM recording are the same as for Direct Recording (paragraph 6.3.2).

6.4.3 Head Polarity

Standards for PDM Recording are the same as for Direct Recording (paragraph 6.3.3).

6.4.4 Tape Guiding

Standards for PDM Recording are the same as for Direct Recording (paragraph 6.3.4).

6.4.5 Record/Reproduce Parameters

6.4.5.1 Recorder/Reproducer Performance

The record/reproduce system shall be capable of recording and subsequently reproducing and reconstructing pulses whose minimum duration as a function of tape speed are given in Table VI.

The record/reproduce system shall be capable of recording and subsequently reproducing and reconstructing pulses with time errors, as a function of tape speed, not to exceed the values given in Table VI. The maximum pulse jitter measured at the half amplitude point of the leading edge of the pulse shall not exceed 2 microseconds.

TABLE VI

PDM RECORD PARAMETERS

Tape Speed (inches/second)	Minimum Pulse Duration (microseconds)	Accuracy (microseconds)
60	75	± 2
30	75	± 2
15	100	± 3

6.4.6 Record Amplifier

6.4.6.1 Input Impedance

20,000 ohms minimum.

6.4.6.2 Normal Input Level

1.0 volt peak to peak.

6.4.6.3 Transfer Characteristic

The record amplifier shall drive the record head with a pulse signal which is obtained by differentiation of the input, duration modulated, rectangular wave pulse train. The time constant of the differentiation shall be 10 microseconds.

6.4.7 Reproduce Amplifier

6.4.7.1 Function

The PDM reproduce amplifier will amplify the pulse output of the reproduce head and reconstruct the basic, duration modulated, rectangular pulse wave train.

6.4.7.2 Output Impedance

100 ohm maximum.

6.4.7.3 Nominal Output Level

20 volts peak-to-peak across 1000 ohms resistance.

6.4.7.4 Pulse Rise Time

Rise and decay time of the output rectangular pulses shall be less than 2 microseconds from 10% to 90% amplitude levels.

6.4.7.5 Missing Pulse Protection

The reproduce amplifier shall incorporate circuitry to detect defective pulses during the reproduce process and provide automatic resetting to preclude loss of subsequent data.

6.5 PCM Recording

The recording of PCM data may be accomplished in several ways. The signal to be recorded (either in the air or on the ground at the output of the receiver) will be in serial form. This serial data may be recorded directly in serial form, utilizing direct recording technique or saturation recording techniques with adequate bandwidth, or it may be converted into a parallel form and recorded in parallel on a multitrack tape recorder. Another method for recording PCM data is the use of predetection recording. Because serial or predetection recording of PCM data involves no special techniques above those required for recording any other type of data, this section will deal specifically with the standards for the recording of PCM data on tape in parallel form. Standards for recording PCM data in other forms are as given in the sections on video and predetection recording. There are two Standard Systems; a 16 track system and a 31 track system. The 31 track system consists of interleaved 16 track and 15 track stacks. The two stacks are employed as independent record/reproduce systems. Track spacing and location of tracks 1-16 in the 31 track system are identical to the 16 track system. Additional optional tracks A and B with track spacing and track width identical to tracks 1 through 31 and located beyond tracks 1 and 16 may be used with the 31 track configuration. Performance standards specified herein shall not apply to the optional tracks.

6.5.1 Tape

6.5.1.1 Tape Width

The standard tape width is a nominal 1 inch. Standard tape width shall be 0.997 inch ± 0.001 inch.

6.5.1.2 Tape Type

Tape for PCM use shall have physical and electrical characteristics equal to or better than the polyester base.

6.5.1.3 Tape Thickness

Paragraph 6.3.1.2 shall apply.

6.5.2 Track Geometry (see Figure 6)

6.5.2.1 Track Width

6.5.2.1.1 Sixteen Track Systems

Track width for 16 track systems shall be 0.025 inch ±0.002 inch. Track width is defined as the physical width of the head which would be used to record or reproduce any given track although the actual width of the recorded track may be somewhat greater because of the magnetic fringing effect around each record head.

6.5.2.1.2 Thirty-one Track System

Track width for 31 track systems shall be 0.020 inch ±0.001 inch. Track width is defined as the physical width of the head which would be used to record or reproduce any given track, although the actual width of the recorded track may be somewhat greater because of the magnetic fringing effect around each record head.

6.5.2.2 Track Spacing

6.5.2.2.1 Sixteen Track System

Spacing between track centers on 16 track systems shall be 0.060 inch.

6.5.2.2.2 Thirty-one Track Systems

Spacing between track centers on 31 track systems shall be 0.030 inch.

6.5.2.3 Track Location

6.5.2.3.1 Sixteen Track Systems

On 16 track systems the center of the tape shall be centered between tracks 8 and 9.

6.5.2.3.2 Thirty-one Track Systems

On 31 track systems the center of the tape shall be centered on track 24 centerline.

6.5.2.4 Track Numbering (see Figure 6)

6.5.2.4.1 Sixteen Track Systems

For 16 track systems. Paragraph 6.3.1.3.3 shall apply.

6.5.2.4.2 Thirty-one Track Systems

Paragraph 6.3.1.3.3 shall apply except that the numbering from top to bottom shall be A (optional) 1, 17, 2, 18, 3, 19, -----31, 16, B (optional).

6.5.3 Head and Head Stack Configuration

6.5.3.1 Head Stack Placement (31 Track Systems).

Paragraph 6.3.2.2 shall apply.

6.5.3.2 Head Stack Numbering (31 Track System).

Paragraph 6.3.2.3 shall apply.

6.5.3.3 Head and Stack Numbering

Heads shall be numbered to correspond to the track on the tape which they normally record or reproduce. Stack number one of a pair will contain heads numbered "one" through "sixteen" and stack number "two" will contain heads numbered "seventeen" through "thirty-one" and, optionally, tracks A and B.

6.5.3.4 Individual Gap Azimuth Alignment

Paragraph 6.3.2.5 shall apply.

6.5.3.5 Mean Gap Azimuth Alignment

Mean gap azimuth error shall not exceed ± 1/3 minute of arc.

6.5.3.6 Head Stack Tilt

Paragraph 6.3.2.6 shall apply.

6.5.3.7 Gap Scatter

Paragraph 6.3.2.7 shall apply.

6.5.3.8 Head Location in Stack

The location of any head in a stack shall be within ±0.001 inch nonaccumulative of the nominal position required to match the track location as set forth in paragraphs 6.5.2.1.1, 6.5.2.1.2, 6.5.2.2.1, and 6.5.2.2.2.

6.5.4 Head Polarity

Section 6.3.3 shall apply.

6.5.5 Tape Guiding

6.5.5.1 Tape Guiding

Tape guiding which determines the position of the tape relative to the head stacks shall not in any way contribute to deterioration of machine performance and shall not permit transverse movement of the tape relative to the head mounting plate and/or misalignment of the tracks to exceed 0.0025 inch, including tape slitting tolerance.

6.5.6 Tape Speeds

Tape speeds for PCM recording shall be 1-7/8, 3-3/4, 7-1/2, 15, 30, and 60 inches per second.

6.5.7 Bit Packing Density

The playback device shall be capable of playing back data recorded at bit packing densities of up to at least 1000 bits per linear inch per track. The nominal maximum bit packing density at the test ranges shall be 1000 bits per linear inch per track.

6.5.8 Crosstalk and Transverse Sensitivity

Crosstalk between any two channels and transverse sensitivity between any two tracks shall be less than 25 db for 16 track systems and 20 db for 31 track systems.

6.5.9 Record/Reproduce Reliability

The maximum allowable error shall be one bit in 100,000.

6.5.10 Skew and Differential Flutter

Shall not exceed 125 microinch peak-to-peak.

6.5.11 Type of Recording

Non-return-to-zero (NRZ) recording shall be employed wherein a positive state of saturation is assigned for recording the digit "one" and a negative state of saturation indicates a "0". Once a saturation level is reached for either a "one" or a "0", the resulting flux level remains constant for consecutive like bits.

6.5.12 Timing

Track 16 shall be reserved for range timing.

6.5.13 Electronic Test of Mechanical Tolerances

It is suggested that the mechanical tolerances of a record/reproduce system can be checked electronically. This test is made by recording on all tracks simultaneously at 15 inches per second and noting, during reproduction at 15 inches per second, the time displacement of the signal on each track when referenced to any one track (the chosen reference track). When the recovered signals are viewed on an oscilloscope the gap scatter appears as a fixed time displacement, while other sources of error such as jitter and skew appear as constantly varying displacements which can be averaged out by the operator. This measurement shall be made while running the tape through in the normal manner and reversed (upside down and backwards) at 15 inches per second. The fixed time displacement for these tests should not exceed 30 microseconds.

6.5.14 Recorder Input Characteristics

6.5.14.1 Input Impedance

20,000 ohms minimum.

6.5.14.2 Input Voltage

2 to 20 volts plus or minus, balanced or unbalanced and polarity selectable.

6.5.14.3 Input Format

Parallel input. Non-return-to-zero.

6.5.15 Output Characteristics

6.5.15.1 Reproduce Output Format

Parallel output. Non-return-to-zero. Reproducer output shall compensate for all recorder/reproducer induced time displacement errors to within 5% of the word interval, or 1.6 microseconds, whichever is greater.

6.5.15.2 Output Impedance

100 ohms maximum.

6.5.15.3 Output Voltage

20 volts peak-to-peak minimum. One polarity for "1", opposite polarity for "0", selectable polarity.

6.6 Single Carrier FM (not including video).

6.6.1 Tape

6.6.1.1 Tape Widths

Paragraph 6.3.1.1 shall apply.

6.6.1.2 Tape Thickness

Paragraph 6.3.1.2 shall apply.

6.6.1.3 Track Geometry

6.6.1.3.1 Track Width

Paragraph 6.3.1.3.1 shall apply.

6.6.1.3.2 Track Spacing

Paragraph 6.3.1.3.2 shall apply.

6.6.1.3.3 Track Numbering

Paragraph 6.3.1.3.3 shall apply.

6.6.2 Head and Head Stack Configuration

6.6.2.1 Head Placement

Paragraph 6.3.2.1 shall apply.

6.6.2.2 Head Stack Placement

Paragraph 6.3.2.2 shall apply.

6.6.2.3 Head Stack Numbering

Paragraph 6.3.2.3 shall apply.

6.6.2.4 Head and Stack Numbering

Paragraph 6.3.2.4 shall apply.

6.6.2.5 Individual Gap Azimuth Alignment

Paragraph 6.3.2.5 shall apply.

6.6.2.6 Head Stack Tilt

Paragraph 6.3.2.6 shall apply.

6.6.2.7 Gap Scatter

Paragraph 6.3.2.7 shall apply.

6.6.2.8 Head Location

Paragraph 6.3.2.8 shall apply.

6.6.2.9 Head Interchangeability

Paragraph 6.3.2.9 shall apply.

6.6.3 Tape Guiding

Paragraph 6.3.4.1 shall apply.

6.6.4 Tape Speeds

6.6.4.1 Table VII

(Input ±1.4 volts DC Nominal)
(Deviation direction vs. voltage not specified)

Tape Speed inches per second	Carrier Center Frequency	Carrier plus deviation	Carrier minus deviation
1-7/8	1,688 cps	2,363 cps	1,012 cps
3-3/4	3,375 cps	4,725 cps	2,025 cps
7-1/2	6,750 cps	9,450 cps	4,050 cps
15	13,500 cps	18,900 cps	8,100 cps
30	27,000 cps	37,800 cps	16,200 cps
60	54,000 cps	75,600 cps	32,400 cps

6.6.5 General Requirements

6.6.5.1 Frequency Drift

Maximum center frequency drift during any 15 minute period after 30 minutes warm-up shall not exceed 0.5% of peak-to-peak deviation.

6.6.5.2 Modulation Frequency

Maximum modulation frequency shall be 20% of the carrier center frequency.

6.7 Video Recording

6.7.1 Stationary Head Video Recording

6.7.1.1 Tape Widths

Paragraph 6.3.1.1 shall apply.

6.7.1.2 Tape Thickness

The preferred overall thickness of tape (base plus coating) shall be 1.0 mil.

6.7.1.3 Tape Type

The preferred tape shall have physical and electrical characteristics equal to or better than the polyester base.

6.7.1.4 Track Geometry

Paragraphs 6.3.1.3.1, 6.3.1.3.2 and 6.3.1.3.3 shall apply.

6.7.1.5 Head and Stack Configuration

Paragraphs 6.3.2.1, 6.3.2.2, 6.3.2.3, 6.3.2.4, 6.3.2.5, 6.3.2.6, 6.3.2.7 and 6.3.2.8 shall apply.

6.7.1.6 Head Polarity

Paragraphs 6.3.3.1, 6.3.3.2 and 6.5.11 shall apply.

6.7.1.7 Tape Guiding

Paragraph 6.3.4.1 shall apply.

6.7.1.8 Tape Speeds

6.7.1.8.1 Table VIII

Tape Speed	3 db Pass Band (cycles/sec)
60 in/sec	400- 500,000
120 in/sec	400-1,000,000
240 in/sec	800-2,000,000

6.7.2 Rotating Head Video Recording

Rotating head video recording, although used for several years, is new to the field of telemetry recording. This particular area of recording may see rapid developments which will culminate in modification of these standards at a later date.

6.7.2.1 Tape

6.7.2.1.1 Tape Width

The standard tape width is 2 inches plus 0.000 inch and minus 0.004 inch.

6.7.2.1.2 Tape Thickness

The standard tape thickness in 1.5 mil (including base and coating). Tape base shall have characteristics equal to or better than the polyester base.

6.7.2.1.3 Tape Coating

The tape coating shall be oriented for transverse (across the width) recording and be of video type.

6.7.2.2 Track Geometry

6.7.2.2.1 Video Track Width

The video track width is 0.010 inch plus 0.0005 inch minus 0.00 inch.

6.7.2.2.2 Servo Control Track Width

The servo control track width is 0.050 inch ± 0.0005 inch.

6.7.2.2.3 Cue Track Width

The cue track width is 0.020 inch ± 0.0005 inch.

6.7.2.2.4 Low Frequency Track Width

The low frequency track width is 0.070 inch ± 0.0005 inch.

6.7.2.2.5 Track Placement (see Figure 7)

TABLE IX

Distances Measured from Bottom Edge of Tape

Track	Minimum	Maximum	
Servo-Control Track	0.00 "	0.00 "	Bottom
	0.045"	0.050"	Top
Spotting Track	0.055"	0.060"	Bottom
	0.075"	0.080"	Top
Video Tracks	0.085"	0.090"	Bottom
	1.905"	1.910"	Top
Low Frequency Track	1.925"	1.930"	Bottom
	1.996"	2.00 "	Top

6.7.2.2.6 Video Track Location

The video tracks lie across the width of the tape in a series of parallel tracks. These tracks have a center to center spacing of 0.0156 inch ± 0.0001 inch.

6.7.2.2.7 Tape and Drum Speeds

TABLE X

Tape Speed	Drum rpm	Single Channel FM Carrier Frequency	Direct Record Low Freq. Channel	Spotting Channel
15 inches per sec.	14,400	6 mc	±2 db 50 to 10,000 cps	± 3 db 50 to 3,000 cps

6.7.2.2.8 Head and Drum Configuration

The heads are mounted in a drum (disc) which is 2.069 inches ± 0.002 inch in diameter. The heads are mounted at 0°, 90°, 180°, and 270° around the periphery of the drum.

6.7.2.2.9 General Requirements

6.7.2.2.9.1 FM Carrier Deviation

The FM carrier shall be shifted a maximum of ±35% carrier center frequency at the maximum input level.

6.7.2.2.9.2 Maximum Input Level

The maximum input level shall be 1.4 volts peak-to-peak.

6.7.2.2.9.3 FM Carrier Identity

The FM carrier shall increase in frequency for a positive input signal.

6.7.2.2.9.4 Maximum Modulation Frequency

The maximum modulation frequency shall be 70% of the carrier frequency.

6.7.2.2.9.5 Speed Control

The drum speed shall be within ± 0.005% of the nominal standard speed.

6.7.2.2.9.6 Head Polarity

Paragraphs 6.3.3.1, 6.3.3.2 and 6.5.11 shall apply.

6.8 Predetection Recording

The advent of tape recorders whose upper limit of frequency response is 8 mc has made possible the recording of receiver IF signals. This type of recording is essentially an adaptation of systems already covered in these standards; however, certain areas for standardization can be covered even at this early date in the art of predetection recording.

6.8.1 Stationary Head Video Predetection Recording

6.8.1.1 Recommended I.F. Frequencies

TABLE XI

Tape Speed	Carrier Frequency	Information Bandwidth
60 in/sec	350,000 cps	300,000 cps
120 in/sec	700,000 cps	600,000 cps
240 in/sec	1,400,000 cps	1,200,000 cps

6.8.2 Rotating Head Video Predetection

6.8.2.1 Recommended I.F. Carrier Frequencies

TABLE XII

Tape Speed	Carrier Frequency	Information Bandwidth
15 in/sec	5,000,000 cps	4,000,000 cps

6.9 Tape Reels, Reel Centering, and Hold-Down

6.9.1 Tape Reels

The standard magnetic tape reel sizes are 10-½ and 14 inch diameter reels. The preferred machine shall handle standard flanged and flangeless reel sizes. Dimensions and tolerances or reel flanges and/or hubs shall be as specified by MIL-T-21029-A (SHIPS) except as specified herein. The thickness of the hub shall be at least as great as the maximum thickness of the reel.

6.9.2 Tape Reel Positioning

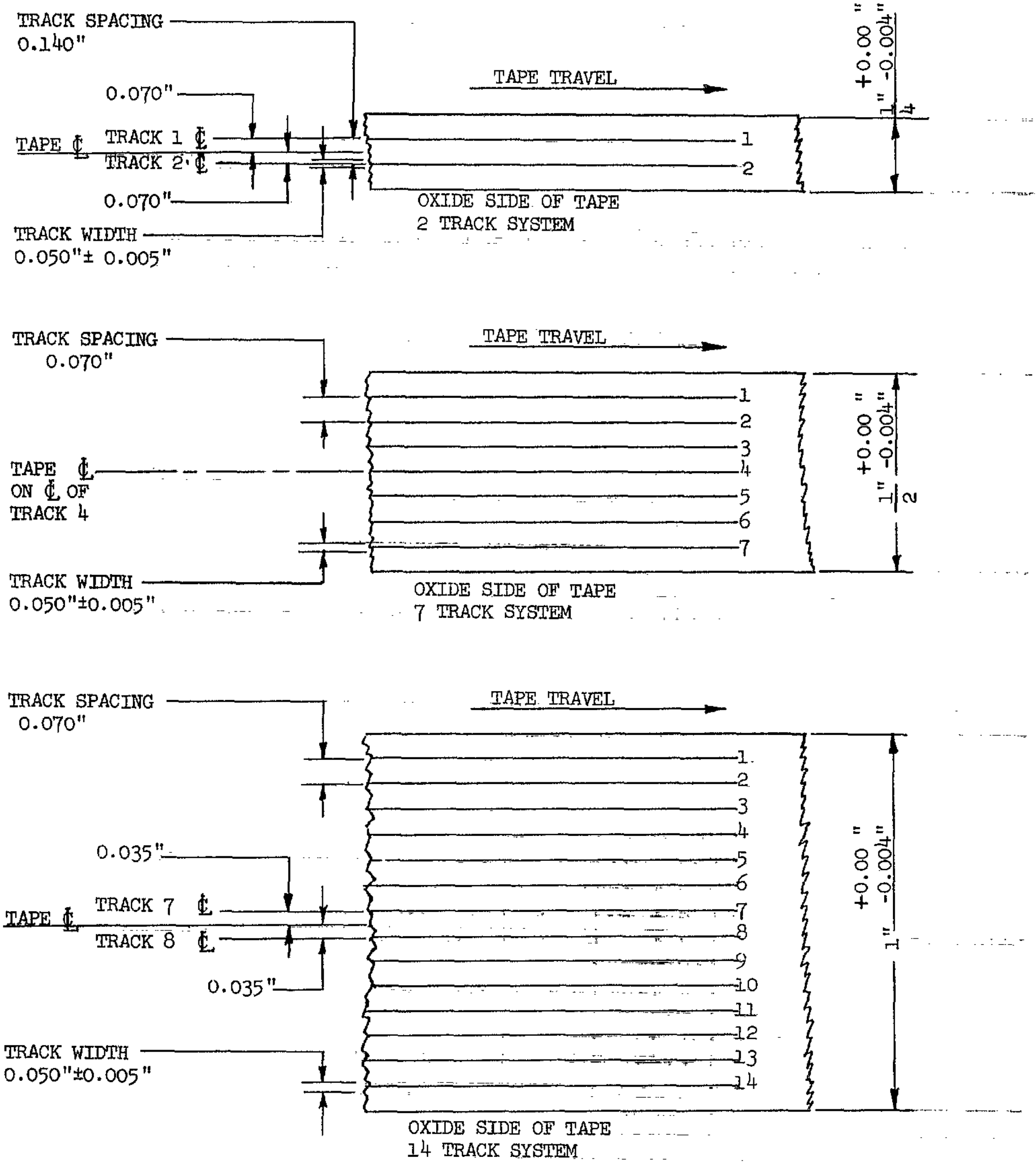
Positioning of the tape reels shall conform to the requirements of paragraph 6.3.4.1.

6.9.3 Tape Reel Centering and Hold-Down Device

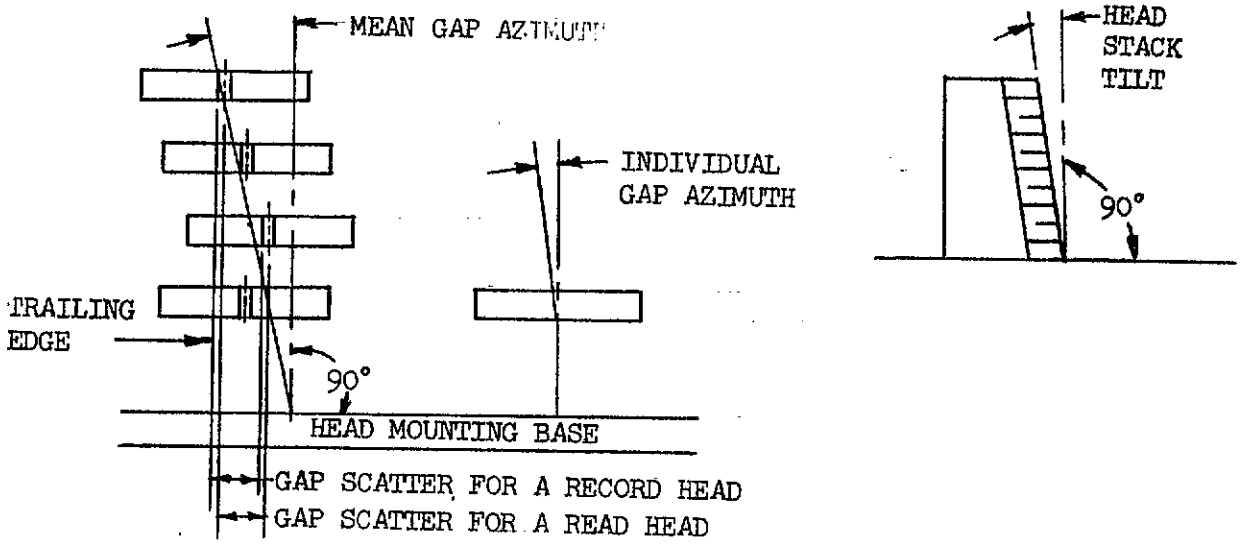
In the engaged position the reel centering and hold-down device shall not permit motion of the reel relative to the reel spindle in any plane. Hold-down eccentricity shall not exceed 0.01 inch.

6.9.4 Tape Wind

Shall conform to MIL-T-21029-A (SHIPS) titled "Military Specification Tapes, Sound Recording, Telemetering Instrumentation, Magnetic Oxide Coated."

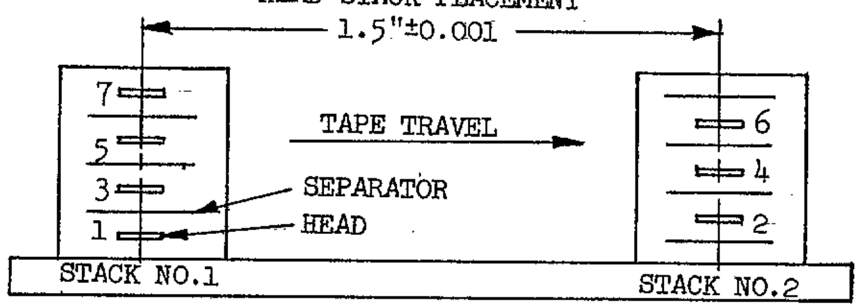


ANALOG TAPE GEOMETRY
FIG. 4

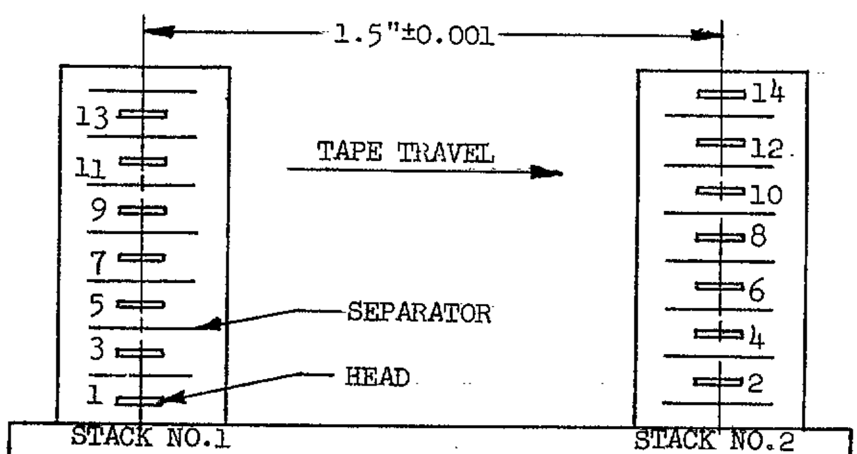


GAP AZIMUTH ALIGNMENT

HEAD STACK PLACEMENT

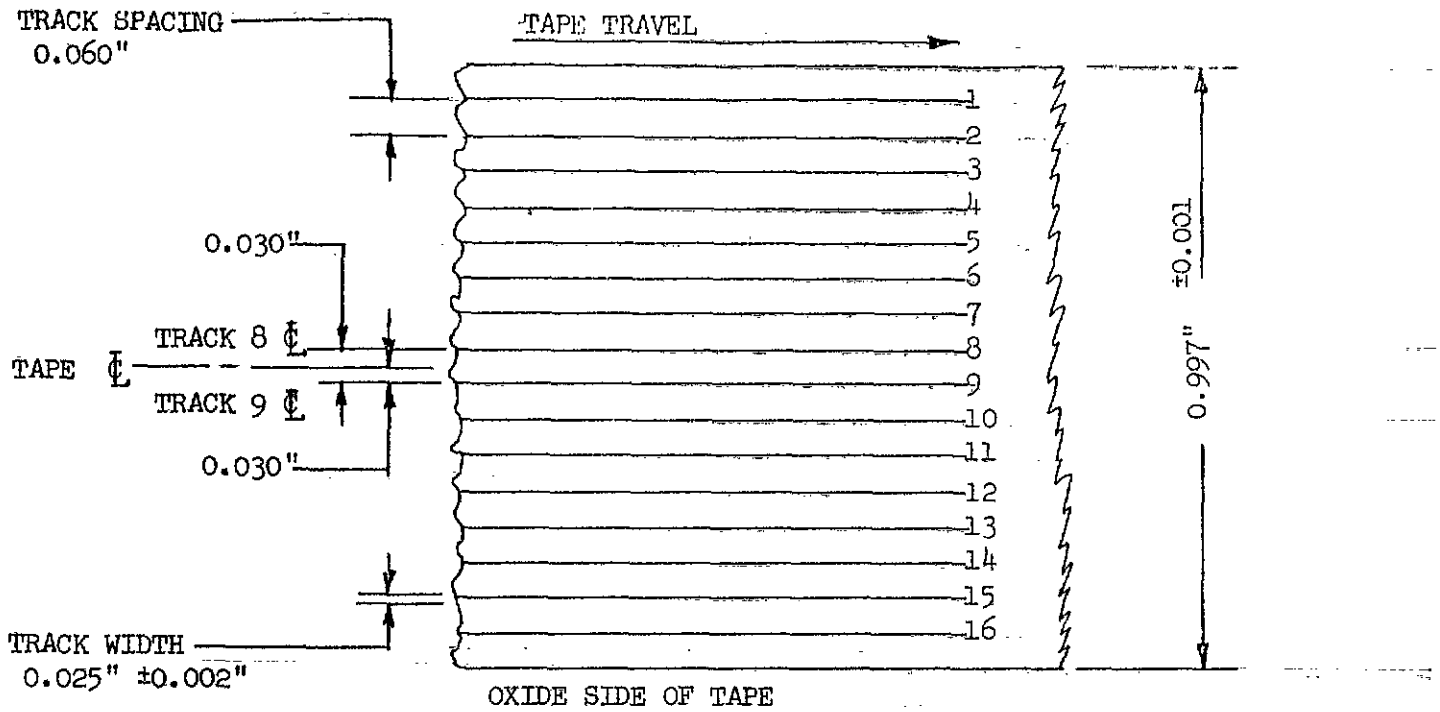


7 TRACK ANALOG HEAD
AND STACK CONFIGURATION

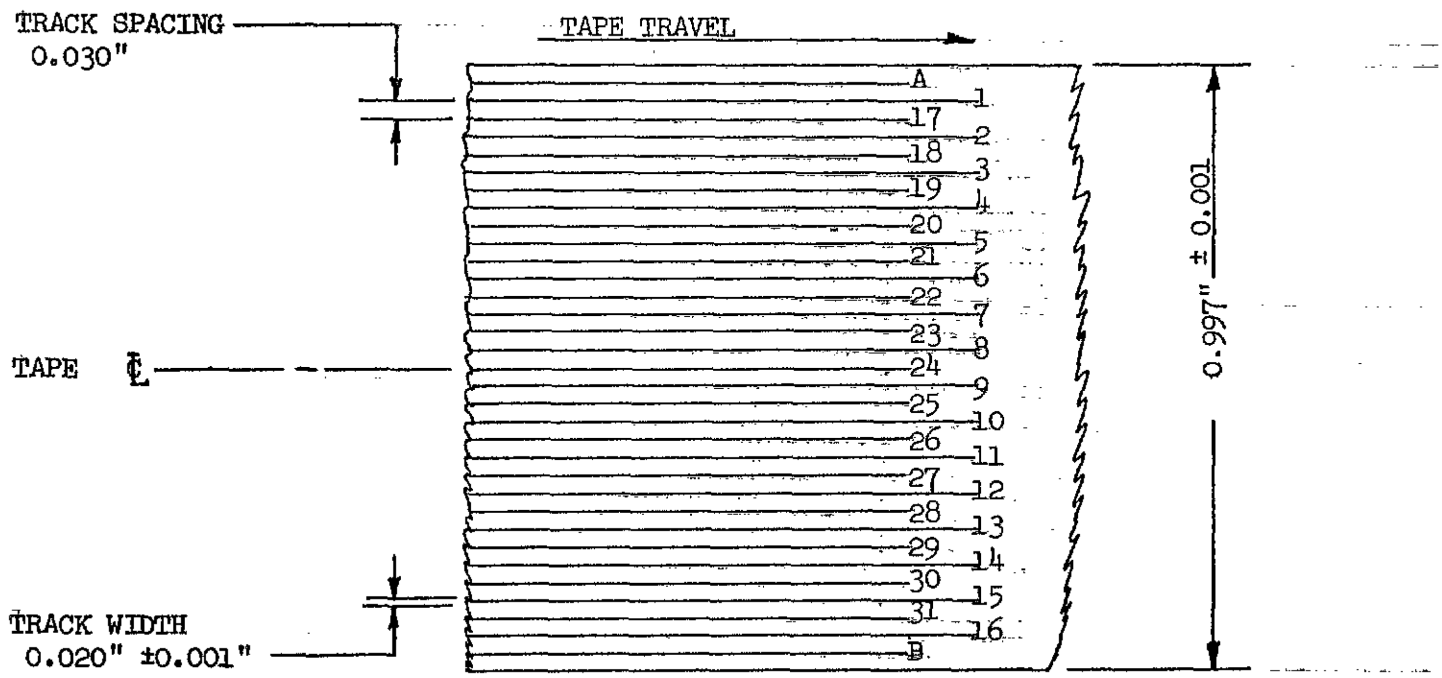


14 TRACK ANALOG HEAD
AND STACK CONFIGURATION

Fig. 5



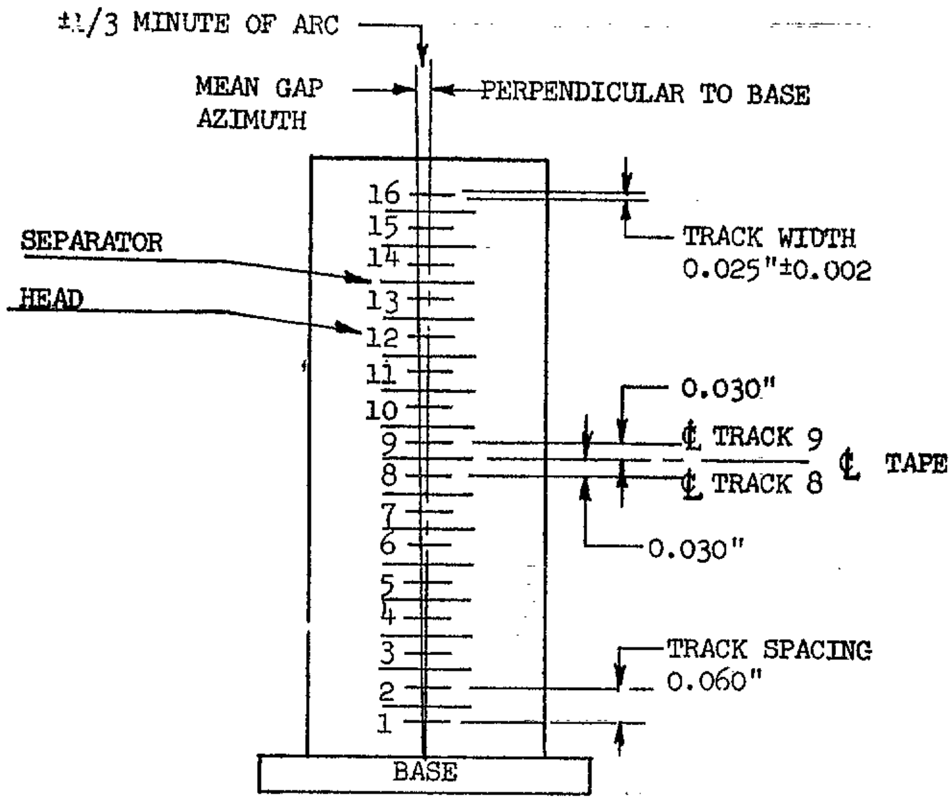
OXIDE SIDE OF TAPE
16 TRACK SYSTEM



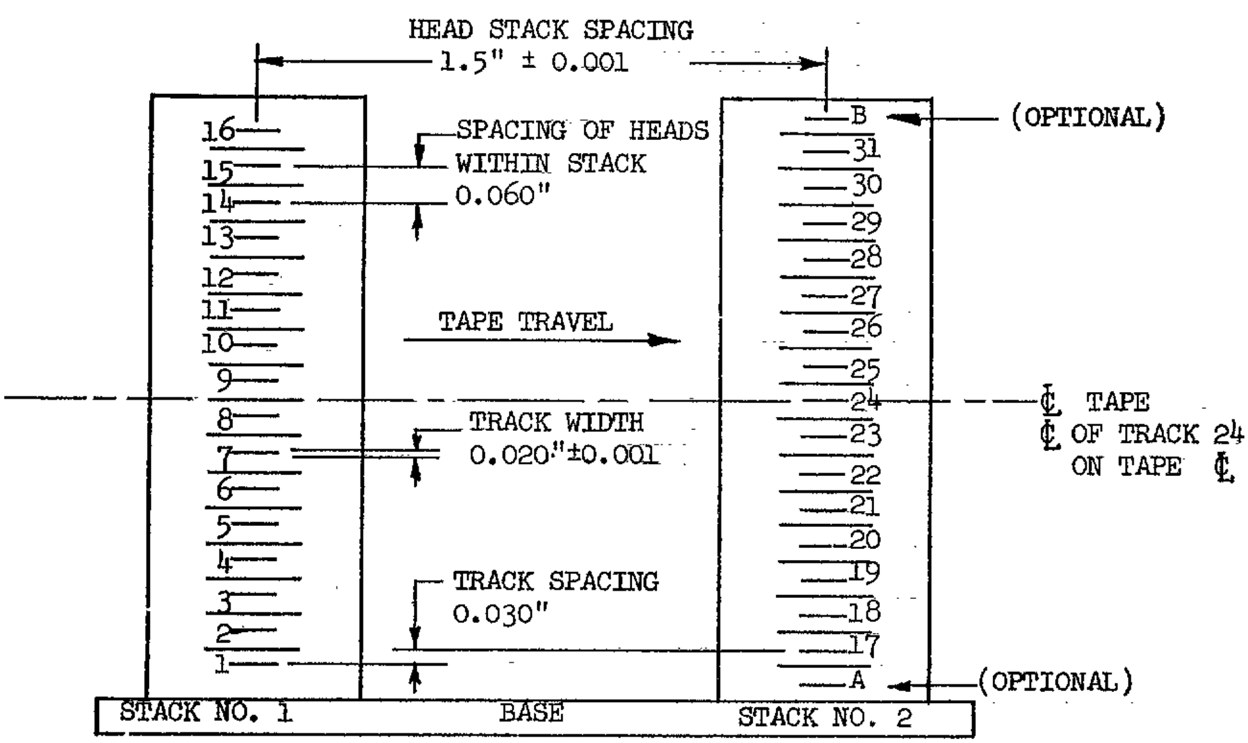
OXIDE SIDE OF TAPE
31 TRACK SYSTEM

PCM TRACK SYSTEM

Fig. 6



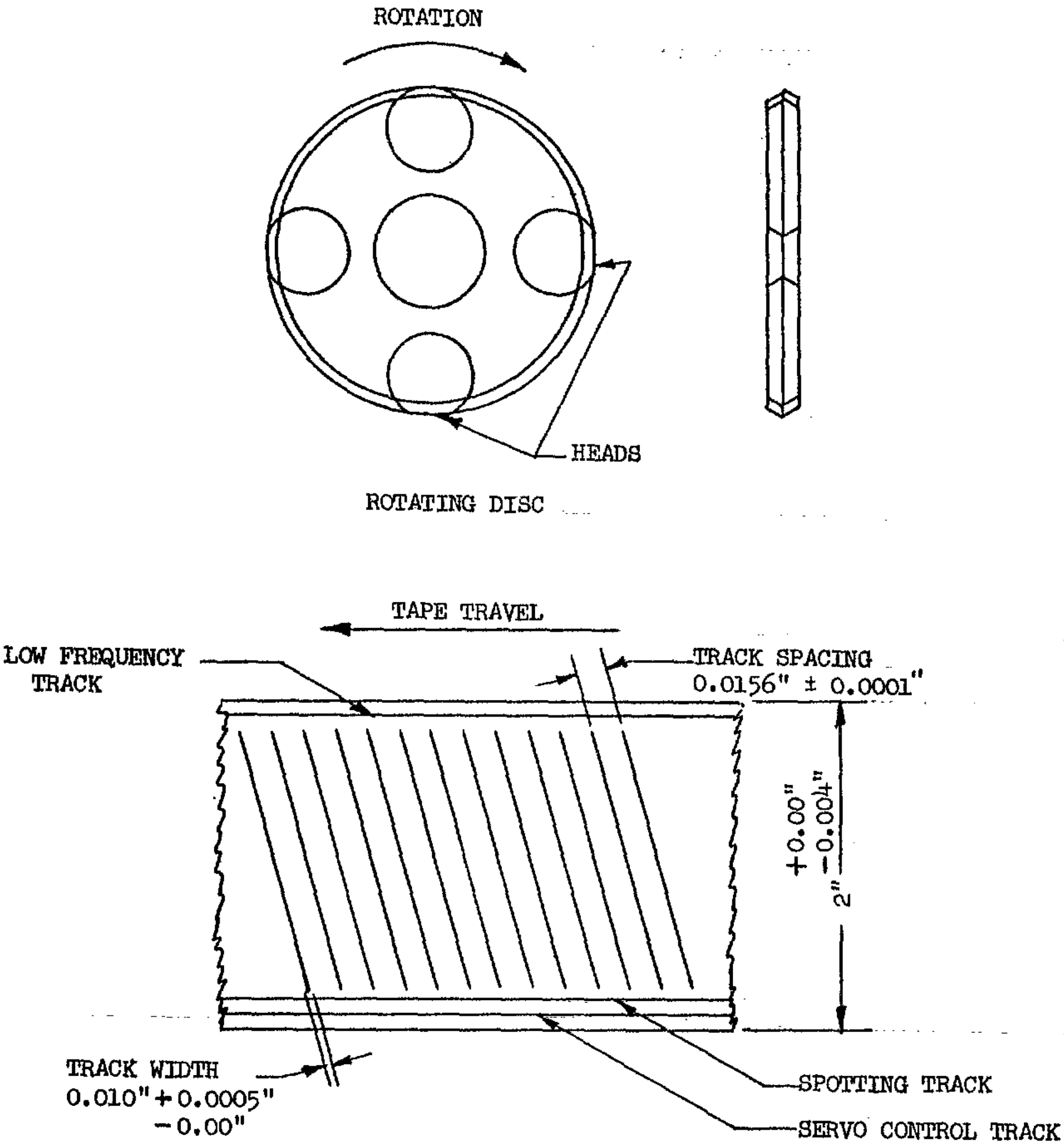
16 TRACK SYSTEM



31 TRACK SYSTEM

Fig. 7

PCM HEAD CONFIGURATION



VIDEO TAPE GEOMETRY

Fig. 8

PART-7 STANDARDS FOR TESTING FOR SPEED ERRORS IN INSTRUMENTATION TYPE MAGNETIC TAPE RECORDERS

7.1 Scope

This standard defines procedures to be used in testing for speed errors in instrumentation type magnetic tape recorders.

Inasmuch as tape and recorder performance are interrelated this standard attempts to insure that the effects of the tape on the recorder measurements are minimized by the particular test procedure.

This standard defines procedures only. The actual performance data will be entered by the tester on the Standard Performance Sheet shown in Figure 9.

7.2 Test Definitions

7.2.1 Speed errors are defined as all distortions in recording and playback which are exhibited as apparent frequency changes.

7.2.2 Absolute speed is defined as the speed at which the tape moves by the heads. For the purpose of this standard, absolute tape speed is the average of five consecutive measurements taken in 1/12 second as described in Section 7.4.1.

7.2.3 Instantaneous Speed Error (without high frequency effects) is defined as the instantaneous speed at which the recorder is reproducing a tape with respect to the speed at which the tape was recorded with all speed effects that occur at rates in excess of 8 cycles/second removed.

7.2.4 Speed errors (wow-and-flutter effects) are defined as the cumulative sum of record and reproduce speed errors produced by instantaneous mechanical characteristics of the recorder when recording and reproducing are not performed simultaneously.

7.3 Test Conditions

7.3.1 General

Each of the error measurements must use a complete reel of tape of the largest size the recorder normally accommodates. If extension arms are used to obtain greater capability, this must be stated and a test made on each alteration. The tape used shall be of random choice from commercially available stock, and the type and manufacturer shall be stated. A complete set of measurements shall be made on one reel of tape, and then repeated on a new reel of tape until five complete tests have been run. The results of these measurements, when averaged, give the final results to be entered in the Standard Performance Sheet. All of the described tests are with the recorder adjusted as stipulated by the recorder manufacturer, and the recorder shall not be readjusted for respective tests.

7.3.2 Calibration

The following procedure determines the standard calibration which is used to arrive at the percentage error figures. Connect the audio oscillator directly to the frequency discriminator input (see Figure 10) and adjust the audio oscillator for the discriminator center frequency while monitoring it with a frequency meter. Display the discriminator output on the direct-coupled oscilloscope and observe the amount that the oscilloscope trace is displaced as the oscillator is readjusted to produce a definite discriminator deviation, e.g., plus 1% of plus 10% of center frequency. The percent deviation of the discriminator causing this displacement is called the Calibrated Deviation.

7.4 Test Procedures

7.4.1 Absolute speed (for Part 7) is the speed per second at which the tape moves by the heads and will be measured in the following manner:

A precision 60 cycle/second source (0.02% or greater accuracy) shall be used to generate a 60 cycle/second square wave. The square wave at a tape speed of 60 IPS (see Figure 11). This signal shall be recorded at a minimum of three places (beginning, center, and end) on a full reel of tape. The three recorded sections of tape will be removed and "developed" with an iron oxide solution. The spacing between five consecutive recorded spikes will be measured on a universal Telereader or equivalent reader. (See Figure 12).

7.4.2 Instantaneous speed error (without high frequency effects) is the speed at which the recorder is reproducing a tape with respect to the speed at which tape was recorded, and will be measured in the following manner:

A complete reel of tape will be recorded with a constant frequency (see Figure 13) (at normal record level) as specified in Table XIII

TABLE XIII

Frequency Recommendations for Measurement of Instantaneous Tape Speed Errors

60 IPS	50 kc
30	25 kc
15	10 kc
7 1/2	5.4 kc
3 3/4	2.3 kc
1 7/8	1.3 kc

All frequencies will be crystal derived of 0.02% (or greater) stability.

The tape will be reproduced with the recorder output signal supplying a discriminator (EMR Model 67F or equivalent) (See Figure 14). The discriminator will use a low pass filter of 8 cps cutoff frequency. The discriminator output will be connected to a DC oscilloscope (such as Tektronix Model 535). The discriminator and oscilloscope will be calibrated as a unit so that a given frequency deviation, e.g. plus 1% of plus 10% of center frequency will produce an oscilloscope deflection of plus one centimeter. The oscilloscope sweep rate will be adjusted to five seconds per centimeter for visual observation or for photographing speed variations, (see Figure 14).

Both of these tests must be performed before the recorder speed performance can be determined.

7.4.3 Speed errors (wow-and-flutter) are the cumulative sum of all record and reproduce speed errors produced by instantaneous mechanical properties of the recorder when recording and reproducing are not performed simultaneously, and will be measured in the following manner:

A complete reel of tape will be recorded (all channels) with a constant 50 kcps frequency (at normal record level) for tape speeds of 60 IPS and 30 IPS (see Figure 15). For measurements at other tape speeds, the frequencies outlined in Table XIII, Section 7.4.2 are recommended. All reference frequency sources will be crystal derived of 0.02% (or greater) stability.

The recorded tape will be reproduced with the recorder output signal (from the desired channel) supplying a discriminator (EMR 67F or equivalent). The discriminator output will be connected to a DC oscilloscope (such as Tektronix Model 535). The discriminator and oscilloscope will be calibrated as a unit (see Section 7.3.2) so that a given frequency deviation, e.g. plus 1% of plus 10% of center frequency will produce an oscilloscope deflection of plus one centimeter (or a convenient deflection for measurement being made). The oscilloscope sweep rate will be adjusted to five seconds per centimeter (minimum) in order to display both low frequency (wow) and high frequency (flutter) effects. The discriminator low pass filter will be selected to cover respective areas of interest. Recommended low pass filters are:

a. 0 - 450 cps

b. 0 - 2100 cps

c. 0 - 10000 cps

Various sections of the speed error (wow-and-flutter) spectrum can be examined by use of a variable filter (such as SKL) supplied by the discriminator output (with a discriminator 0-10000 cps low pass filter). When using such an active variable filter, the filter gain must be unity in order to preserve the calibration, and it must be recognized that the DC to 20 cps (approximate) bandpass is also eliminated because of the AC coupling used in the filter.

7.5 Equipment

Test equipment other than that specified below may be used provided it will produce equivalent results.

7.5.1 Audio Oscillator:

Hewlett Packard Model 200-C.

7.5.2 Frequency Discriminator:

Electro-Mechanical Research sub-carrier discriminator Model 67F with low-pass filter as shown in Figure 10.

7.5.3 Vacuum Tube Voltmeter:

Ballantine Model 320.

7.5.4 Frequency Meter:

Berkeley Model 554 or Hewlett Packard 524.

7.5.5 Oscilloscope:

Tektronix Model 535.

7.6 Statement of Measurements

Test Results shall be tabulated on a Standard Performance Sheet, shown in Figure 9. The test results shall be followed by a statement of the auxiliary equipment that was used when the measurements were made. For example: an external means was used to control the speed; extension arms for 4800-ft tape reels were used, etc.

STANDARD PERFORMANCE SHEET

Data entered in this form is the result of the average of five tests made using five randomly chosen reels of magnetic recording tape.

Type ______________________ Lot No. ______________

Manufactured by ____________________________________

on a reel size of ______________-inch by __________feet in length.

Average absolute speed error is __________% of recorded frequency.

Instantaneous relative reproduce speed error is ______% of recorded frequency.

Wow-and-flutter error is:

__________% peak-to-peak of recorded frequency at 0 - 450 cps bandpass

__________% peak-to-peak of recorded frequency at 0 - 2100 cps bandpass

__________% peak-to-peak of recorded frequency at 0 - 10000 cps bandpass

Recorder Tested:

Model ____________________ Manufacturer ______________

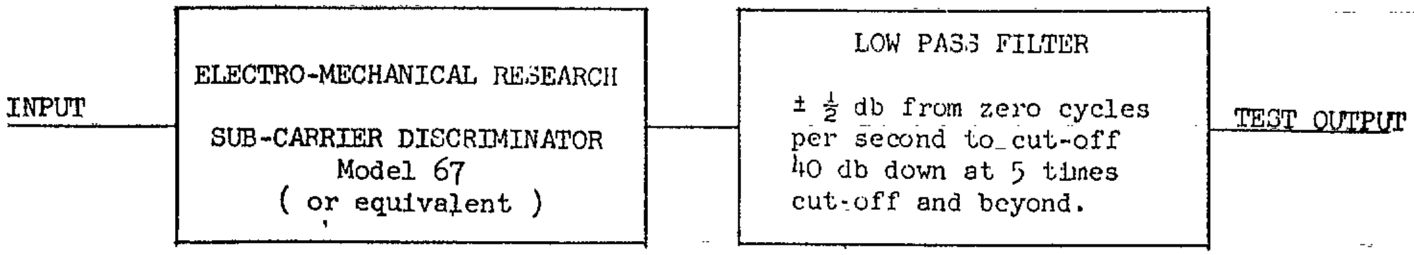
Tape Speed ______________in/sec. Number of tracks __________

Track Tested ______________________________

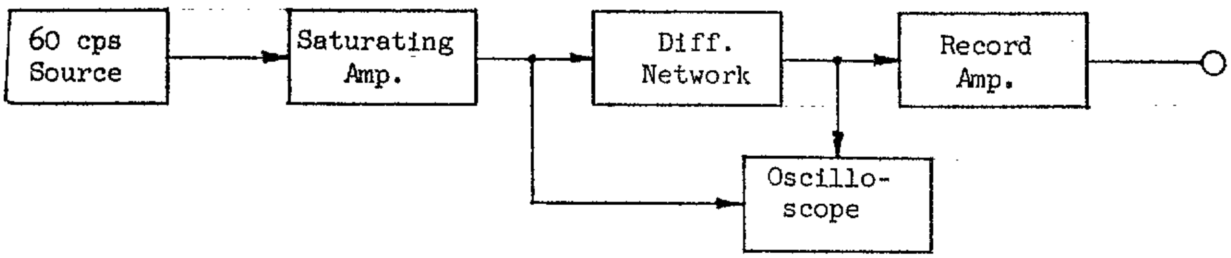
Auxiliary Equipment used in Test:

Test Equipment Used:	Manufacturer:	Model:	Serial:
Audio Oscillator			
Frequency Discriminator			
Vacuum Tube Voltmeter			
Frequency Meter			
Oscilloscope			

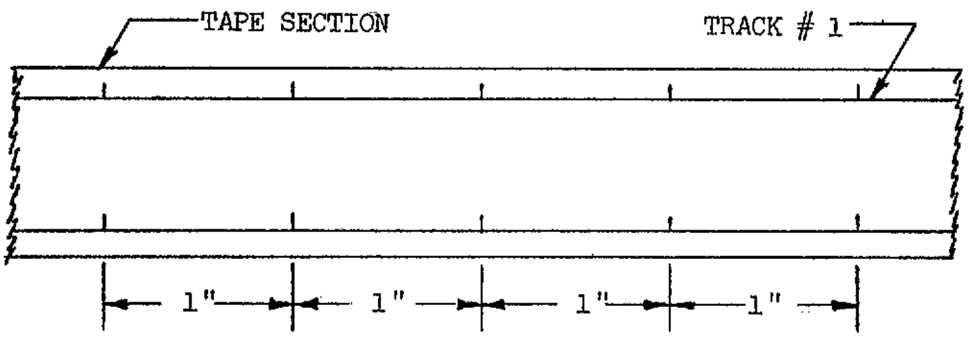
Figure 9



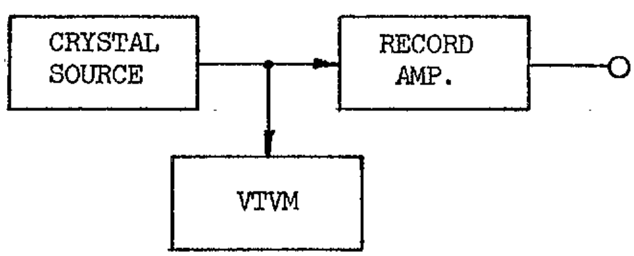
FREQUENCY DISCRIMINATOR
Fig. 10



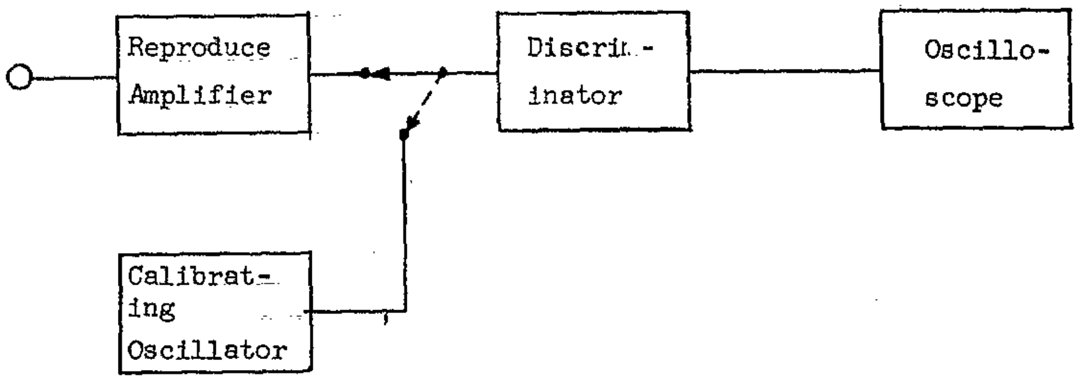
ABSOLUTE SPEED TEST SET-UP
Fig. 11



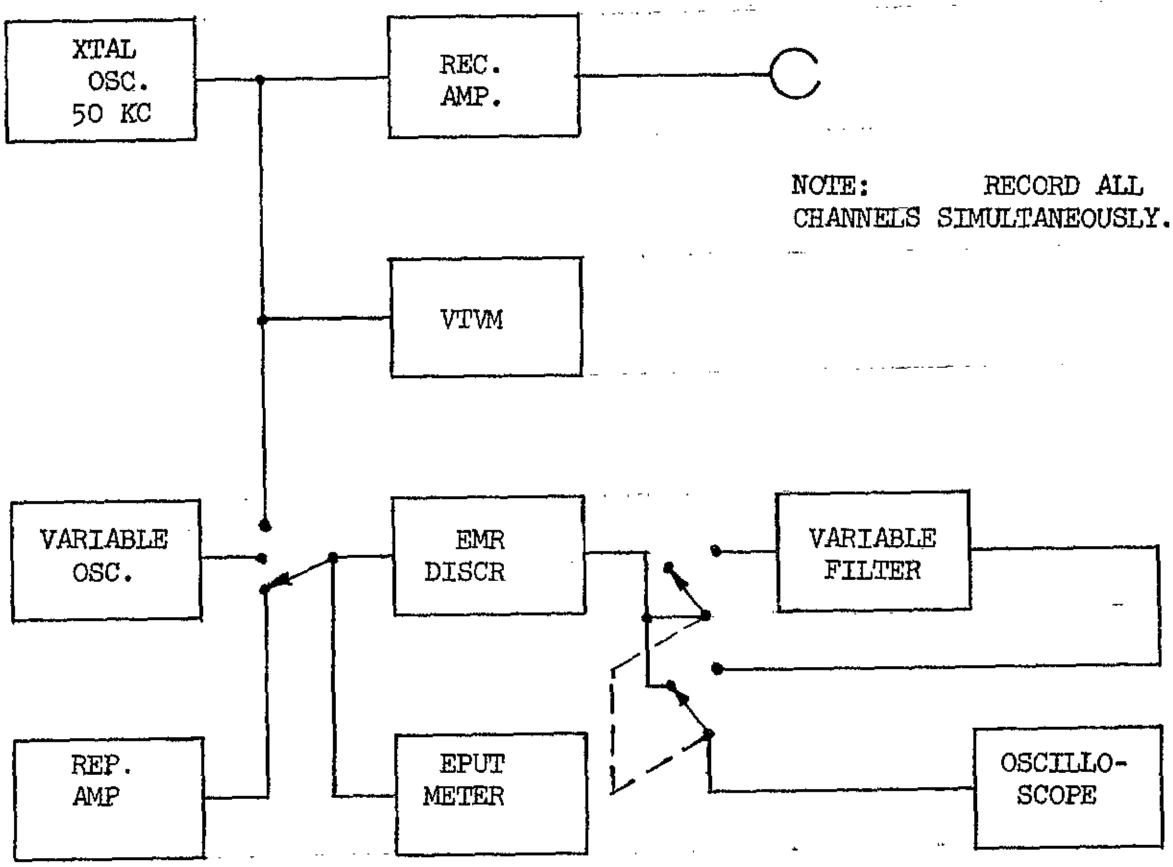
ABSOLUTE SPEED TEST MEASUREMENT
Fig. 12



RECORD SET-UP FOR MEASURING INSTANTANEOUS SPEED ERROR
Fig. 13



REPRODUCE SET-UP FOR MEASURING INSTANTANEOUS SPEED ERROR
Fig. 14



MEASUREMENTS OF SPEED ERRORS (WOW AND FLUTTER)
Fig. 15

APPENDIX I

IRIG RECOMMENDATION NUMBER 101-59

TELEMETRY

FREQUENCY UTILIZATION

PARAMETERS AND CRITERIA

REVISED JULY 1960

Inter-Range Instrumentation Group
Of The
RANGE COMMANDERS' CONFERENCE

Air Force Flight Test Center
Air Proving Ground Center
Atlantic Missile Range
Naval Ordnance Test Station
Pacific Missile Range
White Sands Missile Range

IRIG Recommendation No. 101-59

TELEMETRY FREQUENCY UTILIZATION PARAMETERS AND CRITERIA
REVISED JULY 1960

Prepared by

Frequency Coordination Working Group

Recommendation Approved 22 January 1959

This revised document was issued September 1960.
Additional copies may be obtained from:

Secretariat
Inter-Range Instrumentation Group
White Sands Missile Range, New Mexico

or

Armed Services Technical Information Agency
Arlington Hall Station, Arlington 12, Virginia

FREQUENCY UTILIZATION

PARAMETERS AND CRITERIA

(TELEMETRY FREQUENCY BANDS)

The enclosed parameters and criteria have been devised by the Frequency Coordination Working Group of the Inter-Range Instrumentation Group, with the assistance of members of the Telemetry Working Group, development groups of the three military services, and aircraft industries. The purpose of these parameters is to provide development and coordination agencies with design specifications on which to base equipment development and modification in an effort to insure interference free operation for all concerned and efficient utilization of the telemetry radio frequency spectrum.

It has long been recognized that the frequency spectrum is a limited entity, a resource which must be conserved. It has been further recognized that frequency utilization is a system problem; the transmitter-receiver link must be considered as a system. Efficiency of spectrum utilization should be a goal; susceptibility to interference should be minimized.

Wasteful use of the spectrum by any system using electromagnetic radiation and reception can have far-reaching effects in many phases of military and civil activities. It is firmly believed that unless the basic philosophy of spectrum conservation is recognized and applied by all agencies in the electronic field, (designers, manufacturers, testers and users) serious consequences are inevitable.

It is emphasized that these parameters and criteria have been devised for application at military test ranges where congestion of portions of the usable frequency spectrum is a severe problem. It is hoped that, where applicable, these same principles will be applied to other fields outside the scope of instrumentation systems.

- Date of review: May 1962

- This supersedes that portion of IRIG Document 102-56 which makes reference to the 216-260 MCS telemetry band. -

FREQUENCY PARAMETERS AND CRITERIA FOR DESIGN OF

TELEMETRY TRANSMITTER AND RECEIVER SYSTEMS

I. FREQUENCY BAND 216 - 260 MCS

216-225 MCS - Channel spacing is based on 0.5 MCS separation on the integral and one-half megacycle channels. Assignments are made on a non-interference basis to established services.

225-260 MCS - A total of 44 (500 KCS) channels, are allocated on a protected basis until 1 January 1970.

A. Efficiency of Spectrum usage (216-260 MCS Band):

1. TRANSMITTER SYSTEMS (FM/FM; PDM/FM; PAM/FM; and PCM/FM)

a. Maximum r-f deviation: plus or minus 125 KCS.

b. Transmitter Frequency Tolerance: The transmitted r-f carrier, including drift and all other variables, will be within 0.01% of the assigned carrier frequency.

c. Bandwidth: The bandwidth of the modulated carrier shall not exceed 500 KCS. Carrier components appearing outside the 500 KCS bandwidth must meet the limits for spurious and harmonic emissions as stated in paragraph e. (1) below.

d. Power: 100 watts maximum, never more than absolutely necessary.

e. Spurious and Harmonic Emissions:

(1) Spurious and harmonic emissions from the transmitting antenna system are of primary importance insofar as these criteria are concerned. Spurious and harmonic outputs, antenna conducted (i.e., measured in antenna transmission line) as well as antenna radiated (i.e., measured in free space), shall be limited to the values derived from the formula:

db (down from carrier) $= 55 + 10 \log_{10} Pt$, where Pt is the measured power output in watts.

Measurements to determine relative levels of r-f power shall be made under the following condition:

(a) Transmitter to be operated into a matched shielded dummy load with a suitable coupling device inserted in the antenna cable to sample the transmitter r-f output. As an alternative, the actual antenna can be substituted for the dummy load with provisions being made to remove the field strength meter from the influence of signals radiated from the antenna.

(b) Transmitter to be tested under conditions of zero and full normal modulation.

(c) Commercial, Category Class "I" Field Strength Measuring Equipment, as listed in current MIL-I-6181 will be used.

(2) Spruious, harmonic, and fundamental signals conducted by power leads or radiated directly from equipment units or cable (except antenna) shall be within the limits specified in the current MIL-I-6181.

f. Flexibility of operation: Shall be capable of operating on any of the following frequencies without design modification.

216.5 MCS	223.0 MCS	228.2 MCS	237.8 MCS	248.6 MCS
217.0 MCS	223.5 MCS	229.9 MCS	240.2 MCS	249.1 MCS
217.5 MCS	224.0 MCS	230.4 MCS	241.5 MCS	249.9 MCS
218.0 MCS	224.5 MCS	230.9 MCS	242.0 MCS	250.7 MCS
218.5 MCS		231.4 MCS	243.8 MCS	251.5 MCS
219.0 MCS		231.9 MCS	244.3 MCS	252.4 MCS
219.5 MCS		232.4 MCS	244.8 MCS	253.1 MCS
220.0 MCS	225.0 MCS	232.9 MCS	245.3 MCS	253.8 MCS
220.5 MCS	225.7 MCS	234.0 MCS	245.8 MCS	255.1 MCS
221.0 MCS	226.2 MCS	235.0 MCS	246.3 MCS	256.2 MCS
221.5 MCS	226.7 MCS	235.5 MCS	246.8 MCS	257.3 MCS
222.0 MCS	227.2 MCS	236.2 MCS	247.3 MCS	258.5 MCS
222.5 MCS	227.7 MCS	237.0 MCS	247.8 MCS	259.7 MCS

NOTE: All telemetry assignments within the 225-260 MCS band shall conform with the above assignments. No change in assignments in the 216-225 MCS band is contemplated. However, it should be kept in mind that telemetry assignments in the 216-225 MCS band are on a non-interference basis to other established users.

2. RECEIVER SYSTEMS (FM/FM, PDM/FM; PAM/FM; and PCM/FM):

a. Maximum bandwidth between 60 db points: 600 KCS.

b. Receiver Stability: 0.005%

c. Spurious receiver responses: More than 60 db below fundamental frequency response.

d. Spurious emissions: Oscillator energy, either radiated from the unit or antenna conducted, shall be within the limits specified in current MIL-I-6181.

e. Flexibility of Operation: Shall operate on any of the frequencies listed under PARA.I.A.I.f. without design modification.

II. FREQUENCY BAND 1435 - 1535 MCS

Channel spacing of the 1435-1535 MCS band should be on increments of 1 MCS.

The 1435-1485 MCS portion of the band should be reserved primarily for use in connection with aeronautical flight testing of manned aircraft.

The 1486-1535 MCS portion of the band should be reserved primarily for use in connection with aeronautical flight testing of missile and space vehicles.

A. Efficiency of Spectrum Usage

1. TRANSMITTER SYSTEMS (1435-1535 MCS Band)

a. Transmitter frequency tolerance: The transmitter r-f carrier, including drift and all other variables, shall be within .005% of the assigned carrier frequency.

b. Power: As dictated by intended use, never more than absolutely necessary.

c. Spurious and Harmonic Emissions: Spurious and harmonic emissions from the transmitting antenna system are of primary importance insofar as these criteria are concerned. Spurious and harmonic outputs, antenna conducted (i.e., measured in antenna transmission line) as well as antenna radiated (i.e., measured in free space), shall be limited to the values derived from the formula:

db (down from carrier) = 55 plus 10 $\log_{10}$Pt, where Pt is the measured power output in watts

d. Spurious, harmonic, and fundamental signals conducted by power leads or radiated directly from equipment units or cables (except antenna) shall be within the limits specified in the current MIL-I-6181 specifications.

e. Measurements to determine relative levels of spurious and harmonic signals shall be made under the following conditions:

(1) Transmitter to be operated into a matched shielded dummy load with a suitable coupling device inserted in the antenna cable to sample the transmitter r-f output. As an alternative, the actual antenna can be substituted for the dummy load with provisions being made to remove the field strength meter from the influence of signals radiated from the antenna.

(2) Transmitter to be tested under conditions of zero and full normal modulation.

(3) Commercial, Category Class "I" Field Strength Measuring Equipment, as listed in current MIL-I-6181, will be used.

f. Flexibility of Operation: The r-f transmitter shall be capable of operating throughout the entire frequency band 1435-1535 MCS without design modification.

2. RECEIVER SYSTEMS (1435 - 1535 MCS Band)

a. Receiver stability: .001%

b. Spurious receiver responses: More than 60 db below fundamental frequencies.

c. Spurious Emissions: Oscillator energy either radiated from the unit or antenna conducted shall be within the limits specified in the current MIL-I-6181.

d. Flexibility of operation: Tunable over the entire 1435-1535 MCS band without design modification and with variable bandwidth selection.

3. BANDWIDTHS

a. In specifying bandwidths, the transmitter and receiver shall be considered as a system. Designer should be required to adhere to rigid engineering design practices to conserve frequency spectrum. Each system should be subjected to a critical review as to the amount of information contained in a given bandwidth versus type of modulation. Designer should be required to demonstrate and prove system design in order to justify frequency spectrum usage.

b. As a general guideline it is anticipated that for a deviation of plus or minus 125 KCS a maximum of 1 MCS bandwidth as reference to the 60 db points will be permitted. For a wide band system with a deviation of plus or minus 1.4 MCS a maximum of 10 MCS as reference to the 60 db points will be permitted. Also for PCM systems signal bandwidth in CPS at 3 db points can be roughly calculated by 1.5 times the bit rate and the bandwidth in CPS at the 60 db points can be calculated by 3.6 times the bit rate. It is anticipated the maximum bit rate will be 1×10^6 per second and the minimum bit rate will be 50×10^3 per second. Bandwidth for telemetry systems in excess of 10 MCS as reference to th 60 db points shall not be used. Bandwidth requirements for transmission of video (television) shall be considered on a case-to-case basis. For further information refer to IRIG Telemetry Standards.

III, FREQUENCY BAND 2200 - 2300 MCS

Channel spacing of the 2200-2300 MCS band shall be on increments of 1 MCS.

A. Efficiency of Spectrum Usage

1. TRANSMITTER SYSTEMS (2200 - 2300 MCS)

a. Transmitter Frequency Tolerance: The transmitted r-f carrier, including drift and all other variables, shall be within .005% of the assigned carrier frequency.

b. Power: As dictated by intended use, never more than absolutely necessary.

c. Spurious and Harmonic Emissions: Spurious and harmonic emissions from the transmitting antenna system are of primary importance insofar as these criteria are concerned. Spurious and harmonic outputs, antenna conducted (i.e., measured in antenna transmission line) as well as antenna radiated (i.e., measured in free space), shall be limited to the values derived from the formula:

db (down from carrier) = 55 plus 10 $\log_{10}$ Pt, where Pt is the measured power output in watts.

d. Spurious, harmonic, and fundamental signals conducted by power leads or radiated directly from equipment units or cable (except antenna) shall be within the limits specified in the current MIL-I-6181 specifications.

e. Measurements to determine relative levels of spurious and harmoic signals shall be made under the following conditions:

(1) Transmitter to be operated into a matched shielded dummy load with a suitable coupling device inserted in the antenna cable to sample the transmitter r-f output. As an alternative, the actual antenna can be substituted for the dummy load with provisions being made to remove the field strength meter from the influence of signals radiated from the antenna.

(2) Transmitter to be tested under conditions of zero and full normal modulation.

(3) Commercial, Category Class "I" Field Strength Measuring Equipment, as listed in current MIL-I-6181, will be used.

f. Flexibility of Operation: The r-f transmitter shall be capable of operating throughout the entire frequency band 2200-2300 MCS without design modification.

2. RECEIVER SYSTEMS (2200 - 2300 MCS)

a. Receiver stability: .001%

b. Spurious receiver response: More than 60 db below fundamental frequencies.

c. Spurious emissions: Oscillator energy either radiated from the unit or antenna conducted shall be within the limits specified in the current MIL-I-6181.

d. Flexibility of Operation: Tunable over the entire 2200-2300 MCS band without design modification and with variable bandwidth selection.

3. BANDWIDTHS

a. In specifying bandwidths the transmitter and receiver shall be considered as a system. Designer should be required to adhere to rigid engineering design practices to conserve frequency spectrum. Each system should be subjected to a critical review as to the amount of information contained in a given bandwidth versus type of modulation. Designer should be required to demonstrate and prove system design in order to justify frequency spectrum usage.

b. As a general guideline it is anticipated that for a deviation of plus or minus 125 KCS a maximum of 1 MCS bandwidth as reference to the 60 db points will be permitted. For a wide band system with a deviation of ± 1.4 MCS a maximum of 10 MCS as referenced to the 60 db points will be permitted. Also for PCM systems, signal bandwidth in CPS at 3 db points can be roughly calculated by 1.5 times the bit rate and the bandwidth in CPS at the 60 db points can be calculated by 3.6 times the bit rate. It is anticipated the maximum bit rate will be 1×10^6 per second and the minimum bit rate will be 50×10^3 per second. Bandwidth in excess of 10 MCS for telemetry systems as reference to the 60 db points shall not be used. Bandwidth requirements for transmission of video (television) shall be considered on a case-to-case basis. For further information refer to the IRIG Telemetry Standards.

APPENDIX II

Glossary of Terms Used in Telemetry Standards

Accuracy

Accuracy is a measure of conformity to a specified value.

Amplitude

A measure of the departure of a phenomenon from any given reference. Applied to vibratory conditions it pertains generally to the peak magnitude of the acceleration applied.

Analog to Digital Conversion

A process by which a sample of analog information is transformed into a digital code.

Analog to Digital Converter (Also called Digitizer, ADC, and Encoder)

A device which will convert an analog voltage sample to an equivalent digital code of some finite resolution.

Analog Voltage

A voltage that varies in a continuous fashion in accordance with the magnitude of a measured variable.

Attenuation

The relationship, in complex notation, between the input stimulus and the output response of a system or device. As generally employed, attenuation implies amplitude or power reduction and corresponding phase change of a stimulus or signal between the input and output of a system or device.

Automatic Zero and Full Scale Calibration Correction

Zero and sensitivity stabilization by utilization of electronic servos for continuous comparison of demodulated "zero" and full scale signals with "zero" and full scale reference voltages.

Band

A bounded continuous portion of a frequency spectrum.

Barker Code

A binary code suitable for PCM frame synchronization having optimal correlation properties with the unique property, when decoded, of relative immunity to phase displacement by random pulses immediately adjacent to the pattern, and relative immunity to phase displacement by error in the transmitted code. The Barker Codes are 3-bit: 110; 7-bit: 1110010; 11-bit: 11100010010.

Reference: Communication Theory; Willis Jackson; Academic Press Inc., London 1953; "Papers read at a Symposium 'Applications of Communication Theory' held at Institution of Electrical Engineers, London, September 22-23, 1952".

Bias Set Frequency

In direct magnetic tape recording, a specified recording frequency employed during the adjustment of bias level for optimum record performance. (Not the bias frequency).

Binary Code

A code composed of a combination of characters each of which can assume one of two possible states and which is identifiable in time and space.

Binary Coded Decimal System

A system of number representation in which each of the decimal digits is expressed by binary numbers.

Binary Number System

A number system which uses two symbols (usually denoted by "0" and "1") and therefore has 2 as its base, just as the decimal system uses ten symbols (0, 1, 2.....9) and has the base ten.

Bit

A quantity of intelligence which is carried by an indentifiable entity and which can exist in either of two states (an abbreviation of binary digit).

Bit Rate

The frequency derived from the period of time required to transmit one bit (leading edge to leading edge).

Blanking Level

Level of multiplexed signal between channel pulses.

Carrier

A wave suitable for being modulated to transmit intelligence. The modulation represents the information; the original wave is used only as a "carrier" of the modulation.

Carrier Frequency

In a periodic carrier, the reciprocal of its period. In a PCM system the carrier frequency is the midpoint between the deviation limits.

Channel

The route required to convey the specified characteristic of a single telemetric measurand.

Channel Interval

Time allocated to a channel including ON and OFF time.

Channel Pulse Synchronization

Synchronization of local channel rate oscillator by comparison and phase-lock with separate channel synchronizing pulses.

Channel Sampling Rate

Number of times per second individual channels are sampled.

Note: Use of "channel sampling rate" to designate commutation rate, or commutator switching rate is not recommended because of likelihood of confusion in terms.

Channel, Subcarrier

The channel required to convey telemetric information involving a subcarrier band.

Channel Translator

A device which converts individual separated channel pulses or signals derived therefrom to analog form for subsequent monitoring and/or recording. Alternate names for channel translator are channel demodulator, channel decoder, information gate.

Clock Pulse

A pulse used for timing purposes. In PCM systems, a timing pulse which occurs at the bit repetition rate.

Closed Loop Telemetry

(1) A telemetry system which is used as the indicating portion of a remote control system.

(2) A system used to check out test vehicle and/or telemetry performance without radiation of r-f energy.

Code

A system of characters and rules for representing information (IRE).

Commutation

Sequential sampling, on a repetitive time sharing basis, of multiple data sources for transmitting and/or recording on a single channel.

Commutation Duty Cycle

Channel dwell period expressed as percent of channel interval.

Commutation Frame Period

Time required for sequential sampling of all input signals. This period would correspond to one revolution of a simple multicontact rotary switch.

Commutation Rate

Number of commutator inputs sampled per second.

Commutator

A device used to accomplish time division multiplexing by repetitive sequential switching.

Commutator Channel Dwell Period

Channel ON time.

Commutator Segment

One of the stationary contacts of a mechanical commutator.

Compensation Signals

A compensation signal is a signal recorded on the tape, along with the data and in the same track as the data, which is used during the playback of data to electrically correct for the effects of tape speed errors.

Cross Talk

Interference in a given transmitting or recording channel which has its origin in another channel. Often used as equivalent to transverse sensitivity.

Cycle

A cycle is defined as a completed scheduled sequence of events, i.e., a frame cycle would be the sequence of samples from all the prime channels.

Decommutator

Equipment for separation, demodulation or demultiplexing commutated signals.

Deviation

In frequency modulation, the difference between the instantaneous frequency of the modulated wave and the carrier center frequency.

Deviation Ratio

Deviation Ratio is given by $m = \frac{\Delta f}{f_{max}}$ where Δf is the maximum frequency difference between the modulated carrier and the unmodulated carrier and f_{max} is the maximum modulation frequency.

Differential Flutter

Speed change errors occurring at different magnitudes, frequencies or phases across the width of the tape.

Digital

Expressing value in terms of numbers. Measurable in discrete, discontinuous steps.

Digital Magnetic Tape Recording

The method of recording binary coded information using two discrete flux levels.

Digital Resolution

The value of the least significant digit in a digitally coded representation.

Digitizer

A device which converts analog data into numbers expressed in digits in a system of notation.

Direct Recording, Magnetic Tape

The method of recording using high frequency bias in which the input (electrical) signal is delivered to the recording head unaltered in form.

Dropout

Any discrete variation in signal level during the reproduction of recorded data which results in a data reduction error.

Discriminator, FM

A device which converts variations in frequency to proportional variations in voltage or current.

Error

The difference between the indicated value and the true value of the measurand.

FM/AM

Amplitude modulation of a carrier by subcarrier(s) which is (are) frequency modulated by information.

FM/FM

Frequency modulation of a carrier by subcarrier(s) which is (are) frequency modulated by information.

FM/PM

Phase modulation of a carrier by subcarrier(s) which is (are) frequency modulated by information.

FM Discriminator (Subcarrier)

A device which converts frequency variations to proportional variations in the amplitude of an electrical signal. Discriminators may be of several basic types, such as: Pulse Averaging, Foster Seely, Ratio Detector, Phase-Lock Correlation Detector.

Frame

In time division multiplexing, one complete commutator revolution. In PCM systems, a recurring integral number of words which includes a single synchronizing signal.

Frame Frequency

The frequency derived from the period of one frame.

Frame Pulse Synchronization

Synchronization of local channel rate oscillator by comparison and phase-lock with separated frame synchronizing pulses.

Frame Rate

The frequency derived from the period of one frame.

Frame Synchronization Signal

In PAM, uniquely coded pulse or interval to mark start of commutation frame period. In PCM, any signal used to identify a frame of data.

Frequency Division Multiplex

A system for the transmission of information about two or more quantities (measurands) over a common channel by dividing the available frequency bands. Amplitude, frequency or phase modulation of the subcarriers may be employed.

Frequency Response

The portion of the frequency spectrum which can be sensed by a device within specified limits of amplitude error.

FSK-Frequency Shift Keying

Modulation accomplished by switching from one discrete frequency to another discrete frequency.

Gap Azimuth Alignment

The azimuth is the alignment of the line through the gaps relative to a line perpendicular to the precision-milled mounting pads in a plane parallel to the surface of the tape.

Gap Scatter

Gap scatter is defined as the distance which includes the trailing edges of the gaps for a record head and the center lines of the gaps for the read head.

Head Stack

A group of two or more heads mounted in a single unit for the purpose of obtaining multiple track recording or reproduction.

Head Stack Tilt

The prependicularity alignment of the front surface relative to the precision-milled mounting pads in a plane perpendicular to the surface of the tape.

High Frequency Bias

A sinusoidal signal which is mixed with the data signal during the record process on magnetic tape for purpose of increasing the linearity and dynamic range of the recorded signal. The bias frequency is usually 3 to 4 times the highest information frequency which is to be recorded.

I.F. Bandwidth

For this document, see Post Conversion Bandwidth.

Individual Gap Azimuth

The angle of a gap relative to a line perpendicular to the precision milled mounting pads in a plane parallel to the surface of the tape.

Information Gate

A device which, when triggered, allows information pulses to pass.

Inhibitor Gate

A device which, when triggered, prevents information pulses from passing.

Intermodulation

Modulation of the components of a complex wave by each other, producing new waves whose frequencies are equal to the sums and differences of integral multiples of the component frequencies of the original complex wave.

Magnetic Tape

A magnetic-oxide coated plastic tape upon which signals are recorded and stored in a magnetic recorder/reproducer system.

Magnetic Tape Recorder/Reproducer

A machine which converts electrical data signals to magnetic patterns on a magnetic tape during a recording process and/or converts the remanent magnetic patterns on a magnetic tape to electrical data signals during a reproducing process.

Maximum Record Level-Direct Recording

Maximum record level is the level of record head current required to produce 3% third harmonic distortion of the reproduced signal at the record level set frequency, when the distortion is a function of magnetic tape saturation and is not a function of electronic circuitry.

Mean Gap Azimuth

The angle between a line of least gap dispersion and a line perpendicular to the base plate in the plane of the tape.

Measurand

A physical quantity, force, property or condition being measured.

Modulation

The process of impressing information on a carrier for transmission.

AM Amplitude Modulation

PM Phase Modulation

FM Frequency Modulation

Modulation Index

In angle modulation with a sinusoidal modulating wave, the modulation index is the ratio of the frequency deviation to the frequency of the modulating wave.

Multiplexing

The simultaneous transmission of two or more signals within a single channel. The three basic methods of multiplexing involve the separation of signals by time division, frequency division and phase division.

Noise

Any unwanted disturbance or signal which degrades the desired data.

Nominal Bit Rate

Bit rate established as a specific system design center.

Normal Record Level

Normal record level is the level of record head current required to produce 1% third harmonic distortion of the reproduced signal at the Record Level Set Frequency when the distortion is a function of magnetic tape saturation and is not a function of electronic circuitry.

Octave

The interval between two frequencies having a ratio of 2:1.

PAM

Pulse Amplitude Modulation.

PAM/FM

Frequency modulation of a carrier by pulses which are amplitude modulated by information.

PAM/FM/FM

Frequency modulation of a carrier by subcarrier(s) which is (are) modulated by pulses which are amplitude modulated by information.

Parallel Recording

Parallel recording is the technique of simultaneously energizing heads in a head stack to record an ordered set of bits.

Parameter

Any physical entity to be measured.

Parity Bit

A bit added to a binary code group which is used to indicate whether or not the number of recorded "1's" or "0's" is even or odd.

Parity Check

A self-checking code employing binary digits in which the total number of 1's (or 0's) in each permissible code expression is always even or always odd. A check may be made for either even parity or odd parity.

PCM

Pulse Code Modulation-Pulse modulation of a carrier by coded information. In PCM telemetry, information transmission by means of a code representing a finite number of possible values of the information at the time of sampling.

PCM/FM

Frequency modulation of a carrier by pulse code modulated information.

PCM/FM/FM

Frequency modulation of a carrier by subcarrier(s) which is (are) frequency modulated by pulse code modulated information.

PCM/PM

Phase modulation of a carrier by pulse code modulated information.

PDM (PWM)

Pulse Duration Modulation (Pulse Width Modulation.).

PDM/FM

Frequency modulation of a carrier by pulses which are modulated in duration by information.

PDM/FM/FM

Frequency modulation of a carrier by subcarrier(s) which is (are) frequency modulated by pulses which are duration modulated by information.

PDM/PM

Phase modulation of a carrier by pulses which are duration modulated by information.

PDM Recording

The method of recording Pulse Duration Modulated telemetry data in which the signal delivered to the recording head is the differential of the input signal.

Peak-To-Peak

Pertaining to the maximum algebraic difference between two or more stimuli or signals.

Pedestal, PAM

An arbitrary minimum signal value assigned to provide for channel synchronization and decommutation.

Post Conversion Bandwidth

The bandwidth presented to the detector.

PPM

Pulse Position Modulation

PPM/AM

Amplitude modulation of a carrier by pulses which are position modulated by information.

Predetection Recording

Recording of a receiver I.F. frequency.

Prime Channels

The channels which are sequentially sampled by the basic commutator of the system.

Prime Frame

A group of words resulting from a complete sampling of the prime channel.

Quantization

The process of converting from continuous values of information to a finite number of discrete values.

Quantization Error

The difference between actual values of information and the corresponding discrete values resulting from quantization.

Quantization Noise

Inherent noise resulting from quantization.

Radio Telemetry

Telemetry in which an r-f link is used as a portion of the transmission path.

Range

The range is the statement of the quantitative limits of the system.

Read

See Reproduce, Magnetic Tape.

Record, (Magnetic Tape)

The process by which an electromagnetic transducer (record head) and associated electronic circuitry convert electrical data to a magnetic flux pattern on a magnetic tape.

Record Head

An electromagnetic transducer used during the record process for inducing magnetic patterns into the magnetic tape.

Reliability

A measure of the probability that an instrument will continue to perform within specified limits of error for a specified length of time under specified conditions.

Repeatability

The ability of a system to repeat a measurement of a fixed stimulus to a specified accuracy.

Reproduce (Playback), Magnetic Tape

The process by which an electromagnetic transducer (reproduce head) and associated electronic circuitry convert the magnetic flux pattern on a magnetic tape to an electrical signal containing the recorded information.

Reproduce Head

An electromagnetic transducer which converts the remanent flux patterns in a magnetic tape into electrical signals during the reproduce process.

Serial Recording, PCM

The technique of recording a train of bits on a single track.

Signal

The output, or intelligence, emanating from a device.

Signal Leakage

Interference in a given playback channel which has its origin in the record system, shunting the tape. This interference occurs during simultaneous record/reproduce and has a leading time displacement with reference to the signal on the tape.

Single Carrier FM Recording

The method of recording in which the input signal is frequency modulated onto a carrier and the carrier is recorded on a single track at saturation and without bias.

Skew

Tape motion characterized by an angular velocity between the gap center line and a line perpendicular to the tape center line.

Speed Control Signal

A signal recorded for the control of tape speed during the playback process.

Standard

A value or a concept that has been established by authority, custom, or agreement, to serve as a model or rule in the measurement of a quantity or in the establishment of a practice or procedure.

Standardization

The act or process of reducing something to, or comparing it with, a standard.

Stimulus

The cause which produces change.

Subcarrier

A carrier which is applied as a modulating wave to modulate another carrier or an intermediate subcarrier.

Subcarrier Band

A band associated with a given subcarrier and specified in terms of maximum subcarrier deviation.

Subcarrier Composite

Two or more subcarriers combined in a frequency division multiplexing scheme.

Subcommutation

Commutation of additional channels with output applied to individual channel of the primary commutator. Subcommutation is synchronous if its rate is a submultiple of that of the primary commutator. Unique identification must be provided for the subcommutation frame pulse.

Subcommutation Frame

In PCM systems, a recurring integral number of subcommutator words which includes a single subcommutation frame synchronization word. The number of subcommutator words in a subcommutation frame is equal to an integral number of primary commutator frames. The length of a subcommutation frame is equal to the total number of words or bits generated as a direct output of the subcommutator.

Supercommutation

Commutation at a higher rate by connection of single data input source to equally spaced contacts of the commutator (crosspatching). Corresponding crosspatching is required at the decommutator.

Synchronizing Pulse Selector

Unit for separating synchronizing pulses from commutated pulse trains.

Tape Speed Errors

Any variation of the tape speed from its nominal speed over the record or reproduce head regardless of cause.

Tape Speed Error Compensation

The process of correcting for tape speed errors electrically.

Telemetering

A measurement accomplished with the aid of intermediate means which allows perception, recording or interpretation of data at a distance from a primary sensor. The widely employed interpretation of telemetering restricting its significance to data transmitted by means of electromagnetic propagation is more properly called Radio Telemetry.

Telemetry

The science of measuring a quantity or quantities, transmitting the results to a distant station, and there interpreting, indicating and/or recording the quantities measured.

Time Division Multiplex

A system for the transmission of information about two or more quantities (measurands) over a common channel by dividing available time intervals among the measurands to form a composite pulse train. Information may be transmitted by variation of pulse duration, pulse amplitude, pulse position, or by a pulse code. Abbreviations used are PDM, PAM, PPM and PCM respectively.

Timing Signal

Any signal recorded simultaneously with data to provide a time index.

Track

A portion of a magnetic tape whose width and position on the magnetic tape is specified. A track extends throughout the entire length of a reel of tape and always exists regardless of its state of magnetization.

Track Spacing

The center to center distance between adjacent tracks on a magnetic tape.

Transducer, Instrumentation

A device which responds to a phenomenon and produces a signal which is a function of one or more characteristics of the phenomenon.

Transverse Recording

The technique of recording with rotating heads which are oriented perpendicular to the edge and the surface of the tape.

Transverse Sensitivity, Tape Recording

Susceptibility of a track to interference from flux patterns generated by adjacent record heads.

Variable-Erase Recording

The method of recording on magnetic tape by selective erasure of a pre-recorded signal.

Video Recording (Magnetic Tape)

The methods of recording information having a bandwidth in excess of 100 kilocycles on a single track.

Word

An ordered set of bits processed as a unit.

Word Rate

The frequency derived from the elapsed period between the beginning of transmission of one word and the beginning of transmission of the next word.

Write

See Record, Magnetic Tape.