
International Standard



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Information processing — Recording characteristics of instrumentation magnetic tape (including telemetry systems) — Interchange requirements

Traitement de l'information — Caractéristiques d'enregistrement de la bande magnétique de mesure (y compris les systèmes de télémesure) — Spécifications d'échanges

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Foreword

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Information processing — Recording characteristics of instrumentation magnetic tape (including telemetry systems) — Interchange requirements

1 Scope and field of application

This International Standard specifies the tape and recorder/reproducer characteristics and modes of recording to enable users of different systems to interchange information recorded on instrumentation magnetic tape.

Modulation patterns are described in clause 6.

Test procedures recommended for use in measuring performance parameters of magnetic tape recorder and reproducer systems are described in annex B.

Annexes C to F provide additional information but do not form part of this International Standard. The characteristics of unrecorded tape are specified in ISO 6371.

2 References

ISO 1858, *Information processing — General purpose hubs and reels, with 76 mm (3 in) centre hole, for magnetic tape used in interchange instrumentation applications.*

ISO 1860, *Information processing — Precision reels for magnetic tape used in interchange instrumentation applications.*

ISO 3802, *Information processing — General purpose reels with 8 mm (5/16 in) centre hole for magnetic tape for interchange instrumentation applications.*

ISO 6371, *Information processing — Interchange practices and test methods for unrecorded instrumentation magnetic tape.*

3 Definitions

The following terms have a special technical meaning in this International Standard, and no attempt is made to lay down definitive terminologies outside the specific context of this International Standard.

3.1 bi-phase (or Bi- ϕ) : Form of representation for binary "1" and "0" in pulse code modulation (PCM). Three variants, known as "level", "mark" and "space", are defined in 6.3.3 and figure 1.

3.2 data azimuth¹⁾ : Angle in the plane of the tape, at any instant in time, between a line perpendicular to the reference edge of the tape and either of the two parallel lines defining data scatter.

NOTE — Data azimuth may be expressed as the sum of static and dynamic components in the form :

$$A + Bf(t)$$

where

$$\int_0^t f(t) dt = 0$$

3.3 data azimuth (dynamic)¹⁾ : Maximum angular deviation, over a period of time, of the data azimuth from its mean value as defined by data azimuth (static). For the purposes of this definition, the word maximum is interpreted as being at the 95 % probability level. For a Gaussian distribution, this is two standard deviations (2σ).

NOTE — Data azimuth (dynamic) is the maximum value of the quantity $Bf(t)$ in the note on data azimuth.

3.4 data azimuth (static)¹⁾ : Mean value, over a period of time, of the data azimuth.

NOTE — Data azimuth (static) is the quantity A in the note on data azimuth.

3.5 data scatter¹⁾ : Minimum distance between two parallel lines, in the plane of the tape, between which all data transitions recorded in the same head, at the same time, shall fall.

3.6 data spacing : Distance on the tape between simultaneous events recorded on odd and even numbered tracks, when interlaced heads are used.

NOTE — On recording, this is equal to the head spacing, but on reproducing is only exactly equal to head spacing when record and reproduce tensions are equal. Different record and reproduce tensions will give rise to small errors in time correlation between the signals from the two heads.

1) The errors in location and angular relation among transient data recorded simultaneously on all odd or even tracks are defined by the terms : data azimuth, data scatter, and individual track data azimuth difference. These are approximately equivalent to the terms : head azimuth, gap scatter and head segment gap azimuth difference; however, guiding misalignment is included in the data location error definitions.

3.7 duty factor (of a pulse) : Percentage occupancy of pulse duration within a pulse period or time-slot.

3.8 edge margin (M) : Distance between the outside edge of the highest numbered track and the tape edge (see figure 5).

3.9 edge margin, minimum (M_m) : Minimum allowable value of edge margin.

NOTE — This value places an additional constraint on track configurations since, in general, the simultaneous application of all worst case tolerances for track width, track location and tape width will result in a value of edge margin less than M_m .

3.10 frequency division multiplex (FDM) : Multiplexing technique in which modulated subcarriers are combined in such a way that each of a number of data channels occupies a unique and defined section of the available bandwidth.

3.11 frame, major : The minimum overall repetitive sequence of pulses, in which each input channel is sampled at least once. The period of the major frame is determined by the length of the longest submultiple frame(s).

3.12 frame, minor : A group of data pulses or samples; it includes and ends with a synch. pulse or pattern. The minor frame is an integral submultiple of the major frame and, in the absence of subcommutation, is repetitive and equal to the major frame.

3.13 frame, submultiple : A repetitive group of subcommutated data pulses. Supercommutation within a submultiple frame is possible (see figure 2).

3.14 gap length : Distance from the leading edge to the trailing edge of the head gap measured perpendicular to the track width (see figure 3).

3.15 gap scatter : Minimum distance between two parallel lines, in the plane of the tape, between which gap trailing edges in a recorder head shall fall (see figure 3).

3.16 head : Grouping of individual head segments in a fixed assembly with the gap lines on a common plane.

3.17 head azimuth : Angle formed, in the plane of the tape, between a line passing through the gap centres of the two outside head tracks and a line perpendicular to the head reference plane (see figure 3).

3.18 head numbering : Head 1 of a pair of heads is the first head over which an element of tape passes when moving in the normal operating direction.

3.19 head reference plane : The plane, which may be imaginary (for some head designers, it is the nominal head mounting surface), parallel to the reference edge of the tape and perpendicular to the plane of the tape (see figure 3). (For the purpose of the definition, the tape shall be considered as perfect.)

3.20 head segment : Single transducer which records or reproduces one track on magnetic tape (see figure 3).

3.21 head segment gap azimuth : The angle, in the plane of the tape, between a line perpendicular to the head reference plane and the gap trailing edge in a record head segment (see figure 3).

3.22 head segment gap azimuth difference : Angular deviation of the azimuth of head segment gaps, in a head, from the head azimuth (see figure 3).

3.23 head segment numbering : Numbering of a head segment shall correspond to the track number on the magnetic tape on which that head segment normally operates. Head 1 of a pair will contain all odd-numbered segments while head 2 will contain all even-numbered segments (see figures 3 and 4).

3.24 head spacing (S) : The distance along the tape path between the gap centre lines of head 1 and head 2, when interlaced heads are used (see figure 4).

3.25 head tilt : Angle, between the plane tangent to the front (active) surface of the head at the centre-line of the head segment gaps, and a line perpendicular to the head reference plane (see figure 3).

3.26 heads in-line : For in-line recording, only one record head and one reproduce head will be used.

3.27 heads interlaced : Head placement for interlaced recording is to locate the head segments (both record and reproduce) for alternate tracks in separate heads. Thus, to record on all tracks of a tape, two record heads will be used; to reproduce all tracks on a tape, two reproduce heads will be used.

The two heads of a pair of record or of reproduce heads for interlaced recording shall be mounted in such a manner that the centre-line through the head segment gaps of each head are parallel and spaced according to the head spacing (S) (see figure 4).

3.28 individual track data azimuth difference¹⁾ : Angular deviation of the data azimuth of individual odd or even recorded tracks from the data azimuth of all odd or even tracks.

The difficulty of making direct optical angular measurements requires this error to be expressed as the loss of signal amplitude permitted when the tape is reproduced on an ideal reproducing head, whose gap is aligned to coincide with the data azimuth of all odd or even tracks, as compared to the maximum signal amplitude obtainable by optimizing the reproduce head azimuth for the individual tracks (see figure 3).

3.29 mode : In telemetry systems, one of two techniques generally used for recording on a given track on magnetic tape; direct recording and single-carrier FM (frequency modulation).

NOTE — Single-carrier FM (and PCM) may itself be recorded by either direct recording (with bias) or saturation (without bias) techniques, and in other instrumentation systems may be regarded as a modulation pattern.

3.30 modulation pattern : Form in which data is encoded prior to transmission or recording, for example, multiple-carrier FM, PAM, PCM. See note accompanying the definition of mode on single-carrier FM (see 3.2.9).

3.31 NRZ (non-return-to-zero) : Form of representation for binary "1" and "0" in pulse-code modulation (PCM). Three variants, known as "level", "mark" and "space", are defined in 6.3.3 and figure 1.

3.32 pulse amplitude modulation (PAM) : Time Division Multiplexing (TDM) technique in which pulses in a sequence are amplitude-modulated, so that the pulse amplitudes represent samples of analogue-variable parameters.

3.33 PAM/FM : Frequency modulation of a radio-frequency carrier by a PAM waveform.

3.34 PAM/FM/FM : Frequency modulation of a radio-frequency carrier by an FDM set of subcarriers, which in turn are frequency-modulated by PAM waveforms.

3.35 pulse code modulation (PCM) : Time Division Multiplexing (TDM) technique in which samples of data are represented in binary form by a group of discrete pulses (words) (see figure 1).

3.36 PCM/FM : Frequency modulation of a radio-frequency carrier by a PCM waveform.

3.37 PCM/FM/FM : Frequency modulation of a radio-frequency carrier by an FDM set of subcarriers, which in turn are frequency-modulated by PCM waveforms.

3.38 pseudo-noise (PN) waveform : Non-random waveform having mean, variance, and other properties resembling random noise (see annex C).

3.39 reference edge : Edge of the tape nearest track 1 (see figure 5).

3.40 reference track location (G) : Location of the centre-line of track 1 relative to the reference edge of the tape (see figure 5).

3.41 standard tensile force : Reference longitudinal tensile force in magnetic tape in the vicinity of the head(s) during recording or reproducing.

3.42 subcommutation : Assigning more than one input channel (data source) to the same time-slot in successive minor frames. The sources assigned to such a time-slot recur in a repetitive sequence.

3.43 supercommutation : Assigning an input channel (data source) to more than one time-slot within each minor frame.

3.44 synchronization : Establishing the timing of a data sequence. A number of different synch formats may be required to identify minor frames, major frames (submultiple frames) and (in PCM) bits and words.

3.45 tape speed, actual (V_{act}) : Tape speed during recording or reproducing. In general the actual tape speed will not be equal to the standard tape speed.

3.46 tape speed, effective (V_{eff}) : Actual tape speed after applying corrections for the effects on the tape of differences between operating and standard conditions, i.e. tensile force, tape materials and thickness, and environment (temperature and humidity). The effective tape speed should be equal to one of the standard tape speeds.

NOTE — Environmental effects on the recorder/reproducer system are not included in this definition.

3.47 tape speed, standard (V_{std}) : Range of defined nominal tape speeds for tapes operating at the standard tensile force and in standard environmental conditions.

3.48 tape tensile force : Tape tensile force applied to the tape during operation. The value of this tensile force is not necessarily the standard tensile force but it is assumed to be applied uniformly across the width of the tape.

3.49 time division multiplex (TDM) : Multiplexing technique in which data samples are transmitted or recorded sequentially in time, each sample occupying a unique and defined period or time-slot within the sequence.

3.50 time-slot : A channel interval; the period allocated for each pulse or sample within a minor frame.

3.51 track location (H_n) : Distance from the centre-line of the reference track (track 1) to the centre-line of the recorded track (n) (see figure 5).

1) The errors in location and angular relation among transient data recorded simultaneously on all odd or even tracks are defined by the terms : data azimuth, data scatter, and individual track data azimuth difference. These are approximately equivalent to the terms : head azimuth, gap scatter and head segment gap azimuth difference; however, guiding misalignment is included in the data location error definitions.

3.52 track numbering : Tracks on tape shall be numbered consecutively, starting with track 1, from top to bottom when viewing the magnetic surface of the tape with the earlier portion of the recorded signal to the observer's right (bottom to top if the earlier portion of the recorded signal is to the observer's left) (see figure 5).

3.53 track spacing (*D*) : Centre-to-centre distance between adjacent recorded tracks (see figure 5).

3.54 track width (*W*) : Mechanical width of the common interface of the record head segment at the gaps. This does not include the effects of fringing fields which will tend to increase the recorded track width by small amount (see figures 3 and 5).

4 Tape and recorder/reproducer characteristics

4.1 General

This clause specifies the tape and recorder/reproducer characteristics required to assure interchange, so that tapes recorded at one facility may be successfully reproduced at another. Recommended test procedures for magnetic tape recording/reproducing equipment are given in annex A.

4.2 Tape and reel characteristics

4.2.1 Tape widths

Standard tape widths are specified in table 1.

Table 1 — Standard tape widths

mm	in
6,30 0,00 – 0,06	0.248 0.000 0 – 0.002 5
12,70 0,00 – 0,10	0.500 0.000 – 0.004
25,40 0,00 – 0,10	1.000 0.000 – 0.004
50,80 0,00 – 0,10	2.000 0.000 – 0.004

4.2.2 Reels

Tapes shall be wound on hubs or reels complying with the requirements of ISO 1860, ISO 1858 or ISO 3802.

4.3 Tape speeds

4.3.1 Standard tape speeds

The standard tape speeds (V_{std}) for instrumentation magnetic tape recorders are as specified in table 2.

Table 2 — Standard tape speeds

mm/s	in/s
6 096	240
3 048	120
1 524	60
762	30
381	15
190,5	7 1/2
95,2	3 3/4
47,6	1 7/8
23,8	15/16

4.3.2 Effective tape speeds

The effective tape speed (V_{eff}) throughout a reel (in the absence of tape-derived servo speed control) shall be within $\pm 0,5 \%$ of the required standard speed for low-band DR recorders and $\pm 0,2 \%$ for intermediate-band and wide-band DR recorders (see 5.1.1.1). Tape speed errors are defined as departures of average speed from the standard value.

Recommended methods for measuring effective tape speed are given in A.2.2.

NOTE — Errors at frequencies above 0,5 Hz are known as flutter (see 4.6).

4.4 Track configurations

Track configurations are illustrated in figure 5 and specified in tables 2 to 9. It should be noted that although a tape reference edge is specified, edge guiding of the tape is not an implied requirement of the recorder/reproducer.

The head spacing for adjustable heads refers to equipment having facilities for adjusting the azimuth of reproduce heads; these are required for wide-band DR recorder/reproducers (see 5.1.1.1).

4.5 Recorder/reproducer characteristics

4.5.1 Data scatter

The maximum data scatter shall be as follows :

Tape width	Maximum data scatter
6,3 mm (0.25 in)	1,25 μ m (50 μ in)
12,7 mm (0.5 in)	2,5 μ m (100 μ in)
25,4 mm (1 in)	5,0 μ m (200 μ in)
50,8 mm (2 in)	10,0 μ m (400 μ in)

It is the responsibility of an equipment manufacturer to decide whether or not data scatter may be equated to gap scatter (see figure 3 and the footnote to 3.2).

4.5.2 Data azimuth (static)

Data azimuth (static) shall be not greater than $\pm 0,3$ mrad ($\pm 1'$ of arc). It is the responsibility of an equipment manufacturer to decide whether or not data azimuth (static) may be equated to head azimuth (see figure 3 and the footnote to 3.2).

4.5.3 Data azimuth (dynamic)

Data azimuth (dynamic) shall be not greater than $\pm 0,3$ mrad ($\pm 1'$ of arc) as determined from measurements of the dynamic interchannel time displacement error (ITDE) between outer tracks on the same head. It is the responsibility of an equipment manufacturer to decide whether or not data azimuth (dynamic) may be equated to the mechanical restriction placed on tape angular motion by the tape guides; the guides shall not cause damage to the tape. (See the footnote to 3.2.) A recommended method for the measurement of ITDE is given in A.2.4.

4.5.4 Individual track data azimuth difference

The maximum signal loss due to individual track data azimuth difference shall be not greater than 1 dB (excluding reproduce head error) at the shortest wavelength specified for the equipment. The overall record/reproduce error shall not be greater than 2 dB.

4.5.5 Head tilt

Head tilt shall be not greater than $\pm 0,9$ mrad ($\pm 3'$ of arc) for low- and intermediate-band DR recorders (see 5.1.1.1) and $\pm 0,3$ mrad ($\pm 1'$ of arc) for wide-band DR recorders (see figure 3).

4.5.6 Head interchangeability

Where rapid interchangeability of heads is specified, the method of head mounting, locating and securing shall ensure that all alignment and location requirements are satisfied without shimming or mechanical adjustment, except for azimuth adjustment of the reproduce head (wide band).

4.5.7 Head polarity

(Refer to A.2.1 for a recommended polarity test and B.2 for further information.)

4.5.7.1 Record head

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

4.5.7.2 Reproduce head

Each reproduce head winding shall be connected to its respective amplifier in such a manner that a segment of tape ex-

hibiting 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.

4.5.8 Standard tensile force

For tapes using a polyethyleneterephthalate (PET) base, standard tensile force shall be 0,131 N/mm (12 ozf/in) of tape width. For ideal interchange, recorder/reproducer operating tape tensile forces should be equal to standard tensile force; as the operating tensile force departs from standard tensile force, the corrections to be applied to make the effective tape speed (V_{eff}) equal to the standard tape speed (V_{std}) become increasingly unreliable due to non-linearities, etc.

NOTE — It is current practice in some countries to use a standard tensile force of 0,175 N/mm (16 ozf/in) tape width. Interchange parties should exercise caution when defining tests involving this parameter.

4.6 Other characteristics

Reference has been made in 4.3.2 to flutter, and other related characteristics are time-base error (TBE) and pulse-to-pulse jitter. Requirements for these characteristics are not specified in this International Standard since they depend on the intended application, but recommended test methods for measuring such characteristics are given in A.2.3 (flutter), A.2.5 (TBE) and A.2.6 (pulse-to-pulse jitter).

**Table 3 — Dimensions — Recorded tape format,
4 tracks in line on 6,3 mm (1/4 in) wide tape
(see figure 5)**

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	0,686	1,778	0,584	0.025 ± 0.002
Track spacing (D)			0,070	
Reference track location (G)	0,483		0,381	0.017 ± 0.002
Track location tolerance (H_n tolerance)	0,051		- 0,051	± 0.002
Track number	Location for nth track (H_n)			in
	mm			
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	1,829		1,727	0.070
3	3,607		3,505	0.140
4	5,385		5,283	0.210

**Table 4 — Dimensions — Recorded tape format,
7 tracks interlaced on 6,3 mm (1/4 in) wide tape**
(see figure 5)

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	0,660		0,610	0.025 ± 0.001
Track spacing (D)		0,889		0.035
Head spacing (S)				
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum (M_m)		0,025		0.001
Reference track location (G)	0,470		0,394	0.017 0 ± 0.001 5
Track location tolerance (H_n tolerance)	0,038		-0,038	± 0.0015
Location for nth track (H_n)				
Track number	mm			in
	max.	nom.	min.	
1 (reference)		0,000		0,000
2	0,927		0,851	0.035
3	1,816		1,740	0.070
4	2,705		2,629	0.105
5	3,594		3,518	0.140
6	4,483		4,407	0.175
7	5,372		5,296	0.210

**Table 5 — Dimensions — Recorded tape format,
7 tracks interlaced on 12,7 mm (1/2 in) wide tape**
(see figure 5)

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	1,40		1,14	0.050 ± 0.005
Track spacing (D)		1,778		0.070
Head spacing (S)				
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum (M_m)		0,127		0.005
Reference track location (G)	1,067		0,965	0.040 ± 0.002
Track location tolerance (H_n tolerance)	0,051		-0,051	± 0.002
Location for nth track (H_n)				
Track number	mm			in
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	1,829		1,727	0.070
3	3,607		3,505	0.140
4	5,385		5,283	0.210
5	7,163		7,061	0.280
6	8,941		8,839	0.350
7	10,719		10,617	0.420

**Table 6 — Dimensions — Recorded tape format,
14 tracks interlaced on 12,7 mm (1/2 in) wide tape**
(see figure 5)

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	0,660		0,610	0.025 ± 0.001
Track spacing (D)		0,889		0.035
Head spacing (S)				
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum (M_m)		0,127		0.005
Reference track location (G)	0,546		0,470	0.020 0 ± 0.001 5
Track location tolerance (H_n tolerance)	0,038		-0,038	± 0.001 5
Location for nth track (H_n)				
Track number	mm			in
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	0,927		0,851	0.035
3	1,816		1,740	0.070
4	2,705		2,629	0.105
5	3,594		3,518	0.140
6	4,483		4,407	0.175
7	5,372		5,296	0.210
8	6,261		6,185	0.245
9	7,150		7,074	0.280
10	8,039		7,963	0.315
11	8,928		8,852	0.350
12	9,817		9,741	0.385
13	10,706		10,630	0.420
14	11,595		11,519	0.455

**Table 7 — Dimensions — Recorded tape format,
21 tracks interlaced on 12,7 mm (1/2 in) wide tape
(see figure 5)**

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	0,483	0,584	0,432	0.018 ± 0.001
Track spacing (D)				0.023
Head spacing (S)				
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum (M_m)		0,178		0.007
Reference track location (G)	0,470		0,394	0.0170 ± 0.0015
Track location tolerance (H_n tolerance)	0,025		-0,025	± 0.001

Track number	Location for nth track (H_n)			in
	mm			
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	0,610		0,559	0.023
3	1,194		1,143	0.046
4	1,778		1,727	0.069
5	2,362		2,311	0.092
6	2,946		2,896	0.115
7	3,531		3,480	0.138
8	4,115		4,064	0.161
9	4,699		4,648	0.184
10	5,283		5,232	0.207
11	5,867		5,817	0.230
12	6,452		6,401	0.253
13	7,036		6,985	0.276
14	7,620		7,569	0.299
15	8,204		8,153	0.322
16	8,788		8,738	0.345
17	9,373		9,322	0.368
18	9,957		9,906	0.391
19	10,541		10,490	0.414
20	11,125		11,074	0.437
21	11,709		11,659	0.460

**Table 8 — Dimensions — Recorded tape format,
14 tracks interlaced on 25,4 mm (1 in) wide tape
(see figure 5)**

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	1,40	1,778	1,14	0.050 ± 0.005
Track spacing (D)			0.070	
Head spacing (S)				
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum(M_m)		0,279		0.011
Reference track location (G)	1,168		1,067	0.044 ± 0.002
Track location tolerance (H_n tolerance)	0,051		-0,051	± 0.002

Track number	Location for nth track (H_n)			in
	mm			
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	1,829		1,727	0.070
3	3,607		3,505	0.140
4	5,385		5,283	0.210
5	7,163		7,061	0.280
6	8,941		8,839	0.350
7	10,719		10,617	0.420
8	12,497		12,395	0.490
9	14,275		14,173	0.560
10	16,053		15,951	0.630
11	17,831		17,729	0.700
12	19,609		19,507	0.770
13	21,387		21,285	0.840
14	23,165		23,063	0.910

**Table 9 — Dimensions — Recorded tape format,
28 tracks interlaced on 25,4 mm (1 in) wide tape
(see figure 5)**

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	0,660	0,89	0,610	0.025 ± 0.001
Track spacing (D)				0.035
Head spacing (S)		0,229		
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum (M_m)				0.009
Reference track location (G)	0,698		0,622	$0.026 0 \pm 0.001 5$
Track location tolerance (H_n tolerance)	0,038		-0,038	$\pm 0.001 5$

Track number	Location for nth track (H_n)			in
	mm			
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	0,927		0,851	0.035
3	1,816		1,740	0.070
4	2,705		2,629	0.105
5	3,594		3,518	0.140
6	4,483		4,407	0.175
7	5,372		5,296	0.210
8	6,261		6,185	0.245
9	7,150		7,074	0.280
10	8,039		7,963	0.315
11	8,928		8,852	0.350
12	9,817		9,741	0.385
13	10,706		10,630	0.420
14	11,595		11,519	0.455
15	12,484		12,408	0.490
16	13,373		13,297	0.525
17	14,262		14,186	0.560
18	15,151		15,075	0.595
19	16,040		15,964	0.630
20	16,929		16,853	0.665
21	17,818		17,742	0.700
22	18,707		18,631	0.735
23	19,596		19,520	0.770
24	20,485		20,409	0.805
25	21,374		21,298	0.840
26	22,263		22,187	0.875
27	23,152		23,076	0.910
28	24,041		23,965	0.924

**Table 10 — Dimensions — Recorded tape format,
42 tracks interlaced on 25,4 mm (1 in) wide tracks
(see figure 5)**

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	0,483	0,584	0,432	0.018 ± 0.001
Track spacing (D)			0.023	
Head spacing (S)				
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum (M_m)		0,305		0.012
Reference track location (G)	0,737		0,660	0.027 5 ± 0.001 5
Track location tolerance (H_n tolerance)	0,025		-0,025	± 0.001

Track number	Location for nth track (H_n)			in
	mm			
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	0,610		0,559	0.023
3	1,194		1,143	0.046
4	1,778		1,727	0.069
5	2,362		2,311	0.092
6	2,946		2,896	0.115
7	3,531		3,480	0.138
8	4,115		4,064	0.161
9	4,699		4,648	0.184
10	5,283		5,232	0.207
11	5,867		5,817	0.230
12	6,452		6,401	0.253
13	7,036		6,985	0.276
14	7,620		7,569	0.299
15	8,204		8,153	0.322
16	8,788		8,738	0.345
17	9,373		9,322	0.368
18	9,957		9,906	0.391
19	10,541		10,490	0.414
20	11,125		11,074	0.437
21	11,709		11,659	0.460
22	12,294		12,243	0.483
23	12,878		12,827	0.506
24	13,462		13,411	0.529
25	14,046		13,995	0.552
26	14,630		14,580	0.575
27	15,215		15,164	0.598
28	15,799		15,748	0.621
29	16,383		16,332	0.644
30	16,967		16,916	0.667
31	17,551		17,501	0.690
32	18,136		18,085	0.713
33	18,720		18,669	0.736
34	19,304		19,253	0.759
35	19,888		19,837	0.782
36	20,472		20,422	0.805
37	21,057		21,006	0.828
38	21,641		21,590	0.851
39	22,225		22,174	0.874
40	22,809		22,758	0.897
41	23,393		23,343	0.920
42	23,978		23,927	0.943

Table 11 — Dimensions — Recorded tape format, 84 tracks interlaced on 50,8 mm (2 in) wide tape
(see figure 5)

Dimension	mm			in
	max.	nom.	min.	
Track width (W)	0,483		0,432	0.018 ± 0.001
Track spacing (D)		0,584		0.023
Head spacing (S)				
Fixed heads	38,125		38,075	1.500 ± 0.001
Adjustable heads	38,151		38,049	1.500 ± 0.002
Edge margin, minimum (M_m)		0,711		0.028
Reference track location (G)	1,168		1,092	0.044 ± 0.0015
Track location tolerance (H_n tolerance)	0,025		-0,025	± 0.001
Track number	Location for nth track (H_n)			in
	mm			
	max.	nom.	min.	
1 (reference)		0,000		0.000
2	0,610		0,559	0.023
3	1,194		1,143	0.046
4	1,778		1,727	0.069
5	2,362		2,311	0.092
6	2,946		2,896	0.115
7	3,531		3,480	0.138
8	4,115		4,064	0.161
9	4,699		4,648	0.184
10	5,283		5,232	0.207
11	5,867		5,817	0.230
12	6,452		6,401	0.253
13	7,036		6,985	0.276
14	7,620		7,569	0.299
15	8,204		8,153	0.322
16	8,788		8,738	0.345
17	9,373		9,322	0.368
18	9,957		9,906	0.391
19	10,541		10,490	0.414
20	11,125		11,074	0.437
21	11,709		11,659	0.460
22	12,294		12,243	0.483
23	12,878		12,827	0.506
24	13,462		13,411	0.529
25	14,046		13,995	0.552
26	14,630		14,580	0.575
27	15,215		15,164	0.598
28	15,799		15,748	0.621
29	16,383		16,332	0.644
30	16,967		16,916	0.667
31	17,551		17,501	0.690
32	18,136		18,085	0.713
33	18,720		18,669	0.736
34	19,304		19,253	0.759
35	19,888		19,837	0.782
36	20,472		20,422	0.805
37	21,057		21,006	0.828
38	21,641		21,590	0.851
39	22,225		22,174	0.874
40	22,809		22,758	0.897
41	23,393		23,343	0.920
42	23,978		23,927	0.943
43	24,562		24,511	0.966
44	25,146		25,095	0.989
45	25,730		25,679	1.012
46	26,314		26,264	1.035
47	26,899		26,848	1.058
48	27,483		27,432	1.081
49	28,067		28,016	1.104
50	28,651		28,600	1.127
51	29,235		29,185	1.150
52	29,820		29,769	1.173
53	30,404		30,353	1.196
54	30,988		30,937	1.219
55	31,572		31,521	1.242
56	32,156		32,106	1.265

Track number	Location for nth track (H_n)			in
	mm			
	max.	nom.	min.	
57	32,741		32,690	1,288
58	33,325		33,274	1,311
59	33,909		33,858	1,334
60	34,493		34,442	1,357
61	35,077		35,027	1,380
62	35,662		35,611	1,403
63	36,246		36,195	1,426
64	36,830		36,779	1,449
65	37,414		37,363	1,472
66	37,998		37,948	1,495
67	38,583		38,532	1,518
68	39,167		39,116	1,541
69	39,751		39,700	1,564
70	40,335		40,284	1,587
71	40,919		40,869	1,610
72	41,504		41,453	1,633
73	42,088		42,037	1,656
74	42,672		42,621	1,679
75	43,256		43,205	1,702
76	43,840		43,790	1,725
77	44,425		44,374	1,748
78	45,009		44,958	1,771
79	45,593		45,542	1,794
80	46,177		46,126	1,817
81	46,761		46,711	1,840
82	47,346		47,295	1,863
83	47,930		47,879	1,886
84	48,514		48,463	1,909

5 Modes of recording

5.1 Direct recording (DR)

5.1.1 Bandwidths

5.1.1.1 Wavelengths on tape

For the purposes of this International Standard, four bandwidths are designated :

- a) low-band DR : direct recording response to a minimum recorded wavelength of 15,2 μm (600 μin).

NOTE — For recording subcarrier bands above proportional bandwidth channel 18 or constant bandwidth channel 11 B, intermediate-band recorders are recommended (see 6.1.1 and 6.1.2).

- b) intermediate band DR : direct recording response to a minimum recorded wavelength of 6 μm (240 μin);

- c) wide-band 1,5 MHz DR : direct recording response to a minimum recorded wavelength of 2 μm (80 μin);

- d) wide-band 2,0 MHz DR : direct recording response to a minimum recorded wavelength of 1,5 μm (60 μin).

NOTE — Interchange of tapes between wide-band DR and low- or intermediate-band DR machines is not recommended.

See B.1.1 for notes on extended wide-band DR recording.

5.1.1.2 Frequency response

The frequency response or passband of direct-recorded data as a function of tape speed is given in table 12. In measuring this response, signals throughout the specified pass-band shall be recorded at normal record level (see 5.1.3.4) and the reproduce output signal levels shall be referenced to the playback output at the record level set frequency. See A.3.2 for a recommended test procedure.

5.1.2 Bias

5.1.2.1 Wavelength

The high-frequency bias signal shall have a wavelength on tape not greater than the following :

DR band	Maximum bias wavelength μm (μin)
Low	1,6 (60)
Intermediate	
Wide-band 1,5 MHz	
Wide-band 2,0 MHz	
	0,6 (24)
	0,45 (18)

5.1.2.2 Current

With an input signal at the record bias set frequency (see table 12) and at a level 5 to 6 dB below normal record level (see 5.1.3.4), the record bias current shall be adjusted for maximum reproduced output and then increased until the output falls by the following amounts :

DR band	Fall in output for optimum bias (overbias) dB
Low	3
Intermediate	3
Wide-band 1,5 MHz	1
Wide-band 2,0 MHz	2

See A.3.1 for a recommended test procedure.

5.1.3 Record parameters

5.1.3.1 Input impedances at all frequencies in the low- and intermediate-bands shall be 5 000 Ω minimum resistance shunted by 250 pF maximum, with or without meter. Input impedances for wide-band recorders shall be 75 $\Omega \pm 10\%$ across the specified band.

5.1.3.2 Adjustments shall be provided to enable normal record level to be produced by input signals in the range 1 to 10 V peak-to-peak.

5.1.3.3 The record amplifier shall provide a transfer characteristic which is basically a constant current versus frequency characteristic upon which is superimposed a compensation characteristic to correct only for loss of record head efficiency with frequency. For the test described in A.3.9 (or

equivalent), the difference in the response curves normalized to the 0,02 upper bandedge frequency shall be no greater than the figures given below :

Fraction of upper band edge frequency	Difference dB
0,1	0,5
0,5	1,0
0,8	1,6
1,0	2,0

It should be noted that the procedure above does not establish a uniform recorded flux density on the tape for different heads, see B.4 for further comments.

5.1.3.4 The level of recording shall be set at such a value that a reproduced signal of the record level set frequency indicated in table 12 measured at the output of the playback amplifier under the load specified in 5.1.4.2 shall contain 1 % third harmonic distortion after correction for allowable equalization variations (-40 ± 1) dB referred to the output of a frequency three times the record level set frequency, recorded at normal record level; such distortion is a function of tape saturation, and not a function of record or reproduce amplifier characteristics. This level, the normal record level, is the 0 dB reference level for all other measurements. (See A.3.1 for a recommended test procedure).

5.1.3.5 Record head gap length for wideband recording shall be within the range from 1,65 μm (65 μin) to 2,7 μm (105 μin).

NOTE — In recording complex telemetry signals with varying crest factors, optimum record level should be determined for the particular signal to be recorded. See B.3.

5.1.4 Reproduce parameters

5.1.4.1 Output impedances for low- and intermediate-band recording shall be 100 Ω maximum across the pass bands specified in table 12. Output impedances for wide-band recorders shall be 75 Ω maximum across the specified pass band.

5.1.4.2 When reproducing a signal at the record level set frequency recorded at an input voltage equivalent to that required for normal record level, the output level for low-band and intermediate-band recorders shall be a minimum of 3 V peak-to-peak with a third harmonic distortion of 1 % and a maximum second harmonic distortion of 0,5 % when measured across a resistive load of 600 $\Omega \pm 10\%$ shunted by a maximum of 1 500 pF. The output level for wide-band recorders shall be a minimum of 2 V peak-to-peak with a third-harmonic distortion of 1 % and a maximum second harmonic distortion of 0,5 % when measured across 75 $\Omega \pm 10\%$. Lack of proper output termination shall not cause the reproduce amplifier to oscillate.

5.1.5 Other system parameters

A number of other parameters affecting system performance, such as signal-to-noise ratio, crosstalk etc., are not specified in this International Standard since requirements depend on the

intended application, but recommended test methods for measuring such parameters are given in A.3.3 to A.3.8.

5.2 Single-carrier frequency modulation recording (FM)

5.2.1 Bandwidths

5.2.1.1 Wavelengths on tape

For the purposes of this International Standard, four bandwidths are designated :

- a) low-band FM : carriers at centre frequency having a nominal recorded wavelength on the tape of 28,2 μm (1 110 μin);
- b) intermediate-band FM : carriers at centre frequency having a nominal recorded wavelength on tape of 14,1 μm (555 μin);
- c) wide-band I FM : carriers at centre frequency having a nominal recorded wavelength on tape of 7,1 μm (278 μin);
- d) wide-band II FM : carriers at centre frequency having a nominal recorded wavelength on the tape of 3,4 μm (133 μin).

5.2.1.2 Frequency response

The FM carrier frequencies and data signal pass-bands (modulating frequencies) as a function of tape speed are given in table 13. See A.4.2 a) and A.4.3 for recommended test methods.

5.2.2 Carrier deviations

[See A.4.2 b) for a recommended test method.]

5.2.2.1 General

For low-band, intermediate-band, and wide-band I recording, the fullscale FM carrier deviation shall be $\pm 40\%$.

For wide-band II recording, the fullscale FM carrier deviation shall be $\pm 30\%$.

5.2.2.2 Effect of voltage on frequency

Increasing positive voltage shall give increasing frequency (but see 5.4).

5.2.3 Record characteristics

Single-carrier FM records may employ either direct-recording (see 5.1) or recording without bias (see 5.3) techniques.

5.2.4 Other system parameters

A number of other parameters affecting system performance, such as signal-to-noise ratio, linearity and drift etc., are not

specified in this International Standard since requirements depend on the intended application, but recommended test methods for measuring such parameters are given in A.4.4 to A.4.10.

5.3 Recording without bias

5.3.1 General

In single-carrier FM recording, and pulse-code modulation (PCM) when the pulse stream is recorded directly on tape and not as a modulated FDM sub-carrier, information is not contained in the amplitude of the reproduced signal and a linear amplitude transfer function as provided by direct recording is not essential. Saturation recording without high-frequency bias is therefore permissible. The record signal level (see below) is higher than in direct recording, a higher reproduce head output level is obtained and the need for generating a high-frequency bias signal is avoided; however, guard tracks may be required when saturation and direct recordings are being made on the same head [see also 5.3.8 c)].

5.3.2 Optimum record level

Except at long recorded wavelengths, the reproduce head output level does not increase asymptotically to a maximum as the record level is increased, but reaches a peak and then falls again. As the recorded wavelength becomes shorter, the record level for peak output falls and the output falls more rapidly at record levels below and above that giving peak output. The procedures for setting optimum record level are as follows :

- a) For single-carrier FM recording the optimum record level is that which gives a maximum reproduce head output for a recorded wavelength equal to that of the carrier at the upper end of its frequency deviation range (carrier plus deviation is given in table 13).
- b) For PCM recording the same principle applies except that maximum output is determined at the maximum flux transition rate applicable to the bit representation.

5.4 Predetection recording

Predetection signals consist of frequency-modulated (or phase-modulated) intermediate-frequency (IF) carriers which have been translated in frequency to be compatible with wide-band DR recorder frequency response. These signals shall be recorded by direct recording. Parameters for predetection signals are given in table 14.

Because of the translation technique employed, the deviation direction (see 5.2.2.2) is reversed from the original modulation. Care shall therefore be exercised when interchanging predetection tapes with other tapes.

5.5 Timing signal recording

When recording modulated time-code signals, care shall be taken to ensure that low-frequency response down to 100 Hz is provided. For low-band DR recorders direct-record response

down to 100 Hz is available but the low-frequency cutoff of wide-band DR recorders (and intermediate band DR recorders at the higher tape speeds) exceeds 100 Hz (see table 12). For systems using these recorders it is recommended that the time-code signals be recorded on a single-carrier FM track or on an FM subcarrier; in the latter case the highest subcarrier available should be used to minimize time delay.

5.6 Tape speed correction and flutter compensation

5.6.1 Types of control signals

Two types of sinusoidal speed-control signals are designated in this International Standard: amplitude-modulated and constant-amplitude, and either may be specified by a user; however, the constant-amplitude method is recommended for all applications where the appropriate hardware can be made available. Constant-amplitude signals may also be used for flutter compensation if required.

5.6.2 Amplitude-modulated speed-control signal

This shall have the following characteristics :

Carrier frequency	17,0 kHz $\pm$ 0,5 %
Bandwidth required	16,5 kHz to 17,5 kHz
Percentage modulation	45 to 55 %
Modulating frequency	60 Hz $\pm$ 0,01 %

In single-carrier FM recording, a separate track is always required for the speed-control signal. In multiple-carrier FM recording (see 6.1), the speed-control signal may be mixed with subcarriers on the same track, but shall be recorded 10 $\pm$ 0,5 dB below normal record level.

Proportional-bandwidth channel A or constant-bandwidth channel 1A cannot be used on the same track as the speed-control signal because they may interfere with the control signal. When recorded on a separate track, the amplitude-modulated speed-control signal shall be recorded at normal record level (see 5.1.3.4).

5.6.3 Constant-amplitude speed-control signal

Table 15 lists constant-amplitude speed-control signal frequencies as a function of tape speed. In single-carrier FM recording, a separate track is always required for the speed-control signal. In other types of recording, speed-control signals may be mixed with other signals if recording requirements so demand and system performance permits; table 15 shows the guard band about each signal frequency which shall be left free of other signals in order to give proper operation.

Mixing of the speed-control signal with certain types of signal may degrade system performance. When using high performance servo systems, signals higher than the control signal frequency should not be mixed with the control signal. The level of individual extraneous signals, including spurious harmonics and noise, shall be 40 dB or more below the level of the speed-control signal. For optimum servo speed correction, constant amplitude speed-control signals should be on a separate track.

For use on the same track as multiple-carrier FM subcarriers (see 6.1), the criteria given in table 16 apply to the speed-control signal (reference frequency).

5.6.4 Track allocation

Tape-speed correction and flutter compensation signals shall be recorded on the tracks defined in table 17.

Table 12 — Direct-record parameters

Tape speed mm/s (in/s)	± 3 dB pass-band¹⁾ Hz	Record bias set frequency²⁾ tolerance ± 10 % kHz	Record level set frequency tolerance ± 10 % kHz
Low-band DR			
1 524 (60)	100 — 100 000	100	10
762 (30)	100 — 50 000	50	5
381 (15)	100 — 25 000	25	2,5
190,5 (7 1/2)	100 — 12 000	12	1,2
95,2 (3 3/4)	100 — 6 000	6	0,6
47,6 (1 7/8)	100 — 3 000	3	0,3
23,8 (15/16)	100 — 1 500	1,5	0,15
Intermediate band DR			
3 048 (120)	300 — 500 000	500	50
1 524 (60)	300 — 250 000	250	25
762 (30)	200 — 125 000	125	12,5
381 (15)	100 — 60 000	60	6,0
190,5 (7 1/2)	100 — 30 000	30	3,0
95,2 (3 3/4)	100 — 15 000	15	1,5
47,6 (1 7/8)	100 — 7 500	7,5	0,75
23,8 (15/16)	100 — 3 800	3,8	0,38
Wide-band 1,5 MHz DR			
3 048 (120)	400 — 1 500 000	1 500	150
1 524 (60)	400 — 750 000	750	75
762 (30)	400 — 375 000	375	37,5
381 (15)	400 — 187 000	187	18,7
190,5 (7 1/2)	400 — 93 000	93	9,3
95,2 (3 3/4)	400 — 46 000	46	4,6
47,6 (1 7/8)	400 — 23 000	23	2,3
23,8 (15/16)	400 — 11 500	11,5	1,15
Wide-band 2,0 MHz DR³⁾			
3 048 (120)	400 — 2 000 000	2 000	200
1 524 (60)	400 — 1 000 000	1 000	100
762 (30)	400 — 500 000	500	50
381 (15)	400 — 250 000	250	25
190,5 (7 1/2)	400 — 125 000	125	12,5
95,2 (3 3/4)	400 — 62 500	62,5	6,25
47,6 (1 7/8)	400 — 31 250	31,2	3,12
23,8 (15/16)	400 — 15 625	15,6	1,56

1) Pass-band response reference is the output as the record level set frequency.

2) Procedures for setting optimum bias current are given in 5.1.2.2.

3) Some recorders provide 4,0 MHz DR sine wave capability at 6 069 mm/s (240 in/s) with ± 3 dB bandwidth 800 Hz to 4 MHz. The bias set frequency is 4 MHz and the record level set frequency is 400 kHz.

Table 13 — Single-carrier FM record parameters

Tape speed mm/s (in/s)			Carrier centre frequency kHz	Carrier deviation limits		Modulating frequency kHz	Response at band limits ¹⁾ dB
Low- band FM	Intermediate- band FM	Wide- band I FM		Carrier plus deviation kHz	Carrier minus deviation kHz		
3 048 (120) 1 524 (60) 762 (30) 381 (15) 190,5 (7 1/2) 95,2 (3 3/4) 47,6 (1 7/8) 23,8 (15/16)	3 048 (120) 1 524 (60) 762 (30) 381 (15) 190,5 (7 1/2) 95,2 (3 3/4) 47,6 (1 7/8) 23,8 (15/16)	3 048 (120)	432,0	604,8	259,2	0 to 80,00	± 1
		1 524 (60)	216,0	302,4	129,6	0 to 40,00	± 1
		762 (30)	108,0	151,2	64,80	0 to 20,00	± 1
		381 (15)	54,00	75,60	32,40	0 to 10,00	± 1
		190,5 (7 1/2)	27,00	37,80	16,20	0 to 5,000	± 1
		95,2 (3 3/4)	13,50	18,90	8,100	0 to 2,500	± 1
		47,6 (1 7/8)	6,750	9,450	4,050	0 to 1,250	± 1
		23,8 (15/16)	3,375	4,725	2,025	0 to 0,625	± 1
			1,688	2,363	1,012	0 to 0,313	± 1
			0,844	1,181	0,506	0 to 0,156	± 1
		Wide- band II FM					
		6 096 (240)	1 800,0	2 340,0	1 260 0	0 to 800,0	+1 - 3
		3 048 (120)	900,0	1 170,0	630,0	0 to 400,0	+ 1 - 3
		1 524 (60)	450,0	585,00	315,00	0 to 200,0	+ 1 - 3
		762 (30)	225,0	292,50	157,50	0 to 100,0	+ 1 - 3
		381 (15)	112,50	146,25	78,750	0 to 50,00	+ 1 - 3
		190,5 (7 1/2)	56,250	73,125	39,375	0 to 25,00	+ 1 - 3
		95,2 (3 3/4)	28,125	36,562	19,688	0 to 12,50	+ 1 - 3
		47,6 (1 7/8)	14,062	18,381	9,844	0 to 6,25	+ 1 - 3

1) Frequency response referred to 1 kHz output for FM channels 13,5 kHz and above, and 100 Hz for channels below 13,5 kHz.

Table 14 — Predetection carrier parameters

Tape speed mm/s (in/s)	Predetection carrier centre frequency kHz	Recommended predetection record/ playback pass-band kHz
6 096 (240)	1 800	200 to 3 000
3 048 (120)	900	100 to 1 500
1 524 (60)	450	50 to 750
762 (30)	225	25 to 375
381 (15)	112,5	12,5 to 187,5

Table 15 — Constant-amplitude speed-control signals

Tape speed mm/s (in/s)	Frequency kHz	Minimum guard-band Hz
6 096 (240)	400 ± 0,01 %	—
3 048 (120)	200 ± 0,01 %	± 13 950
1 524 (60)	100 ± 0,01 %	± 10 500
762 (30)	50 ± 0,01 %	± 2 500
381 (15)	25 ± 0,01 %	± 2 000
190,5 (7 1/2)	12,5 ± 0,01 %	± 2 000
95,2 (3 3/4)	6,25 ± 0,01 %	± 2 000
47,6 (1 7/8)	3,125 ± 0,01 %	± 2 000
23,8 (15/16)	1,562 ± 0,01 %	± 2 000

Table 16 — Reference signal usage with multiple-carrier FM subcarriers
(reference and data signals on same track)

Reference frequency kHz	Subcarrier usage (see also 6.1)
240 $\pm 0,01$ % ¹⁾	For use with all centre frequencies
200 $\pm 0,01$ %	For use with all centre frequencies except channel H
100 $\pm 0,01$ %	Use with centre frequencies up to and including 80 kHz
50 $\pm 0,01$ %	Use with centre frequencies up to and including 40 kHz except channel C
25 $\pm 0,01$ %	Use with centre frequencies up to and including 16 kHz
12,5 $\pm 0,01$ %	Use with centre frequencies up to and including 7,35 kHz
6,25 $\pm 0,01$ %	Use with centre frequencies up to and including 3,9 kHz
3,125 $\pm 0,01$ %	Use with centre frequencies up to and including 0,960 kHz

1) For flutter compensation only, not for tape speed-control.

Table 17 — Allocation of tracks for tape-speed correction and flutter compensation signals

Track configuration (table number)	Track number for tape-speed correction and flutter compensation signal	Optional additional track number
3	2	—
4	4	5
5	4	5
6	7	8
7	11	12
8	7	8
9	13	14
10	21	22
11	TBD	TBD

6 Modulation patterns

6.1 Multiple-carrier FM recording (frequency-division multiplexing)

6.1.1 Proportional-bandwidth subcarrier channels

Table 18 lists 29 FM proportional-bandwidth subcarrier channels. The channels identified with letters permit $\pm 15\%$ subcarrier deviation rather than $\pm 7,5\%$ deviation, but use the same centre frequencies as the eight highest numbered channels; table 18 defines limitations on combinations of channels which may be used. The channels shall be used within the limits of maximum subcarrier deviation.

6.1.2 Constant-bandwidth subcarrier channels

Table 19 list 36 FM constant-bandwidth subcarrier channels. The letters A, B and C identify the channels for use with maximum subcarrier deviations of ± 2 kHz, ± 4 kHz and ± 8 kHz respectively, along with maximum frequency responses of 2 kHz, 4 kHz and 8 kHz respectively. The channels shall be used within the limits of maximum subcarrier deviation.

6.1.3 Subcarrier channel spacing

There is a ratio of approximately 1,33 to 1 between the centre frequencies of adjacent $\pm 7,5\%$ proportional bandwidth channels except between 14,5 kHz and 22 kHz where a larger gap is left to provide a 60 Hz amplitude-modulated 17 kHz carrier for tape speed control (see 6.1.4). The use of an additional FM subcarrier between 14,5 kHz and 22 kHz is not permissible. Combinations of both proportional-bandwidth and constant-bandwidth channels may be used, provided that adequate allowance is made for guard-bands.

6.1.4 Tape speed correction and flutter compensation

Tape speed correction and flutter compensation for multiple-carrier FM formats may be accomplished as indicated in 5.6. Use of the standard reference frequency shall be in accordance with the criteria of table 16 when the reference signal is mixed with data.

6.1.5 Recording mode

Direct recording shall always be used for recording multiple-carrier FM signals, since a non-linear transfer function will result in the generation of unwanted harmonics of the carrier frequencies.

6.1.6 Subcarrier tests

Recommended test methods are given in A.7.

6.1.7 Information for users

Applications notes and a discussion of performance tradeoffs will be found in annex E.

6.2 PAM recording

6.2.1 General

Pulse-amplitude modulated (PAM) waveforms, the characteristics of which are specified herein, consist of time-division multiplexed pulses whose amplitudes represent samples of analogue-variable parameters. For transmission, PAM waveforms may be used either to frequency modulate radio-frequency carriers directly (PAM/FM) or to modulate multiple-carrier FM subcarriers (PAM/FM/FM). For recording, the waveforms may be used to modulate multiple-carrier FM subcarriers or single-carrier FM carriers. PAM waveforms are not recorded directly on magnetic tape.

6.2.2 Waveform structure

6.2.2.1 Minor frame length

The PAM waveform consists of a sequence of minor frames (see figure 2), each of which comprises a constant number of time-sequenced channel intervals or time-slots. The maximum minor frame length shall be 128 channel time intervals or time-slots, including the intervals devoted to synchronization and calibration. The pulse and minor frame structure shall conform to either figure 6 or 7.

6.2.2.2 Commutation pattern

The information channels are allotted equal and constant time intervals within the PAM minor frame. Each interval or time-slot ("T" in figures 6 and 7) contains a sample pulse commencing at the start of the interval and having amplitude determined by the corresponding measurement and according to a fixed relationship (usually linear) between the minimum level (zero amplitude) and the maximum level (full-scale amplitude). For 50 % duty cycle (RZ-PAM), the zero level shall be 20 % of full amplitude level as shown in figure 6. The pulse width shall be the same in all time intervals (the intervals devoted to synchronization excepted). The duration shall be either $0,5 T \pm 0,05 T$, as shown in figure 6 or $T \pm 0,05 T$, as shown in figure 7.

6.2.2.3 Calibration

It is recommended that calibration pulses of known level be inserted into each minor frame to permit the removal of scale and offset errors. Channels 1 and 2, immediately following the minor frame synchronization interval, shall be used for zero-and full-scale calibration, respectively.

6.2.2.4 Minor frame synchronization interval

Each minor frame shall be identified by the presence within it of a synchronization pattern :

- a) 50 % duty factor (RZ-PAM). The synchronization pattern shall have a duration equal to two information channel intervals ($2 T$) and shall be full-scale amplitude for $1,5 T$ followed by the reference level for $0,5 T$ (see figure 6).
- b) 100 % duty factor (NRZ-PAM). The synchronization pattern shall be, in the order given, zero level for a period T ,

full-scale amplitude for a period $3T$, and a level not exceeding 50 % full-scale amplitude for a period T (see figure 7).

6.2.3 Pulse and minor frame rate

6.2.3.1 Pulse rate

The maximum pulse rate shall not be greater than that permitted by the following :

- a) PAM/FM/FM. The reciprocal of the shortest interval between transitions in the PAM pulse train (i.e. twice maximum pulse rate for 50 % duty factor) shall be not greater than one-fifth of the total (peak-to-peak) deviation specified in table 18 or 19 for the FM subcarrier selected.
- b) PAM/FM (only applicable to radio-frequency telemetry systems). The reciprocal of the shortest interval between transitions in the PAM pulse train (i.e. twice maximum pulse rate for 50 % duty factor) shall be limited by whichever is the narrower of the following :

- One-half of the frequency for 3 dB attenuation of the premodulation filter, when employed (see 6.2.7).
- One-fifth of the intermediate frequency (IF) bandwidth (3 dB points) selected from the bandwidths listed in table 20.

6.2.3.2 Minor frame rate

The minor frame rate and pulse-rate values listed below may be used in any combination :

- a) the minor frame rate shall be equal to or greater than 0,125 frames per second;
- b) the minor frame rate shall be no greater than that corresponding to the maximum pulse rate specified in 6.2.3.1.

6.2.4 Accuracy and stability

6.2.4.1 Long term

During the period of desired data, the time between the occurrence of corresponding points in any two successive minor frame synchronization patterns shall not differ from the reciprocal of the specified nominal minor frame rate by more than 5 % of the nominal period.

6.2.4.2 Short term

During a measured period, P , for the occurrence of 1 000 channel intervals or time-slots, the time between the start of any two successive channel intervals (synchronization intervals excepted) shall not differ from the average channel interval established by the formula $T_{ave} = P/1\ 000$ by more than 1 % of the average interval.

6.2.5 Multiple and submultiple sampling

6.2.5.1 General

Data sampling at rates which are multiples and submultiples of the minor frame rate (supercommutation and subcommutation respectively as defined in 3.42 and 3.43 is permissible.

6.2.5.2 Submultiple frame synchronization

The beginning of the longest submultiple frame interval (equal to the major frame interval) shall be identified by the transmission of a synchronization pattern within the identified submultiple frame. All other submultiple frames shall have a fixed and known relationship to the identified submultiple frame. The following submultiple frame interval synchronization patterns shall be used :

- a) 50 % duty factor RZ : a full-scale amplitude pulse in two successive minor frames of the same channel interval (time-slot) as that allocated to data channels of the identified submultiple frame, for example, channels 6-1 and 6-2 in figure 2. The first such pulse shall have a duration equal to the channel interval; the second pulse shall have a duration nominally one-half the channel interval.
 - b) 100 % duty factor (NRZ) : the presence of synchronization information in five successive minor frames of the same channel interval (time-slot) as that allocated to data channels of the identified submultiple frame, for example, channels 6-1 to 6-5 in figure 2. The amplitude of the data channels assigned for synchronization shall be as follows :
- 1) First minor frame — zero amplitude, for example, channel 6-1.
 - 2) Second, third and fourth minor frames — full-scale amplitude, for example, channels 6-2 to 6-4.
 - 3) Fifth minor frame — not more than 50 % of full-scale amplitude, for example, channel 6-5.

6.2.5.3 Maximum submultiple frame (major frame) interval

The interval of any submultiple frame, including the time devoted to synchronizing information, shall not exceed 128 times the interval of the minor frame in which it occupies a recurring position (i.e. the major frame length shall not exceed 128 times the minor frame length).

6.2.6 Frequency modulation

The maximum and minimum amplitude of a PAM waveform shall produce equal and opposite modulation frequency deviations about the assigned carrier or subcarrier frequency. The deviation shall be the same for all occurrences of the same level.

6.2.7 Premodulation filtering

Premodulation filtering is recommended to control the spectral occupancy of the modulated output signal. The filter shall be designed to provide maximally linear phase response and the amplitude response shall have an asymptotic negative slope at high frequencies corresponding to at least 36 dB per octave.

6.2.8 PAM test methods

The values of the modulation parameters recommended in this standard can be measured by oscilloscopic or oscillographic means. Recommended system test methods are given in A.5 (to be added).

6.3 PCM recording

6.3.1 General

Pulse-code modulation (PCM) data, the characteristics of which are specified herein, shall be transmitted or recorded as serial binary-coded time-division multiplexed words, most significant bit first (where applicable).

6.3.2 Word and minor frame structure

6.3.2.1 General

The PCM minor frame shall contain a known number of bit intervals, all of equal duration unless specially assigned identification bits within the bit stream are employed to indicate a change. The duration of the bit interval and the number of bit intervals per minor frame shall remain fixed from frame to frame.

NOTE — The definitions in 3.11, 3.12, 3.13, 3.42, 3.43 and 3.50 relate to words (see 6.3.2.4) or groups of bits, each of which is located within a time-slot or channel interval.

6.3.2.2 Minor frame length

The length of a minor frame shall not exceed 8 192 bit intervals, including intervals devoted to synchronization.

6.3.2.3 Minor frame synchronization

Frame synchronization information consists of a digital word not longer than 33 bits in consecutive bit intervals within the minor frame. Recommendations concerning synchronization are given in D.2.

6.3.2.4 Word length

Individual words shall not be less than 4 bits nor more than 64 bits in length but it is suggested that word lengths be chosen to be integral multiples of 8 bits. Within these limits, words of different length may be multiplexed in a single minor frame. However, the length of a word in any position within a minor frame shall be consistent from frame to frame, except during changes caused by special identification bits appearing in a bit stream.

6.3.2.5 Special words

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

6.3.3 PCM bit representations

Only one bit representation shall be used in a single PCM pulse train. The following conventions for representing binary "one" and "zero" are permissible (see figure 1 for graphic and verbal definitions).

NRZ-L	NRZ-M	NRZ-S	BI-ϕ-L
BI-ϕ-M	BI-ϕ-S		

NOTE — Bold representations are preferred, the other two are obsolescent and may be deleted in future revisions of this International Standard.

Other bit representations may be used with the agreement of interchange parties.

6.3.4 Minimum and maximum bit rates

6.3.4.1 Minimum bit rate

The minimum bit rate shall be one per second.

6.3.4.2 Maximum bit rate

a) PCM/FM/FM. The reciprocal of twice the shortest period between transitions in the PCM bit stream shall not exceed the maximum frequency response for the chosen subcarrier channel (see tables 18 and 19).

b) PCM/FM (only applicable to radio-frequency telemetry systems). The maximum bit rate is limited by the available system bandwidth and the selected bit representation. Receiver intermediate frequency (IF) bandwidth shall be selected from table 20. See also additional information in D.1.

6.3.5 Accuracy and stability

6.3.5.1 Long-term

During any period of desired data, the bit rate shall not differ from the specified nominal bit rate by more than 1 % of the nominal rate.

6.3.5.2 Short-term (bit jitter)

Any transition in the PCM waveform occurring within an interval P shall occur within 0,1 bit period of the time at which the transition is expected to occur based upon the measured average bit period as determined during the immediately preceding interval P . The interval P for the purpose of this re-

quirement shall be equal to the measured time for five successive minor frames; i.e.

$$\text{Average bit period} = \frac{P}{\text{specified bits/frame}} \times \frac{1}{5}$$

6.3.6 Multiple and submultiple sampling

6.3.6.1 General

Data sampling at rates which are multiples and submultiples of the minor frame rate (supercommutation and subcommutation respectively as defined in 3.42 and 3.43 is permissible. When submultiple sampling is employed, the restrictions on minor frame length (see 6.3.2.2) and bit jitter (see 6.3.5.2) are also applicable to the submultiple frames, i.e. the length of the longest submultiple frame (words 6-1 to 6-N in figure 2) shall not exceed 2 048 bits (but see also 6.3.6.3) and for bit jitter the interval P shall be the measured time for five successive minor frames (five successive channel intervals within the submultiple frame, for example, words 6-1 to 6-5 in figure 2).

6.3.6.2 Submultiple frame synchronization

The beginning of the longest submultiple frame interval (equal to the major frame interval) shall be identified by the transmission of a synchronization pattern. All other submultiple frames shall have a fixed and known relationship to the identified submultiple frame. It is recommended that one of the following alternative methods be used for submultiple frame synchronization :

- a) The beginning of a submultiple frame may be identified by a unique digital word in one minor frame, occupying the same word or channel interval (time-slot) as that allocated to data words of the identified submultiple frame, for example, word 6-1 in figure 2.
- b) The beginning of a submultiple frame may be identified by a unique digital word replacing the minor frame synchronization word indicating the start of the submultiple sequence. For example, the minor frame synch words in figure 2 occupy time-slot n in each minor frame, and that in one minor frame, say N , is changed to identify the longest submultiple frame or major frame interval. The complement of the minor frame synch word is often used for this purpose.
- c) Each word within the identified submultiple frame may be separately identified by the addition of identification bits to indicate the position of that word within the submultiple frame sequence, for example, bits may be added to each word in the sequence 6-1 to 6- N in figure 2.

6.3.6.3 Maximum submultiple frame (major frame) interval

The interval of any submultiple frame, including the time devoted to synchronizing of channel identification information, shall not exceed 256 times the interval of the minor frame in which it occupies a recurring position (i.e. the major frame length shall not exceed 256 times the minor frame length).

6.3.7 Premodulation filtering (not applicable when PCM waveforms are recorded directly on magnetic tape)

Premodulation filtering is recommended to control the spectral occupancy of the modulated output signal. The characteristics of the filter shall be as defined in 6.2.7.

6.3.8 PCM record characteristics

- a) It is recommended that the bits forming a word or sample in a PCM pulse train be recorded serially on a magnetic tape track. Where the bits in a word represent a single sample of an input channel, the most significant bit shall occur first.
- b) The inclusion of a word parity bit is optional; if included, it shall provide overall odd parity in the word and shall be the last bit in the word.
- c) The pulse train may be recorded as a modulating input to a carrier (in radio-frequency telemetry systems this may be a predetection recording of a PCM/FM format or a remodulation by a post-detection signal), or recorded directly on tape using either direct recording (see 5.1) or recording without bias (see 5.3) techniques. If recording without bias (saturation recording) is used, guard tracks may be required between a saturated track and any adjacent direct record track so as to minimize crosstalk from the saturated recording.
- d) When PCM signals are recorded directly on tape, provision must be made for the lack of reproduce low frequency response, for example, by constraining NRZ formats to ensure an adequate number of flux transitions, or by using a bi-phase format (see 6.3.3).

These techniques relate to longitudinal packing densities up to about 400 bits/mm (10 000 bits/in). See B.1.2 for comments on the use of higher packing densities.

6.3.9 PCM system tests

Recommended system test methods are given in A.6.

Table 18 — Proportional-bandwidth FM subcarrier channels

Channel	± 7,5 % channels						
	Centre frequency Hz	Lower deviation limit ¹⁾ Hz	Upper deviation limit ¹⁾ Hz	Nominal frequency response Hz	Nominal rise time Hz	Maximum frequency response ²⁾ Hz	Minimum rise time ²⁾ ms
1	400	370	430	6	58	30	11,7
2	560	518	602	8	42	42	8,33
3	730	675	785	11	32	55	6,40
4	960	886	1 032	14	24	72	4,86
5	1 300	1 202	1 398	20	18	98	3,60
6	1 700	1 572	1 828	25	14	128	2,74
7	2 300	2 127	2 473	35	10	173	2,03
8	3 000	2 775	3 225	45	7,8	225	1,56
9	3 900	3 607	4 193	59	6,0	293	1,20
10	5 400	4 995	5 805	81	4,3	405	0,864
11	7 350	6 799	7 901	110	3,2	551	0,635
12	10 500	9 712	11 288	160	2,2	788	0,444
13	14 500	13 412	15 588	220	1,6	1 088	0,322
14	22 000	20 350	23 650	330	1,1	1 650	0,212
15	30 000	27 750	32 250	450	0,78	2 250	0,156
16	40 000	37 000	43 000	600	0,58	3 000	0,117
17	52 500	48 562	56 438	790	0,44	3 938	0,089
18	70 000	64 750	75 250	1 050	0,33	5 250	0,067
19	93 000	86 025	99 975	1 395	0,25	6 975	0,050
20	124 000	114 700	133 300	1 860	0,19	9 300	0,038
21	165 000	152 624	177 375	2 475	0,14	12 375	0,029
Channel	± 15 % channels ³⁾						
A	22 000	18 700	25 300	660	0,53	3 330	0,106
B	30 000	25 500	34 500	900	0,39	4 500	0,078
C	40 000	34 000	46 000	1 200	0,29	6 000	0,058
D	52 500	44 625	60 375	1 575	0,22	7 875	0,044
E	70 000	59 500	80 500	2 100	0,17	10 500	0,033
F	93 000	79 050	106 950	2 790	0,13	13 950	0,025
G	124 000	105 400	142 600	3 720	0,09	18 600	0,018
H	165 000	140 250	189 750	4 950	0,07	24 750	0,014

1) Rounded off to nearest hertz.

2) The indicated maximum data frequency response and minimum rise time is based upon the maximum theoretical response that can be obtained in a bandwidth between the upper and lower frequency limits specified for the channels.

3) Channels A to H may be used by omitting adjacent lettered and numbered channels. Channels 13 and A may be used together with some increase in adjacent channel interference.

Table 19 — Constant-bandwidth FM subcarrier channels

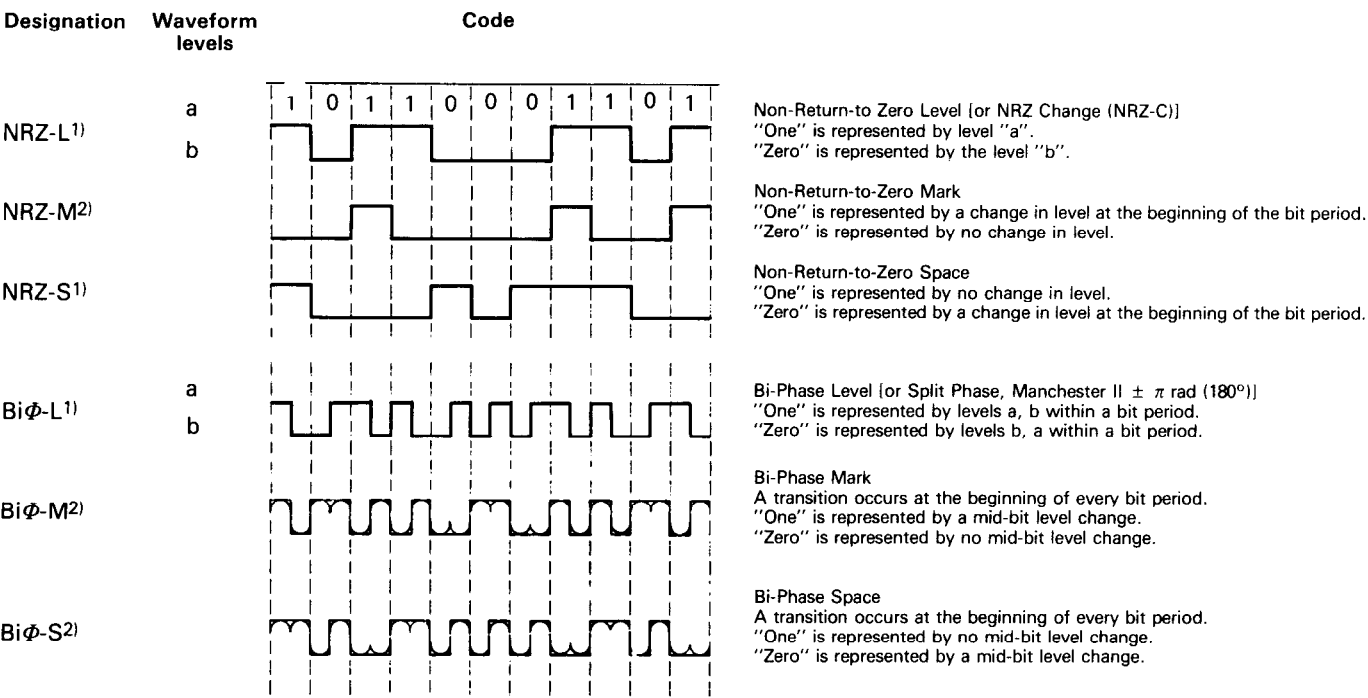
A channels		B channels		C channels	
Deviation limits = ± 2 kHz Nominal frequency response = 0,04 kHz Maximum frequency response = 2 kHz ¹⁾		Deviation limits = ± 4 kHz Nominal frequency response = 0,8 kHz Maximum frequency response = 4 kHz ¹⁾		Deviation limits = ± 8 kHz Nominal frequency response = 1,6 kHz Maximum frequency response = 8 kHz ¹⁾	
Channel	Centre frequency kHz	Channel	Centre frequency kHz	Channel	Centre frequency kHz
1A	16				
2A	24				
3A	32	3B	32	3C	32
4A	40				
5A	48	5B	48		
6A	56				
7A	64	7B	64	7C	64
8A	72				
9A	80	9B	80		
10A	88				
11A	96	11B	96	11C	96
12A	104				
13A	112	13B	112		
14A	120				
15A	128	15B	128	15C	128
16A	136				
17A	144	17B	144		
18A	152				
19A	160	19B	160	19C	160
20A	168				
21A	176	21B	176		

1) The indicated maximum frequency is based upon the maximum theoretical response that can be obtained in a bandwidth between deviation limits specified for the channel.

Table 20 — Receiver intermediate frequency bandwidths (3 dB)

12 500 Hz ¹⁾
25 000 Hz ¹⁾
50 000 Hz ¹⁾
100 000 Hz
300 000 Hz
500 000 Hz
750 000 Hz
1 000 000 Hz
1 500 000 Hz
3 300 000 Hz

1) System instabilities may limit the use of these bandwidths



NOTES

1) In NRZ-L and Bi-phase-L formats it is not essential to define the sense of the waveform; levels "a" and "b" may be positive or negative at the users' discretion. However, the following voltage convention is recommended for use wherever possible; "a" always positive, "b" zero or negative, "sampling" or "data ready" pulse positive. Level "a" should always correspond to logic "1" and level "b" to logic "0" in digital equipment.

2) Since only transitions are significant for NRZ-M, NRZ-S, BiΦ-S and BiΦ-M, waveform levels need not be identified. Voltage levels for equipment interfacing shall be determined by the interchange parties.

Figure 1 — PCM definitions

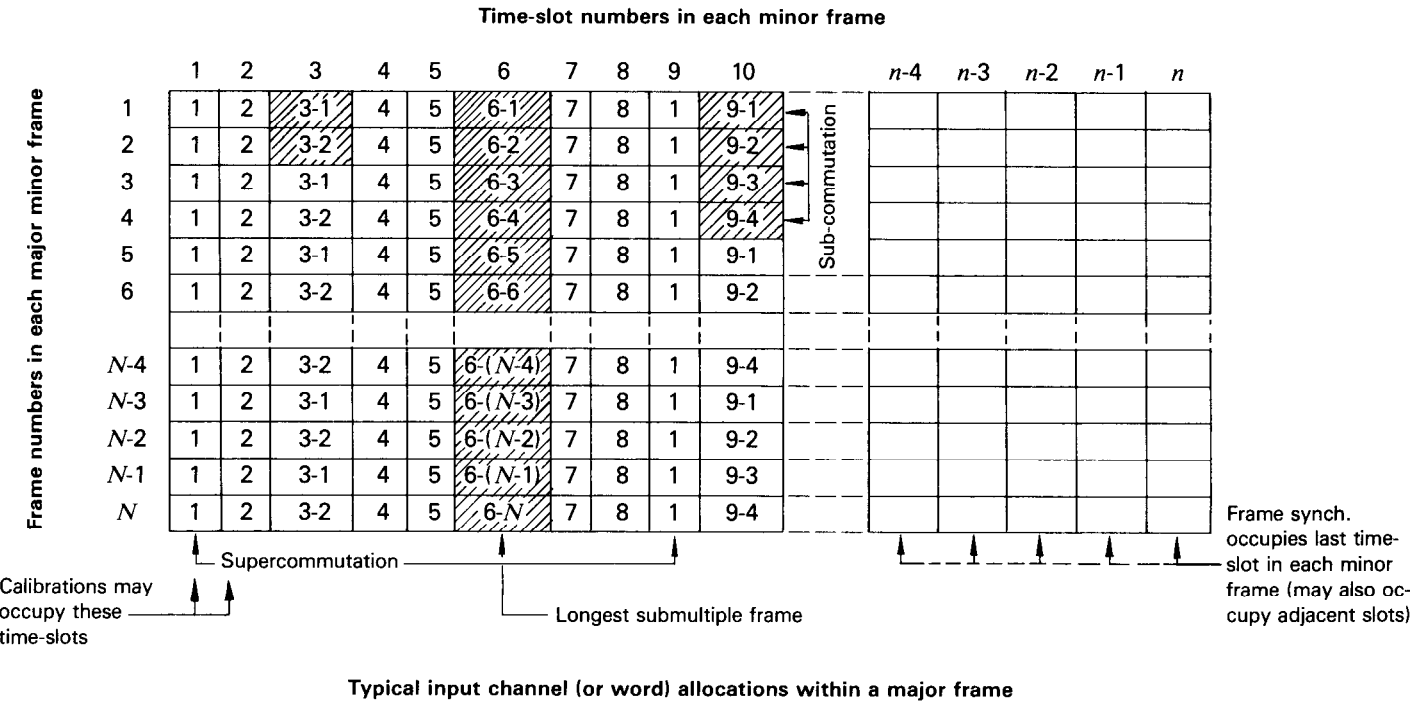
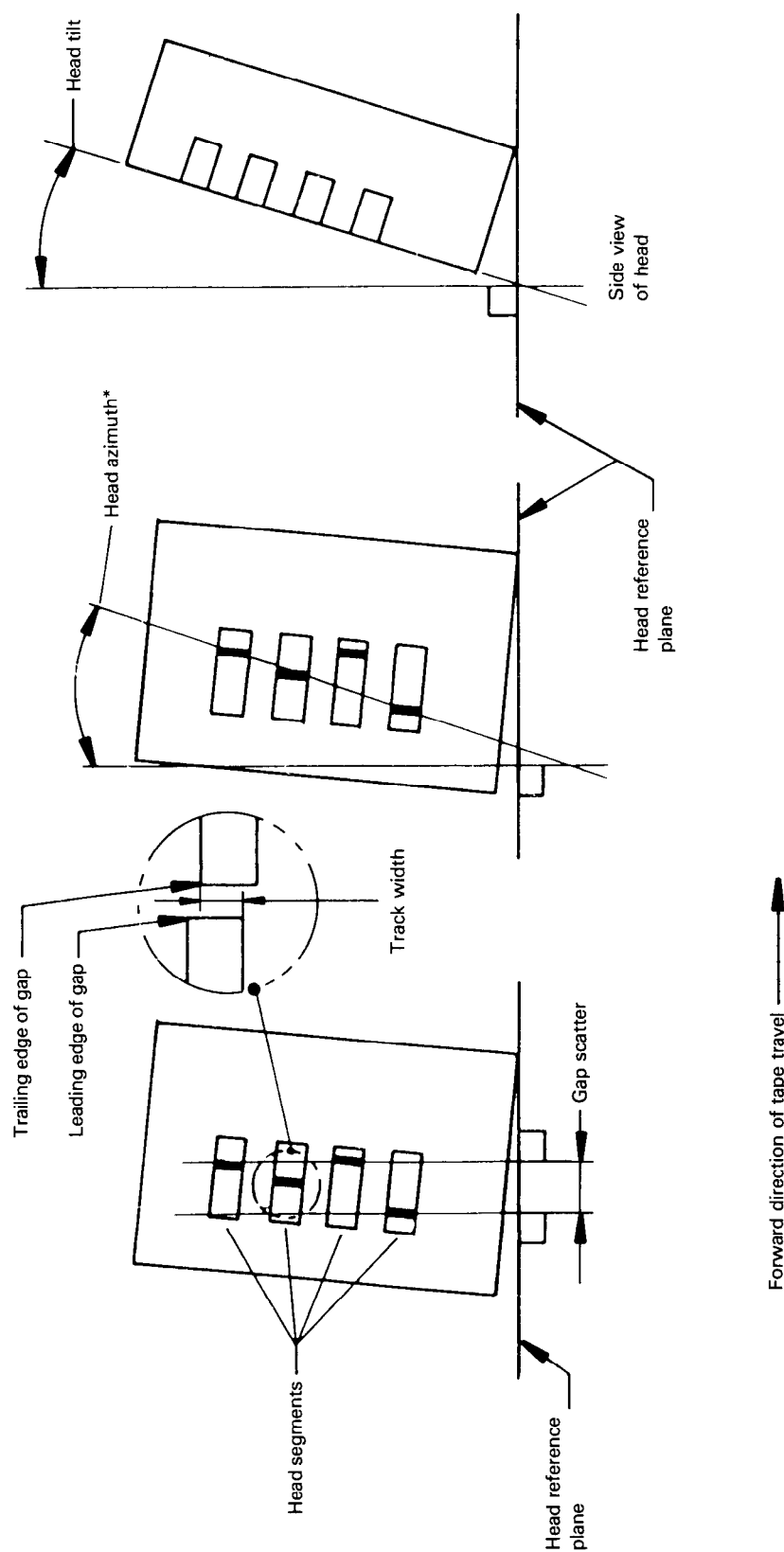
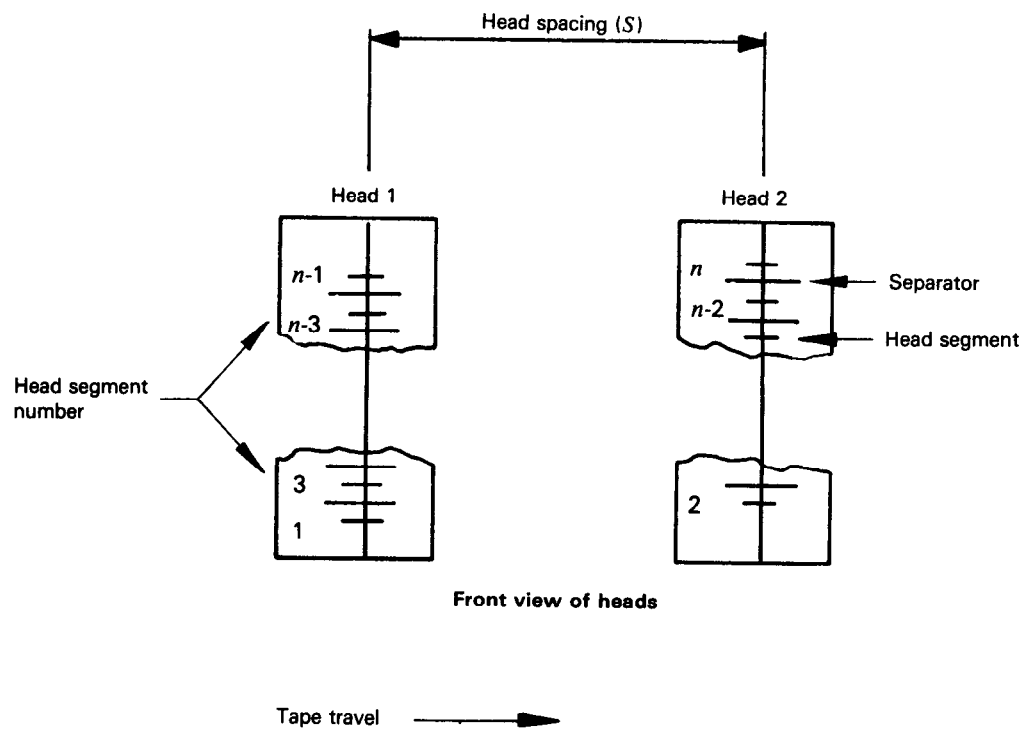


Figure 2 — Time-division multiplexing definitions (PAM and PCM)



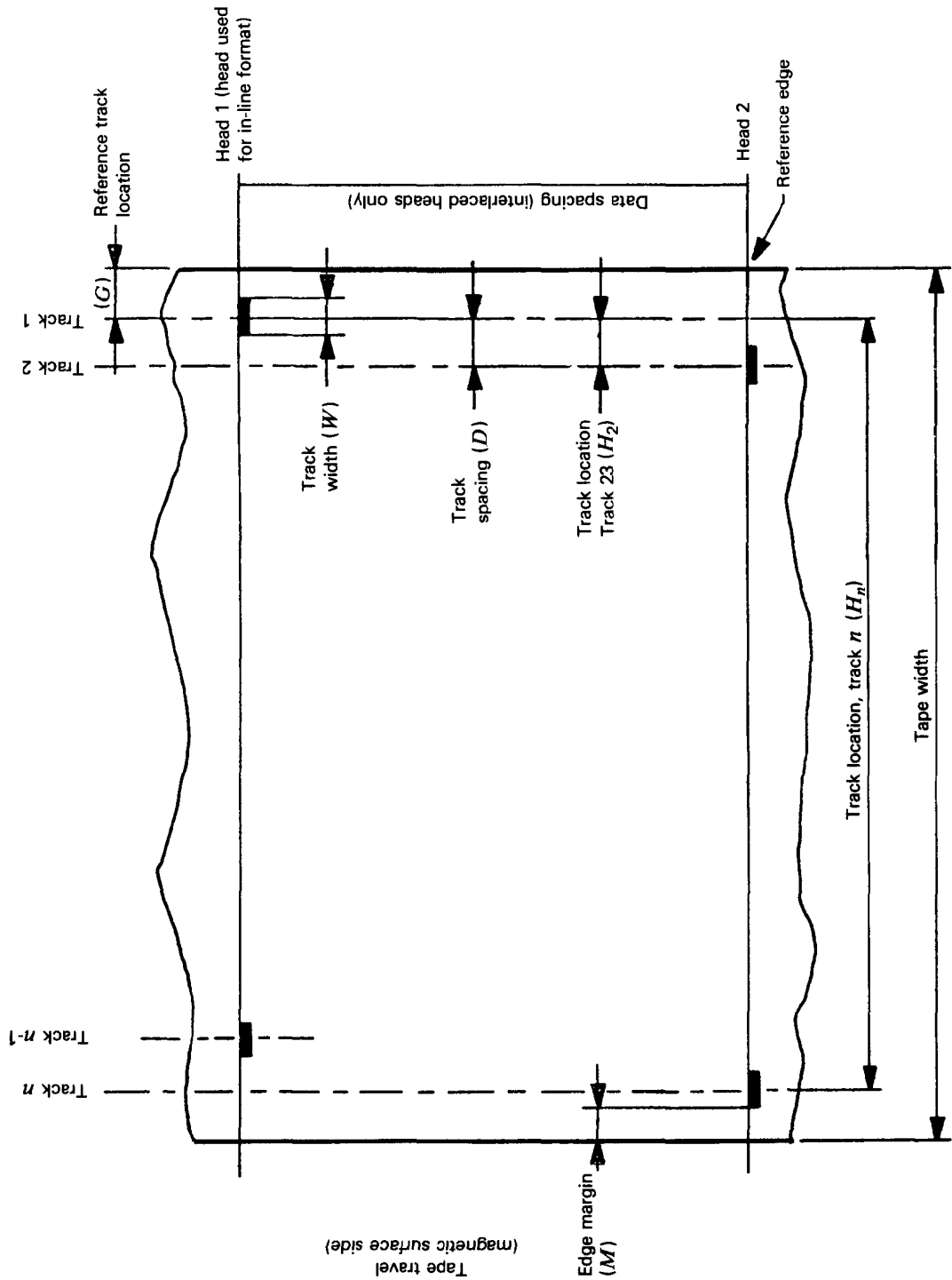
* The head azimuth line passes through the gap centres of the two outside tracks.

Figure 3 — Head mechanical parameters



NOTE — With formats to tables 4, 5 and 7, head segments n , $n-2$, etc. are in Head 1 and head segments $n-1$, $n-3$, etc. are in Head 2.

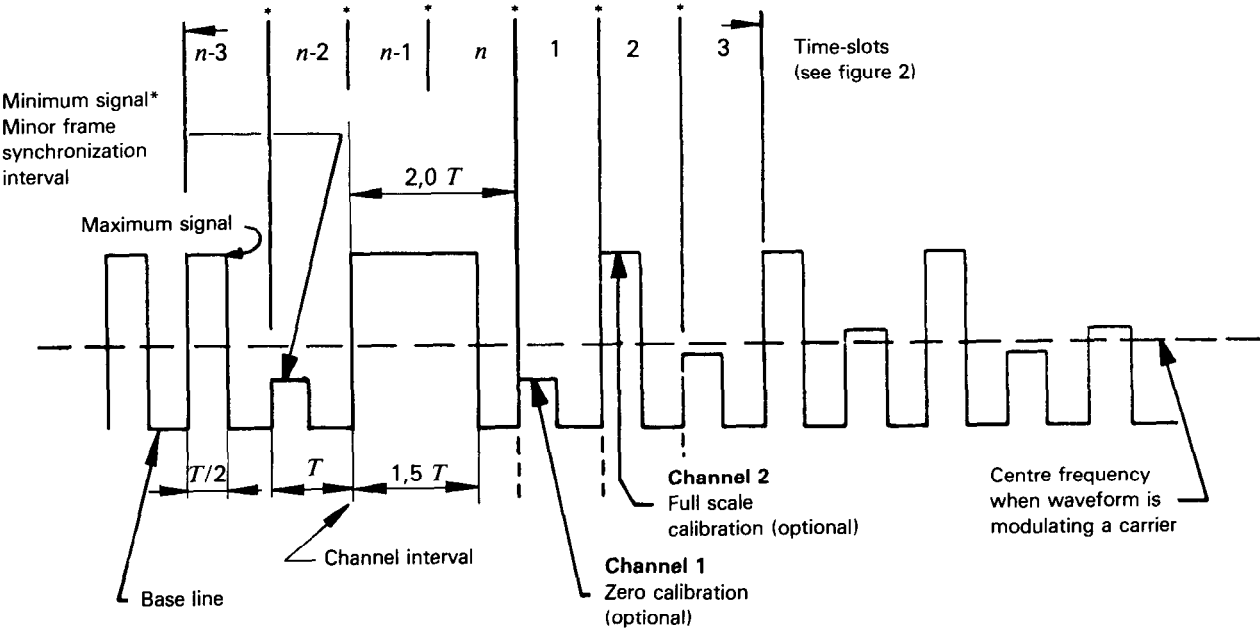
Figure 4 — Heads interlaced, n -track system



NOTES

- 1 With an in-line format, all tracks are in the Head 1 position.
- 2 With formats to tables 4, 5 or 7, track n is in the Head 1 position and track $n-1$ in the Head 2 position.

Figure 5 — Recorded tape format



* 20 to 25 percent of full amplitude reserved for pulse synchronization is recommended.

Figure 6 – Fifty percent duty factor PAM with amplitude synchronization

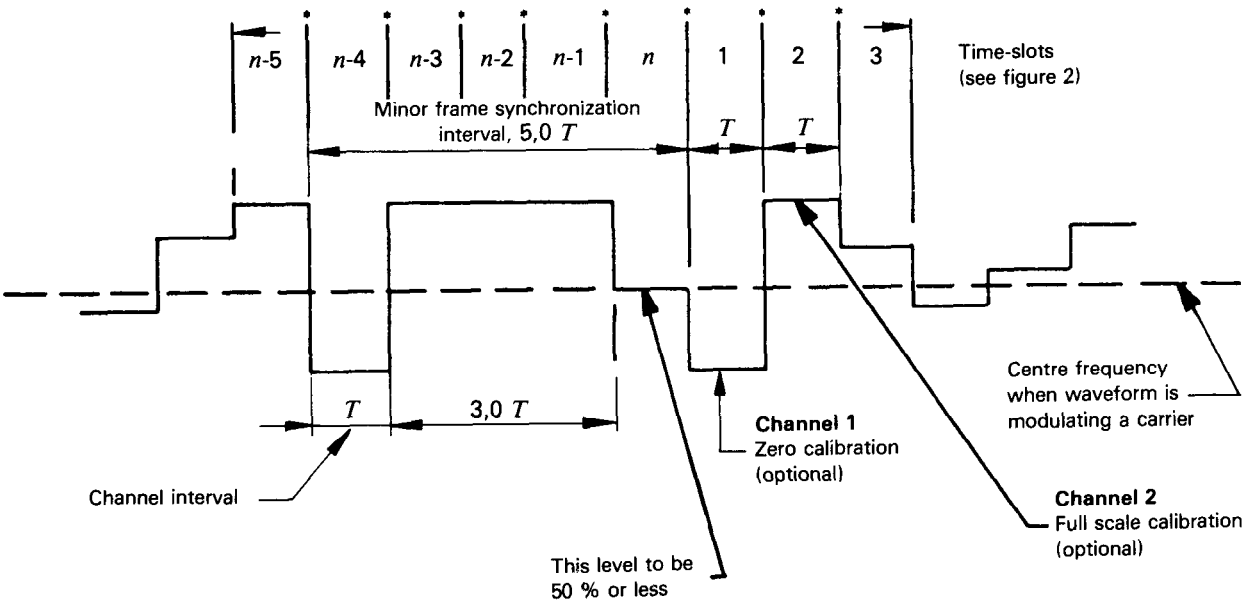


Figure 7 – One-hundred percent duty factor PAM with amplitude synchronization