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SMPTE STANDARD

for Television —

6.35-mm Type D-12 Component Format —

Digital Recording at 100 Mb/s

1080/60i, 1080/50i, 720/60p



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1 Scope

This standard specifies the content, format, and recording method of the data blocks containing video, audio, and associated data which form the helical records on 6.35-mm tape in cassettes as specified in SMPTE 307M.

In addition, this standard specifies the content, format, and recording method for longitudinal cue and control tracks.

One compressed video channel, eight independent audio channels and sub-code data are recorded on tape in the digital form. Each of these channels is capable of independent editing.

The helical recordings are synchronized to on the following digital video formats:

- 1080-line/59.94-Hz field frequency
- 1080-line/50-Hz field frequency
- 720-line/59.94-Hz frame frequency

These are hereafter referred to as the 1080/60i, 1080/50i, and 720/60p systems, respectively. Similarly, in this document, the 60-Hz system nomenclature refers to both 1080/60i and 720/60p systems; whereas, the 50-Hz system refers only to the 1080/50i system. Nomenclature 1080-line system refers to both 1080/60i and 1080/50i systems, while, the 720-line system refers only to the 720/60p system.

The recorded digital video signal shall be compressed according to the DV-based 100-Mb/s specification. The recorded digital video signal, eight audio channels, and sub-code data shall be defined by the data structure according to the DV-based 100-Mb/s specification.

2 Normative references

The following standard contains provisions which, through reference in this text, constitute provisions of the standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below.

AES3-1992 (R1997), Serial Transmission Format for Two-Channel Linearly Represented Digital Audio Data

ANSI/SMPTE 276M-1995, Television — Transmission of AES/EBU Digital Audio Signals Over Coaxial Cable

SMPTE 12M-1999, Television, Audio and Film — Time and Control Code

SMPTE 307M-2002, Television Digital Recording — 6.35-mm Type D-7 and Type D-12 Component Format — Tape Cassette

SMPTE 321M-2002, Television — Data Stream Format for the Exchange of DV-Based Audio, Data and Compressed Video over a Serial Data Transport Interface

SMPTE 370M-2002, Television — Data Structure for DV-Based Audio, Data and Compressed Video at 100 Mb/s 1080/60i, 1080/50i, 720/60p

3 Environment and test conditions

3.1 Environment

Tests and measurements made on the system to check the requirements of this standard shall be carried out under the following conditions:

- Temperature: $20^{\circ}\text{C} \pm 1^{\circ}\text{C}$
- Relative humidity: $(50 \pm 2)\%$
- Barometric pressure: From 86 kPa to 106 kPa
- Tape conditioning: Not less than 24 h
- Center tape tension: $0.09 \text{ N} \pm 0.02 \text{ N}$ (see annex A)

3.2 Reference tape

A blank tape for reference recordings shall be available from the format holder or approved source.

3.3 Calibration tapes

The calibration tapes meeting the requirements of 3.3.1, 3.3.2, and clause 4 are available from manufacturers who produce digital television tape recorders and players in accordance with this standard.

3.3.1 Record locations and dimensions

All tolerances shown in table 1 or table 2 and clause 4.2 will be reduced by 50%.

3.3.2 Calibration signals

Two sets of signals shall be recorded on the calibration tape:

- a) – Video: 100 / 0 / 100 / 0 color bars compressed according to SMPTE 370M
 - Audio: 1 kHz tone at 20 dB below full scale on each audio channel
 - Cue: 1 kHz and 6 kHz tone at the analog recording reference level
- b) A signal of constant recorded frequency (i.e., the Nyquist frequency) for the purpose of mechanical alignment. Recording level shall conform to 6.1.4.3

4 Tape

4.1 Base

The base material shall be polyester or equivalent.

4.2 Width

The tape width shall be $6.350 \text{ mm} \pm 0.005 \text{ mm}$. The tape, covered with glass, is measured without tension at a minimum of five different positions along the tape using a calibrated comparator having an accuracy of 0.001 mm ($1 \text{ }\mu\text{m}$). The tape width shall remain within the above specifications at any measuring position.

4.3 Width fluctuation

Tape width fluctuation shall not exceed $5 \text{ }\mu\text{m}$ peak-to-peak. Measurement of tape width fluctuation shall be taken over a tape length of 900 mm. The tape width fluctuation shall be within the aforementioned specification at each of ten equally spaced points in the 900 mm span.

4.4 Reference edge straightness

The maximum deviation of the reference edge straightness is $6 \text{ }\mu\text{m}$ peak-to-peak. Edge straightness fluctuation is measured at the edge of a moving tape guided by three guides having contact on the same edge and having a distance of 85 mm from the first to second guide and 85 mm from the second to third guide. Edge measurements are averaged over a 10 m length and are made 5 mm from the midpoint between the first and second guide towards the first guide.

4.5 Tape thickness

The total tape thickness shall be $8.8 \text{ }\mu\text{m} + 0.0 \text{ }\mu\text{m} - 0.8 \text{ }\mu\text{m}$ and $6.7 \text{ }\mu\text{m} + 0.0 \text{ }\mu\text{m} - 0.4 \text{ }\mu\text{m}$.

4.6 Transmissivity

Transmissivity shall be less than 5%, measured over the range of wavelengths 800 nm to 1000 nm.

4.7 Offset yield strength

The offset yield strength shall be greater than 3 N. The force to produce 0.2% elongation of a 1000-mm test sample with a pull rate of 10 mm per minute shall be used to confirm the offset yield strength. The line

beginning at 0.2% elongation parallel to the initial tangential slope is drawn and then read at the point of intersection of the line and the stress-strain curve.

4.8 Magnetic coating

The magnetic layer of the tape shall consist of a coating of metal particles or equivalent.

4.9 Coating coercivity

The magnetic coating coercivity shall be a class 2300 (approximately 2300 Oe / 184000 A/m), with an applied field of 10000 Oe / 800000 A/m measured by a vibrating sample magnetometer.

5 Helical recordings

5.1 Tape speed

The tape speed shall be 135.2801 mm/s for the 60-Hz system and 135.4154 mm/s for the 50-Hz system. The tolerance shall be $\pm 0.2\%$.

5.2 Sectors

Each recorded track contains an ITI sector, an audio sector, a video sector and a subcode sector.

5.3 Record location and dimensions

The record location and dimensions for continuous recording shall be as specified in figures 1 and 2 and table 1 or table 2. In recording, sector locations on each helical track shall be contained within the tolerance specified in figure 1 and table 1 or table 2.

The reference edge of the tape for dimensions specified in this standard shall be the lower edge as shown in figure 1. The magnetic coating, with the direction of tape travel as shown in figure 1, is on the side facing the observer.

As indicated in figure 1, this standard anticipates a zero guard band between recorded tracks. The nominal record head width shall be equal to the track pitch of 18 μm . The scanner head configuration should be chosen such that the recorded track widths are contained within the limits of 16 μm to 20 μm .

The format requires flying erasure for recording. In insert editing, this standard provides a guard band of 3 μm $\pm$ 1.5 μm between the previously recorded track and the inserted track at editing points only. A typical track pattern for insert editing is shown in figure B.1 of annex B.

5.4 Helical track record tolerance zones

The lower edge of eight consecutive tracks starting at the first track in each frame shall be contained within the pattern of the eight tolerance zones established in figure 3. Each zone is defined by two parallel lines which are inclined at an angle of 9.1784° basic with respect to the tape reference edge. The centerlines of each zone shall be spaced apart 18.0 μm basic. The width of zone 2 shall be 3 μm and the width of zones 1, 3 to 8 shall be 5 μm . These zones are established to contain track angle errors, track straightness errors, and vertical head offset tolerance (the measuring technique is shown in annex C).

5.5.1 Relative positions of longitudinal tracks

5.5.2 Program area reference point

The end of the preamble and beginning of SSA in the ITI sector shall be recorded at the program area reference point, and the tolerance of dimension X_0 . The locations are shown in figures 1 and 2; dimensions X_0 and Y_0 are specified in tables 1 and 2. The relationship between sectors and contents of each sector is specified in clause 6.

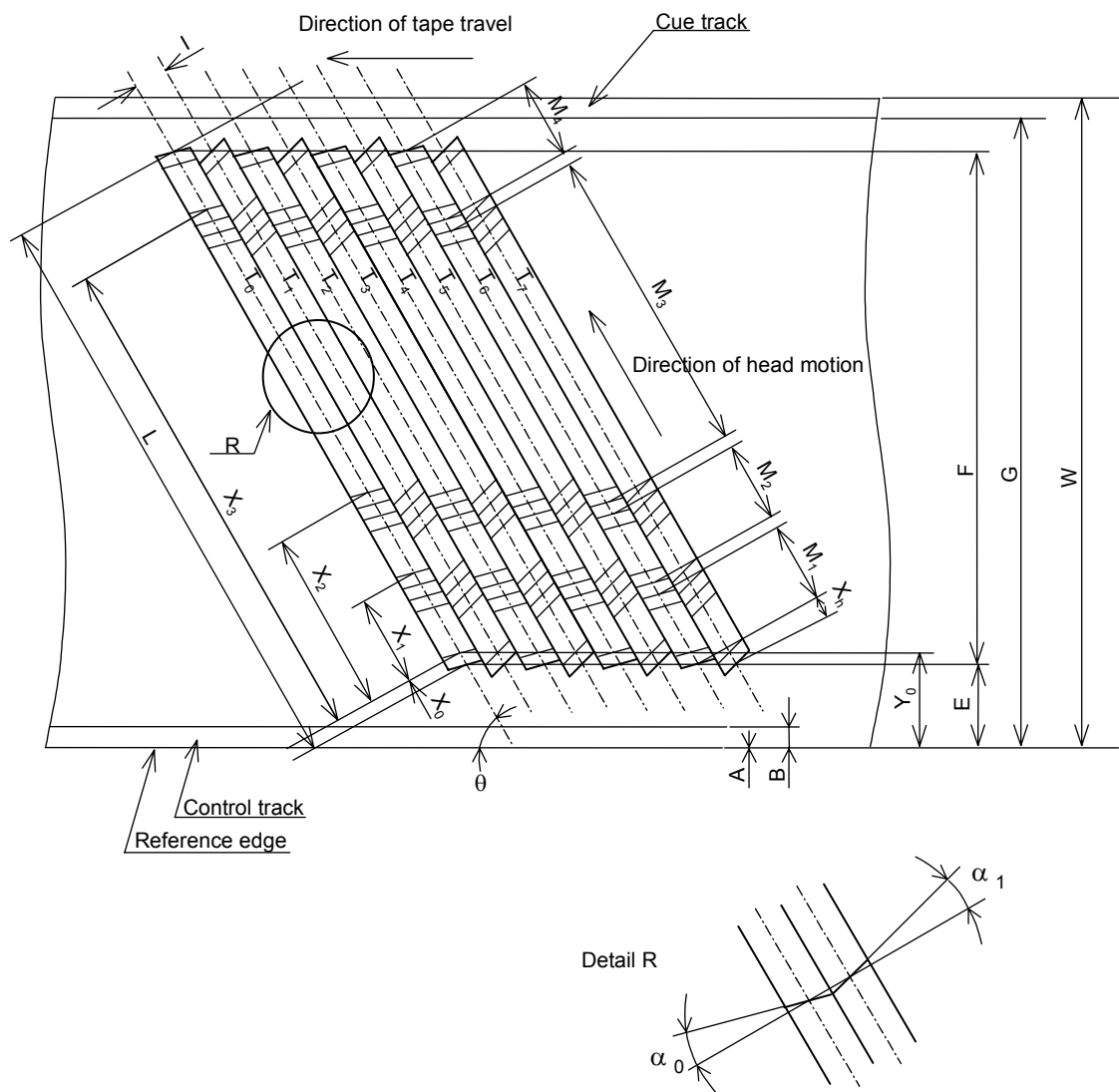


Figure 1 – Location and dimensions of recorded tracks

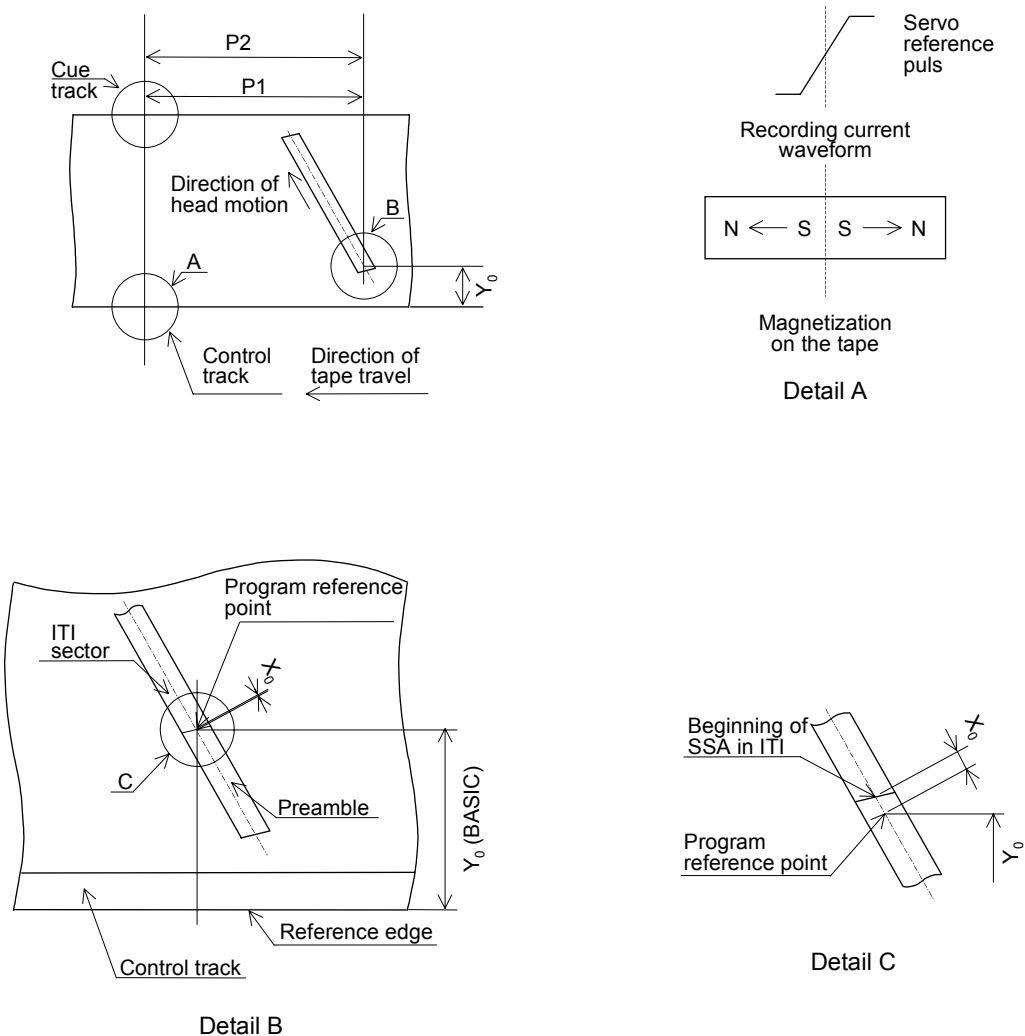


Figure 2 – Location of recorded cue and control track

Table 1 – Record location and dimensions for the 60-Hz system

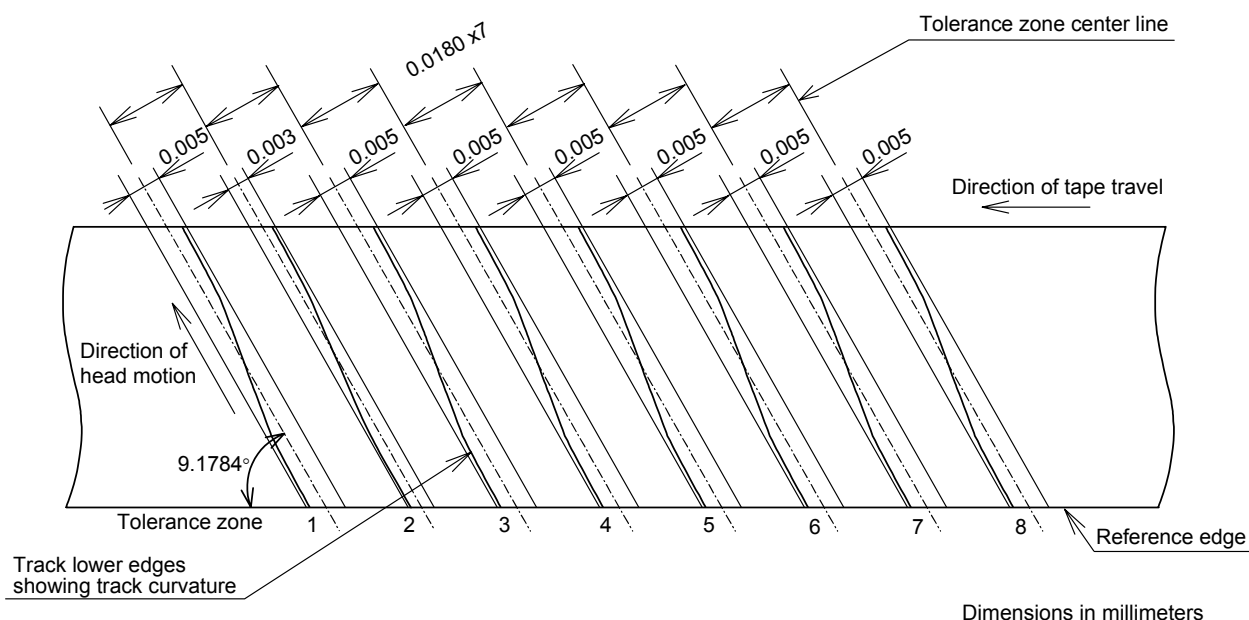
Dimensions		Dimensions in millimeters	
		Nominal	Tolerance
A	Control track lower edge	0	Basic
B	Control track upper edge	0.400	± 0.050
E	Program area lower edge	0.56	Derived
F	Program area width	5.24	Derived
G	Cue track lower edge	6.000	± 0.050
I	Helical track pitch	0.018	Ref.
L	Total length of helical track	32.842	Derived
M ₁	Length of ITI sector with pre and post-amble	0.876	Derived
M ₂	Length of audio sector with pre and post-amble	2.810	Derived
M ₃	Length of video sector with pre and post-amble	27.548	Derived
M ₄	Length of subcode sector with pre and post-amble	0.906	Derived
P ₁	Control track reference pulse to program reference point (see figure 2)	67.500	± 0.030
P ₂	Cue signal, start of codeword of cue to program reference point (see figure 2)	67.500	± 0.300
W	Tape width	6.350	± 0.005
X ₀	Location of beginning of SSA in ITI sector	0	± 0.050
X ₁	Location of start of audio data sync blocks	0.809	± 0.050
X ₂	Location of start of video data sync blocks	3.790	± 0.050
X ₃	Location of start of subcode data sync blocks	31.885	± 0.050
Xh	Head stagger and inline tolerance	0.111	± 0.021
Y ₀	Program track reference point	0.615	Basic
θ	Track angle	9.1784 °	Basic
α_0	Azimuth angle (track 0, 2, 4, 6)	19.97 °	± 0.150 °
α_1	Azimuth angle (track 1, 3, 5, 7)	20.03 °	± 0.150 °

NOTE – Measurements shall be made under the conditions specified in 3.1. The measurements shall be corrected to account for actual tape speed (see figures C.1 and C.2)

Table 2 – Record location and dimensions for the 50-Hz system

		Dimensions in millimeters	
Dimensions		Nominal	Tolerance
A	Control track lower edge	0	Basic
B	Control track upper edge	0.400	± 0.050
E	Program area lower edge	0.56	Derived
F	Program area width	5.24	Derived
G	Cue track lower edge	6.000	± 0.050
I	Helical track pitch	0.018	Ref.
L	Total length of helical track	32.842	Derived
M1	Length of ITI sector with pre and post-amble	0.877	Derived
M2	Length of audio sector with pre and post-amble	2.813	Derived
M3	Length of video sector with pre and post-amble	27.576	Derived
M4	Length of subcode sector with pre and post-amble	0.877	Derived
P1	Control track reference pulse to program reference point (see figure 2)	67.500	± 0.030
P2	Cue signal, start of codeword of cue to program reference point (see figure 2)	67.500	± 0.300
W	Tape width	6.350	± 0.005
X0	Location of beginning of SSA in ITI sector	0	± 0.050
X1	Location of start of audio data sync blocks	0.810	± 0.050
X2	Location of start of video data sync blocks	3.793	± 0.050
X3	Location of start of subcode data sync blocks	31.917	± 0.050
Xh	Head stagger and inline tolerance	0.111	± 0.021
Y0	Program track reference point	0.615	Basic
θ	Track angle	9.1784 °	Basic
α_0	Azimuth angle (track 0, 2, 4, 6)	19.97 °	± 0.150 °
α_1	Azimuth angle (track 1, 3, 5, 7)	20.03 °	± 0.150 °

NOTE – Measurements shall be made under the conditions specified in 3.1. The measurements shall be corrected to account for actual tape speed (see figures C.1 and C.2)

**Figure 3 – Location and dimensions of tolerance zone of recorded helical tracks**

5.6 Gap azimuth

5.6.1 Cue and control track

The angle of the cue and control track head gaps used to produce longitudinal track records shall be perpendicular to the track record.

5.6.2 Helical track

The azimuth of the head gaps which are used for the helical track shall be inclined at angles α_0 and α_1 as specified in table 1 or table 2 with respect to a line perpendicular to the helical track (see figure 1). The azimuth of track No. 0, 2, 4, and 6 for every field shall be oriented in a clockwise direction with respect to a line perpendicular to the helical track direction when viewed from the side of the tape containing the magnetic record.

5.7 Transport and scanner

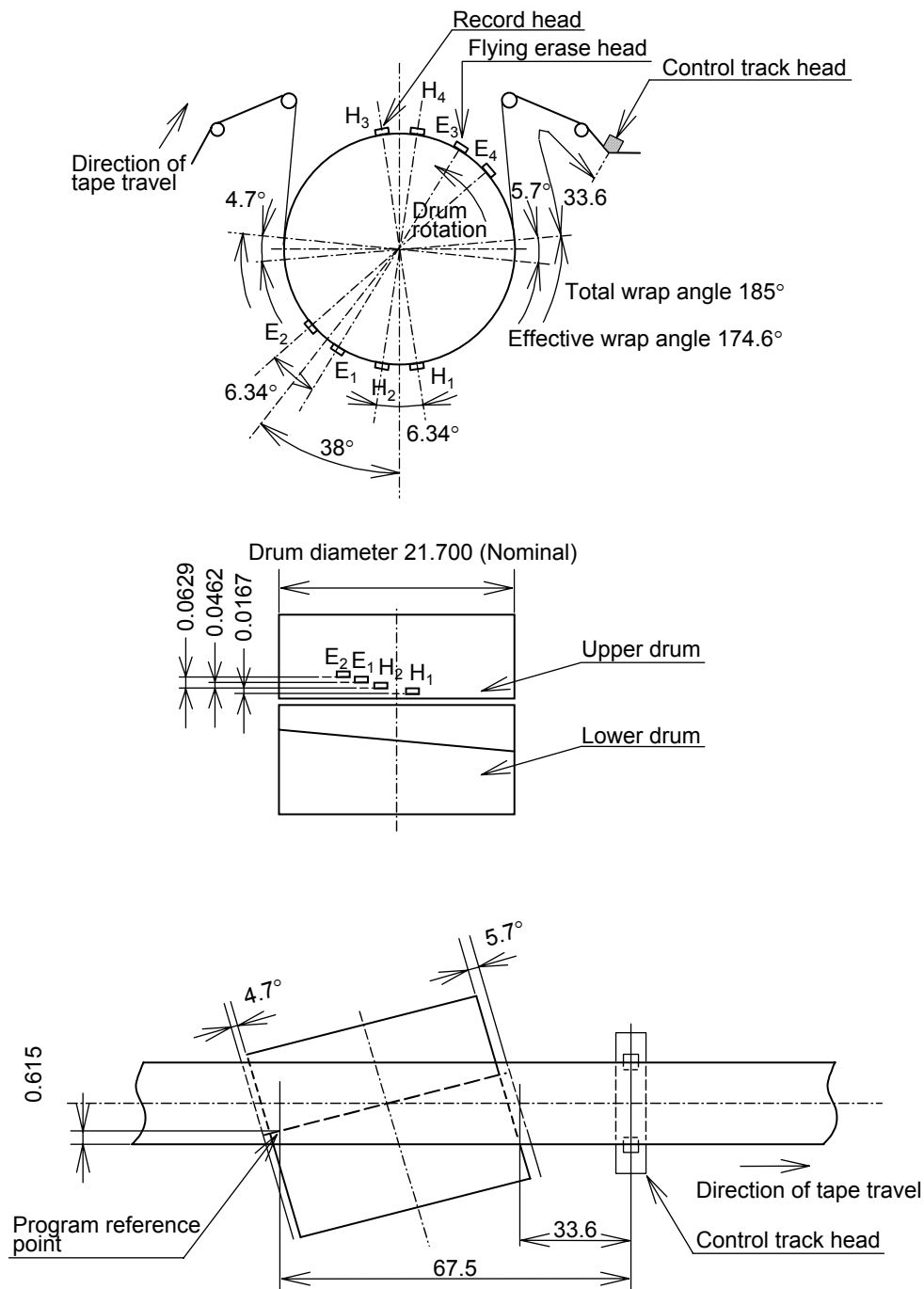
The effective drum diameter, tape tension, helix angle, and tape speed taken together determine the track angle. Different methods of design and/or variations in drum diameter and tape tension can produce equivalent recordings for interchange purposes.

A possible configuration of the transport uses a scanner with an effective diameter of 21.700 mm. Scanner rotation is in the same direction as tape motion during normal playback mode.

Data are recorded by two pairs of heads each mounted 180° apart or four pairs of heads each mounted 90° apart. Figures 4 and 5 shows a possible mechanical configuration of the scanner and the relationship between the longitudinal heads and the scanner. Table 3 shows the corresponding mechanical parameters. Other mechanical configurations are allowable provided the same footprint of recorded information is produced on tape.

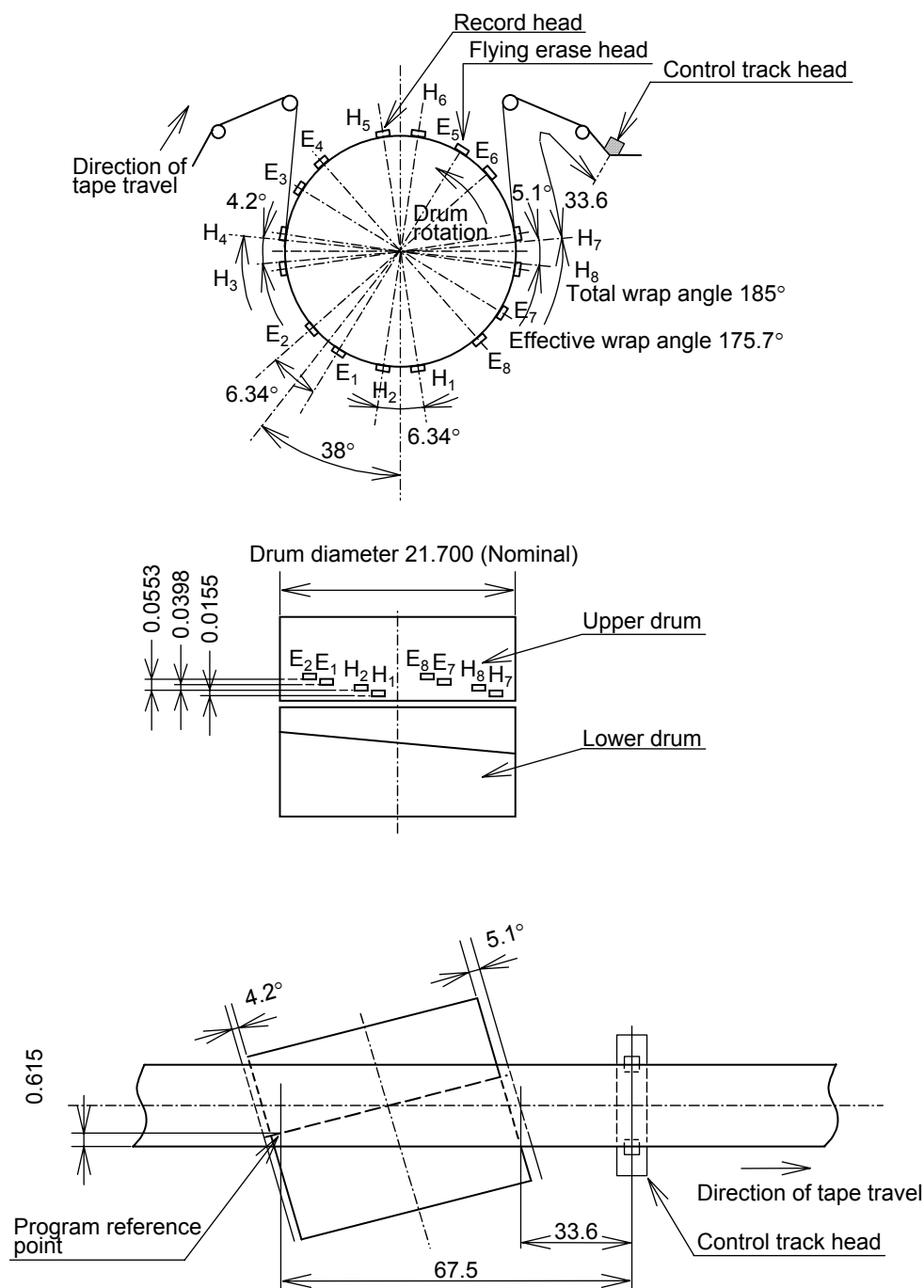
Table 3 – Parameters for a possible scanner design

Parameters	configuration			
	60 Hz system		50 Hz system	
Scanner rotation speed (rpm)	18000/1.001	9000/1.001	18000	9000
Number of tracks per rotation	4	8	4	8
Drum diameter (mm)	21.700	21.700	21.700	21.700
Center span tension (N)	0.09	0.09	0.09	0.09
Helix angle (degrees)	9.1197	9.0592	9.1197	9.0592
Effective wrap angle (degrees)	174.6	175.7	174.6	175.7
Scanner circumferential speed (m/s)	20.298	10.082	20.318	10.092
Bit frequency f_b (Hz)	83430000	41438200	83430000	41438200
H1, H3 over wrap head entrance (degrees)	4.7	4.2	4.7	4.2
H1, H3 over wrap head exit (degrees)	5.7	5.1	5.7	5.1
Maximum tip projection (μm)	20	20	20	20
Record head track width (μm)	18	18	18	18



Dimensions in millimeters

Figure 4 – Possible scanner configuration and tape wrap for four heads construction



Dimensions in millimeters

Figure 5 – Possible scanner configuration and tape wrap for eight heads construction

6 Program track data

6.1 General

6.1.1 Introduction

The helical tracks contain digital data from the ITI sector, audio sector, video sector, and subcode sector. The ITI sector contains the start sync and track information. The subcode sector contains the time and control code data and it may also include other optional data.

Figure 6 shows a block diagram of the typical recording circuit. The compression part in the dotted line rectangle refers to SMPTE 370M. Figure 7 shows the arrangement of the ITI sector, audio and video sectors, and the subcode sector on the tape. All edit gaps between sectors accommodate timing errors during editing.

In 1080/60i and 1080/50i systems, video frame data, audio frame data and subcode data are processed in each frame. The audio frame is defined as an audio-processing unit. In the 720/60p system, data of two video frames are processed within one frame duration of the 1080/60i system. Consequently, video frame can be edited in frame pairs, and audio data and subcode data are processed exactly the same way as the 1080/60i system.

NOTE – SMPTE 12M does not allow distinction between the two identical time code assigned to two adjacent frames in the 720p system.

Each video frame is recorded on 40 tracks in the 1080/60i system, 48 tracks in the 1080/50i system, and 20 tracks in the 720/60p system. Each audio frame is recorded on 40 tracks in the 1080/60i system, 48 tracks in the 1080/50i system, and 40 tracks in the 720/60p system. One audio frame equals two video frames (frames 1 and 2) in the 720/60p system.

Each frame of time code shows a frame number that corresponds to each video frame in 1080-line system, and two video frames each in 720/60p system. Therefore, time codes of the 1080/60i and 720/60p systems are the same.

6.1.2 Labeling convention

The most significant bit is written on the left and first recorded to tape. The lowest numbered byte is shown at the left/top and is the first encountered in the input data stream. Byte values are expressed in hexadecimal notation unless otherwise noted. An h subscript indicates a hexadecimal value.

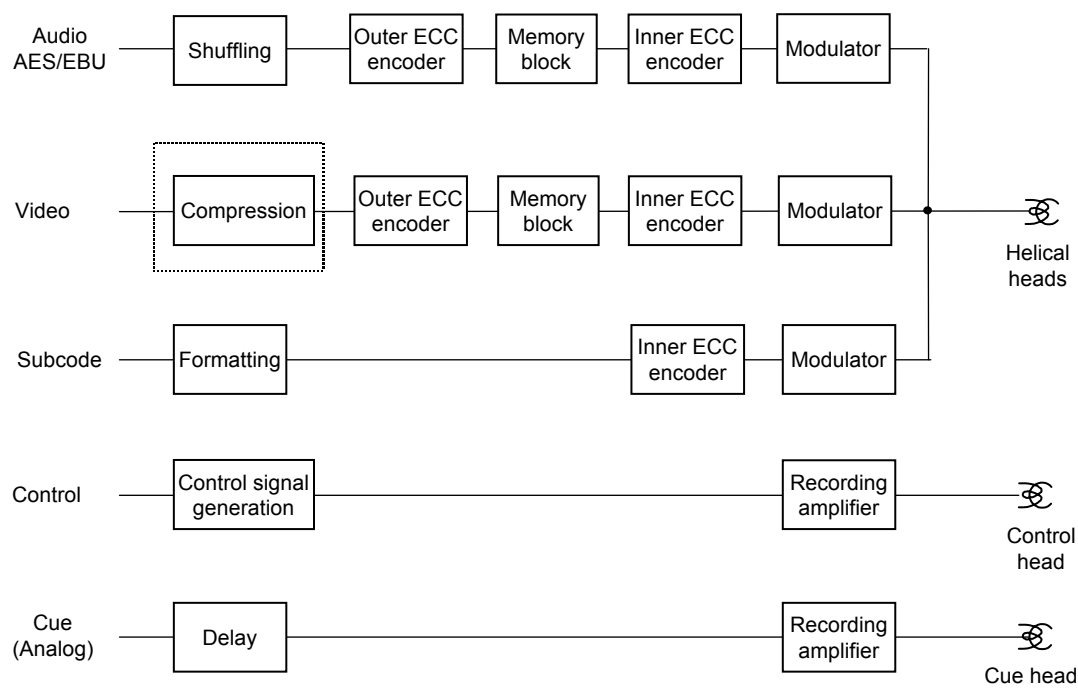
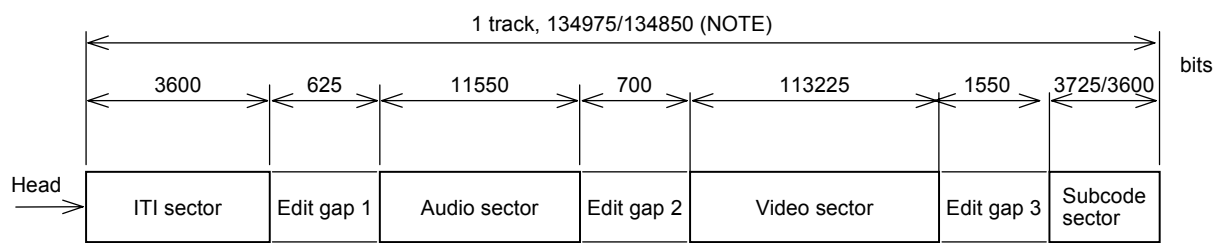


Figure 6 – Possible recording system configuration



NOTE – 60-Hz system / 50-Hz system

Figure 7 – Sector arrangement on helical track

6.1.3 Signal processing

The modulation of this standard adopts the randomization and the 24-25 modulation. The randomization limits the run length of a same binary value. The 24-25 modulation is defined as insertion of an extra bit to the 24 bits data and interleaved NRZI modulation.

Figures 8 to 10 show the processing of modulation related to the recorded signals. The program track data with the exception of ID0 shall be processed through three operations as shown below:

- Randomization;
- 24-25 modulation;
- Precoding.

The program track data of ID0 shall be processed through two operations as shown below:

- Randomization;
- Precoding.

The preamble and postamble shall be 24-25 modulated by selecting pattern A or B according to the modulation rule in 6.1.3.2.

The sync pattern shall not be processed through 24-25 modulation, but is selected from pattern F or G for audio and video sync blocks and pattern D or E for subcode sync block according to modulation rules in 6.1.3.2.

Figure 11 shows a possible block diagram of the process.

6.1.3.1 Randomization

The data except sync patterns shall be randomized. The randomizing is equivalent to performing the exclusive-or operation between the input serial data and the serial data generated by the polynomial function below:

$$X^7 + X^3 + 1$$

where X^i are place-keeping variables in GF(2), the binary field. The first term is the most significant and the first to enter the division computation. The randomization is reset at ID0. The randomization limits the run length of the same binary value.

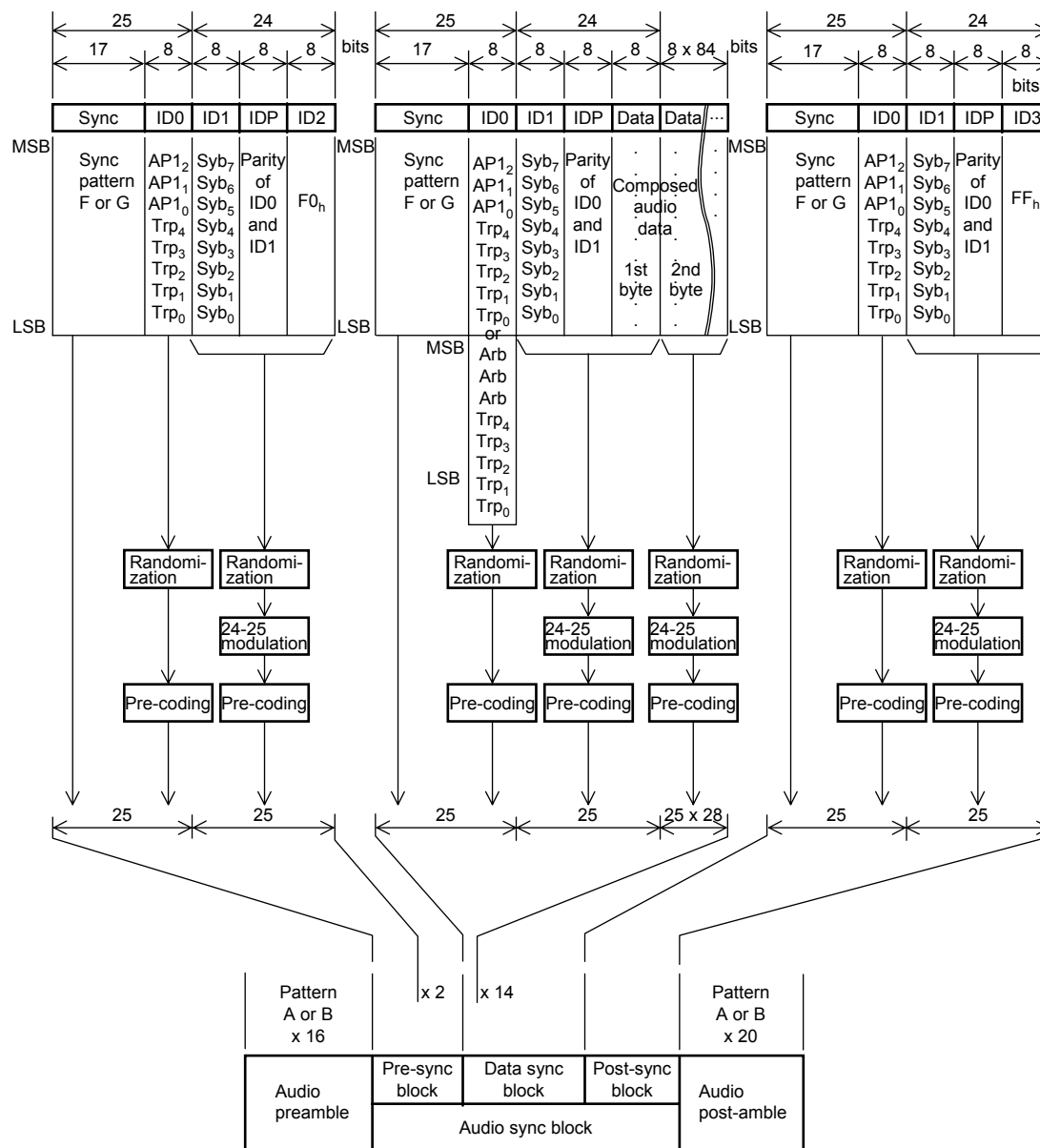


Figure 8 – Modulation for audio sector





Figure 10 – Modulation for subcode sector

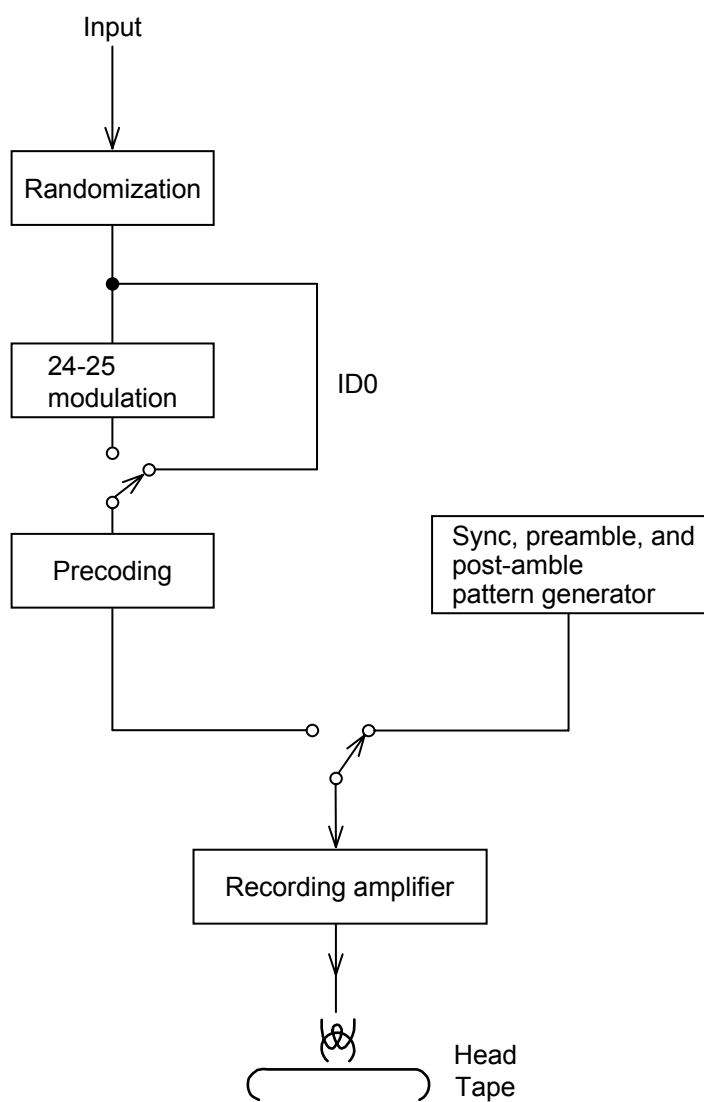


Figure 11 – Possible block diagram for signal processing

6.1.3.2 24-25 modulation

The 24-25 modulation is applied to the randomized data. An extra bit is inserted before the three consecutive randomized bytes as shown in figure 12. The modulated output, 25 bit data, is referred to as a codeword. The following criteria are used to insert the extra bit:

- 1) If the run length of 0s or 1s is ten or more, including the extra bit to be inserted at the junction, then the value of the extra bit shall be chosen so as not to make the run length any longer except in the case that the value of the bit in front and behind the junction is different and the run length is the same.
- 2) If the run length is 9 or less, including the extra bit to be inserted at the junction, then the value of the extra bit shall be chosen to make the frequency characteristics of the pre-coded data nearer to the pilot signal as shown in figures 13 and 14.
- 3) If the value of the bit in front and behind the junction are different and each run length is same, the value of the extra bit shall be chosen to make the frequency characteristics of the pre-coded data nearer to the pilot signal as shown in figures 13 and 14.

For the generation of the ATF signal, 24-25 modulation is applied to the data. The converted data satisfies the following conditions:

- Track F_0 : Attenuation of f_1 and f_2 frequency components by at least 9 dB;
- Track F_1 : Generation of f_1 component of at least 16 dB, but not more than 19 dB;
- Track F_2 : Generation of f_2 component of at least 16 dB, but not more than 19 dB.

where $f_1 = f_b / 90$ (Hz)

$f_2 = f_b / 60$ (Hz)

f_b = The frequency whose period is a time interval of one channel bit(Hz)

The modulated data are recorded on the tracks in the repeated cycle of $F_0 - F_1 - F_0 - F_2$ sequence. Table 4 shows the relation between track and servo information.

6.1.3.3 Precoding

The modulated bit stream shall be converted to interleaved NRZI as shown in figure 15.

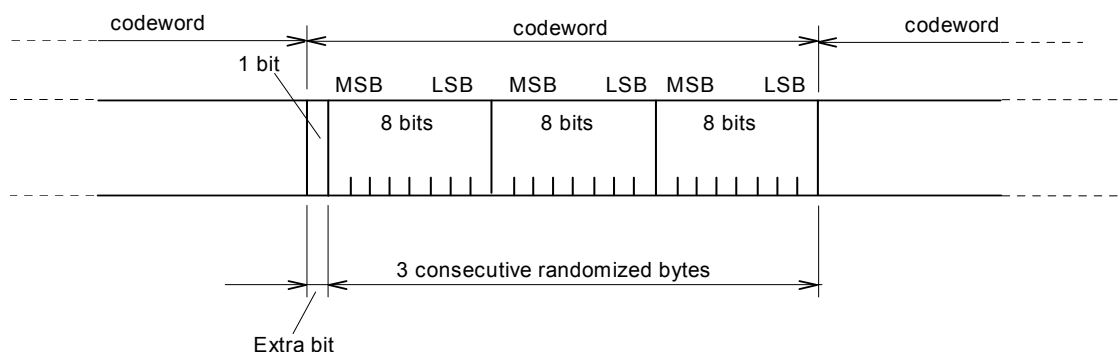
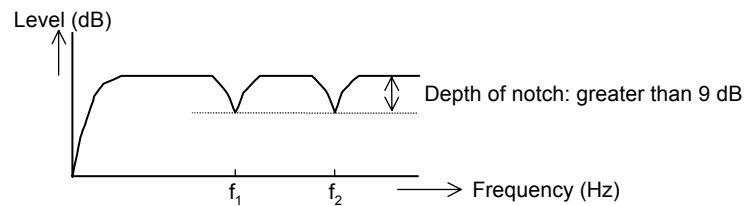
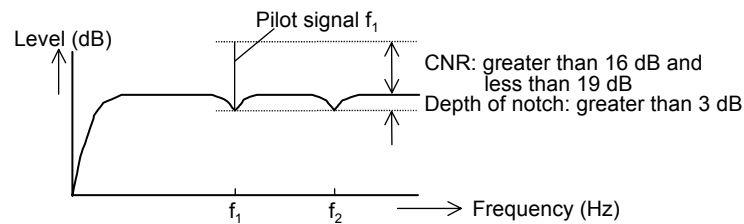


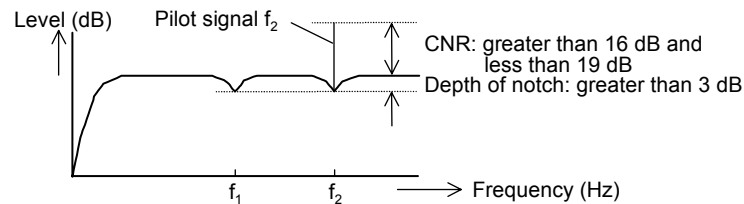
Figure 12 – Bit stream before interleaved NRZI modulation



(a) Track F0



(b) Track F1

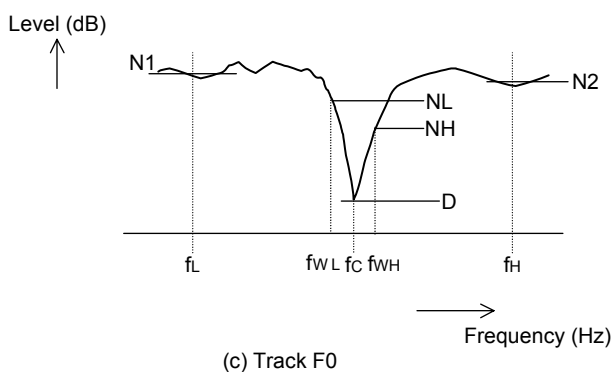
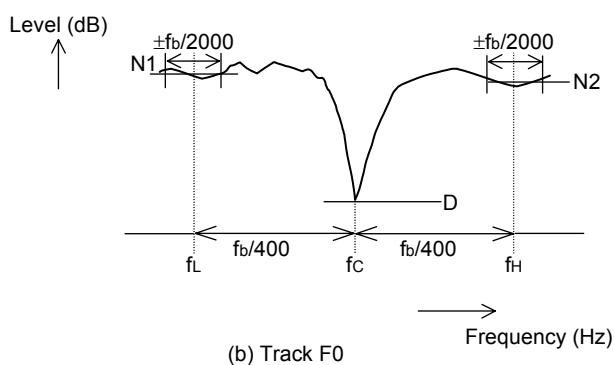
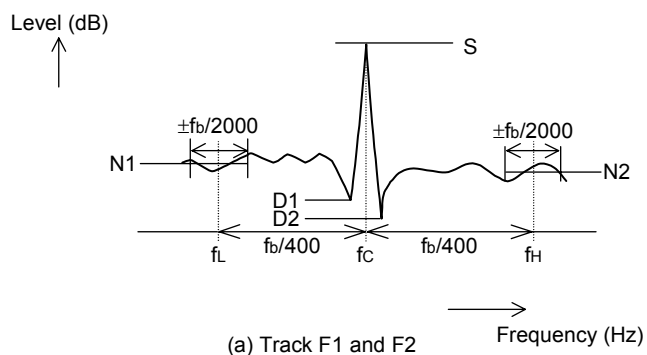


(c) Track F2

NOTES

- 1 $f_1 = f_b / 90$ (Hz)
 $f_2 = f_b / 60$ (Hz)
 f_b = The frequency whose period is a time interval of one channel bit (Hz)
 Resolution bandwidth = $f_b / 20925$ (Hz)
 Data is obtained by integration over 30 repeated cycles
- 2 $CNR = [S - (N1 + N2) / 2]$ (dB)
 Depth of Notch with peak = $[(N1 + N2) / 2 - (D1 + D2) / 2]$ (dB)
 Depth of Notch without peak = $[(N1 + N2) / 2 - D]$ (dB)
 $N1$ is defined as an average value over $f_L \pm f_b / 2000$ (dB)
 $N2$ is defined as an average value over $f_H \pm f_b / 2000$ (dB)
 f_L is defined as $f_c - f_b / 400$ (Hz)
 f_H is defined as $f_c + f_b / 400$ (Hz)
 f_c means a peak or notch frequency (Hz)
- 3 DC free

Figure 13 – Frequency characteristics of tracks



NOTE – The recommended frequency characteristics of the F_0 track shall be defined as follows:

$$[(N1+N2)/2] - [(NL+NH)/2] > 5 \text{ [dB]}$$

f_{WL} is defined as $f_c - f_b/4000$.

f_{WH} is defined as $f_c + f_b/4000$.

NL is defined as amplitude at the f_{WL} .

NH is defined as amplitude at the f_{WH} .

Figure 14 – Frequency characteristics of tracks(detail)