The SMPTE D-6 Digital Recording Format

By Jürgen K. R. Heitmann

This paper describes the 19mm type D-6 digital 1 Gbit/sec recording format, which is now an approved SMPTE standard. Part one of the D-6 format documents (SMPTE 277M) specifies the format and recording method of the data blocks that form the helical records on 19mm tape. This part of the standard is totally independent of the nature of the recorded digital signals and need not be changed in the event of a new image interface standard. Part two of the D-6 documents (SMPTE 278M) specifies the content of the data blocks that form the helical records. The data recorded may be digital video and audio of various image standards up to approximately 1 Gbit/sec. All image standards recordable by this new format employ identical track pattern, inner and outer error correction block structure, and modulation code. Parameters that vary for different interface formats are listed in tables. The later addition of any new interface format can easily be done by adding one additional line with new parameters to these tables.

In mid-1993, BTS and Toshiba jointly proposed to the SMPTE a new digital recording format intended to record extremely high data rates up to 1.2 Gbit/sec. The SMPTE installed a working group and assigned the working title D-6 to that format. The first meeting of that working group was held in December 1993. After a series of only four additional meetings, the proposed D-6 standard was sent to the SMPTE Standards Committee for approval.

Both BTS and Toshiba started independent work initiated by the request for a digital HDTV cassette recorder to handle the high data rates of uncompressed HD video. However, based on the multiplicity of different HDTV formats discussed, it was soon recognized that any new format may not be restricted to only one video interface standard or to conventional video signals.

This is also reflected by the D-6 standard. To deal with such video or image interface standards not yet defined or even discussed, the D-6 format documents consist of two parts: SMPTE 277M and SMPTE 278M. SMPTE 277M specifies the format and recording method of the data blocks that form the helical records on 19mm tape. This part of the standard is totally independent of the nature of the recorded digital signals and need not be changed if new image interface standard is introduced. Part two, SMPTE 278M, specifies the content of the data blocks that form the helical records.

Tape and Cassette

D-6 cassettes are based on the same 19mm cassettes as specified for D-1 and D-2 but contained improved metal particle (MP) tapes. The improvements are in two areas. Tape thickness is reduced from 13 µm to 11 µm while retaining the same mechanical stability of the 13-µm tape. The coercitivity is increased from 1,500 to approximately 1,700 for better recording performance of small wavelengths. Tapes of similar technology, but with a tape width of 12 mm, are used for the new D-5 format. Table 1 shows the recording times for different cassette sizes.

Footprint on Tape

The footprint on tape is independent of the nature of the recorded digital signals and need not be changed for any new image interface standard.

A data rate as high as 1.2 Gbit/sec

Table 1 — D-6 Recording Times for Different Cassette Sizes

19mm cassette type	Large	Medium	Small
Recording time (min)	64	28	8

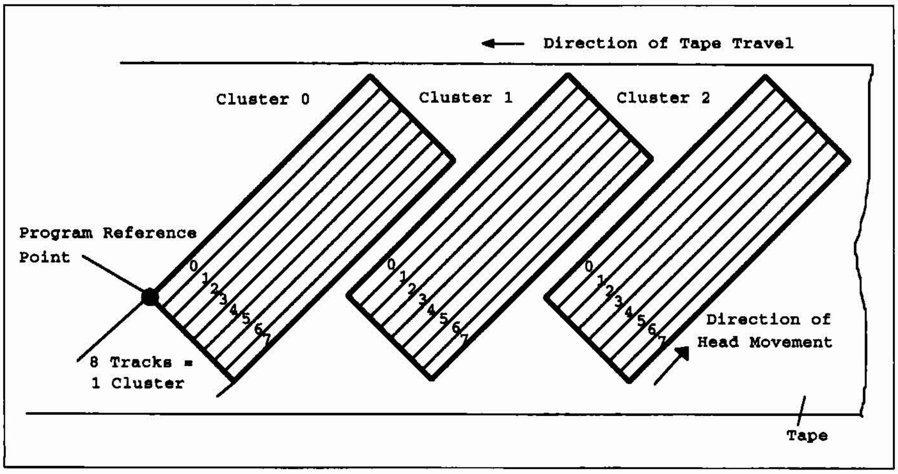

Figure 1. Cluster of tracks.

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Table 2 — Possible Recording Configurations

Configuration I	Total number of bytes per block = 229
Configuration II	Total number of bytes per block = 239

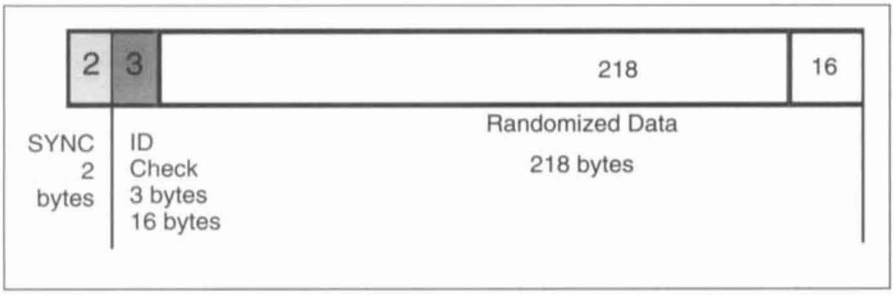

Figure 2. Structure of the inner code block for record configuration II.

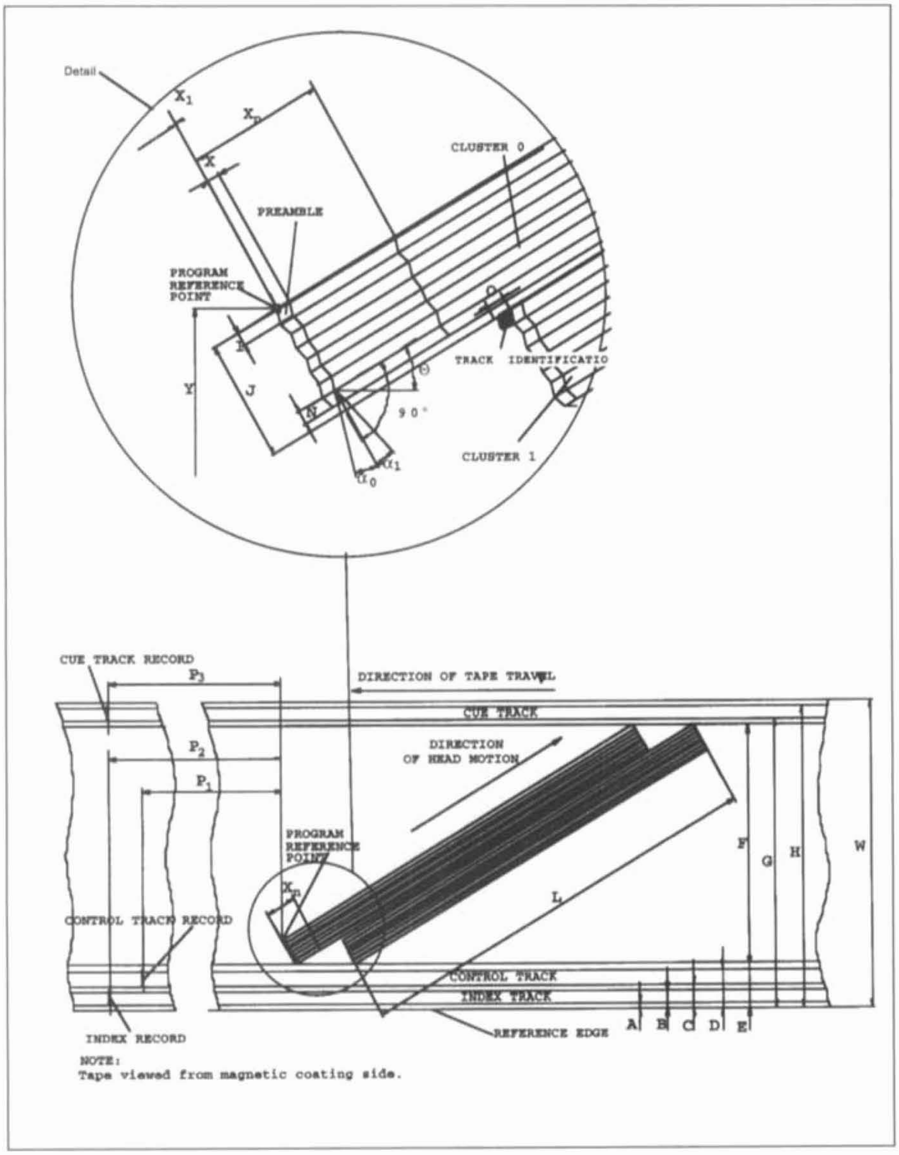

Figure 3. Location and dimensions of recorded tracks.

cannot be processed in a single-channel recording system. Splitting this data stream into eight channels results in a channel data rate of about 150 Mbits/sec, which was considered a realistic target. This number of channels determines the basic structure of the tracks on tape. Eight heads each write a cluster of eight slant tracks without guard band on the tape (Fig. 1). Azimuth recording is used to increase the storage density.

For robust insert editing, flying erase is possible by use of extra-wide erase heads that cover all eight tracks of a cluster. The clusters themselves are separated by a guard band from each other. This tape format is advantageous in the case of insert edits, when mechanical tolerances may cause the new recording not to overwrite the old one completely. Because of the guard band between the clusters the erase heads could be slightly larger, thus improving the compatibility between the recordings made on different machines.

All tracks contain 270 blocks; a block is formed by a packet of data including the preceding synchronization and identification information. All recorded blocks along a slant track are the same size in order to record a data pattern independent of any video, audio, and edit gap parts of the track. Depending on the nature of the interface format (for example, 1,035 or 1,080 active lines), two recording configurations are allowed (Table 2).

Blocks can be preambles/postambles or inner code blocks. The inner code blocks contain randomized data bytes and the preceding block identification (ID), both protected by 16 check bytes (Fig. 2).

Modulation Code

All blocks are subject to an 8-12 modulation coding prior to recording. Tables are used to map incoming data bytes to 12-bit words. The tables are not valid for the sync, which may be a unique 24-bit sequence. The 8-12 mapping code not only reduces low-frequency components but increases the minimum wavelength compared with the original data sequence by 33%. This is most important for recording the extremely high data rates of the D-6 format.

Table 3 — Record Location and Dimensions of the D-6 Format

	Dimensions		Tolerance	Dimen.
A	Time code track lower edge	0.200	±0.100	mm
B	Time code track upper edge	0.700	±0.100	mm
C	Control track lower edge	1.000	±0.100	mm
D	Control track upper edge	1.500	+0.050 -0.100	mm
E	Program area lower edge	1.761	Derived	mm
F	Program area width	16.098	Derived	mm
G	CUE track lower edge	18.200	±0.100	mm
H	CUE track upper edge	18.900	±0.100	mm
I	Helical track pitch	0.021	Basic	mm
J	Helical cluster pitch	0.176	Basic	mm
L	Helical cluster length	150	-0.300	mm
M	Number of blocks per track	270	Basic	
N	Record head track width	0.023	±0.0015	mm
O	Length of TID pattern	0.7	±0.200	mm
P1	Control track pulse	0	±0.060	mm
P2	Index code information	99.5	±0.300	mm
P3	CUE information	99.5	±0.500	mm
V	Tape speed	497.418	±0.05%	mm/sec
W	Tape width	19.010	±0.010	mm
X	Block length	0.55587	Basic	mm
X1	Loc. of start of block 1	0	±0.200	mm
Xn	Loc. of start of block n	n*0.55587	±0.300	mm
Y	Program reference point	1.930	Basic	mm
Zo	Tolerance zone track 0	0.006	Basic	mm
Z	Tolerance zone other tracks	0.010	Basic	mm
Θ	Dynamic track angle	6.0903	Basic	°
α0	Azimuth angle (track 0)	14.93	±0.17	°
α1	Azimuth angle (track 1)	15.07	±0.17	°

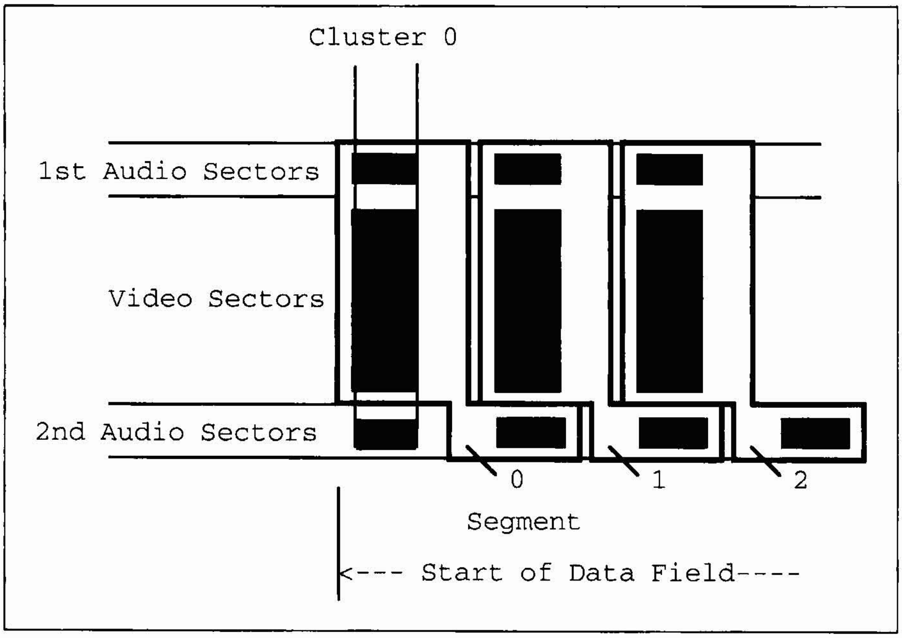

Figure 4. Sector and segment structure.

Record Location and Dimensions

Record location and dimensions are shown in both Table 3 and Fig. 3.

Content of Helical Data

The content of the helical data is defined in SMPTE 278M. Digital video and audio data derived from various image standards is recorded with a data rate of approximately 1 Gbit/sec. All image standards recordable by this format employ identical track pattern, inner and outer block structure, and modulation code.

Eight tracks form a cluster. Each cluster is divided into three sectors, as shown in Fig. 4. The first and last sectors within a cluster contain audio data while the middle sectors contain the video data.

One data field is the minimum edit distance for video and audio. The data field is formed by a group of segments.

Table 4 — Number of Segments per Data Field as Parameter of the Video Standard

No. of Active Samples/Line	No.of Active Lines/Frame	Frames/ Sec	Data Fields/ Frame	Segments/ Data Field
1920	1035	30/29.97	2	5
1920	1080	30/29.97	2	5
1920	1152	25	2	6
1920	1080	24	2	6
1280	720	60	1	5

Each segment starts with the video sector followed by the first audio sector of the same cluster and ends with the second audio sector, which is part of the next recorded cluster (Fig. 4.) The number of segments per data field is a parameter depending on the recorded video standard as defined in Table 4. For a video standard with 30 frames/sec, the arrangement for video and audio data within one data field is shown in Fig. 5.

Video data are distributed over the eight tracks of a cluster as shown in Table 5. The audio data are recorded twice and placed at the beginning and at the end of each track.

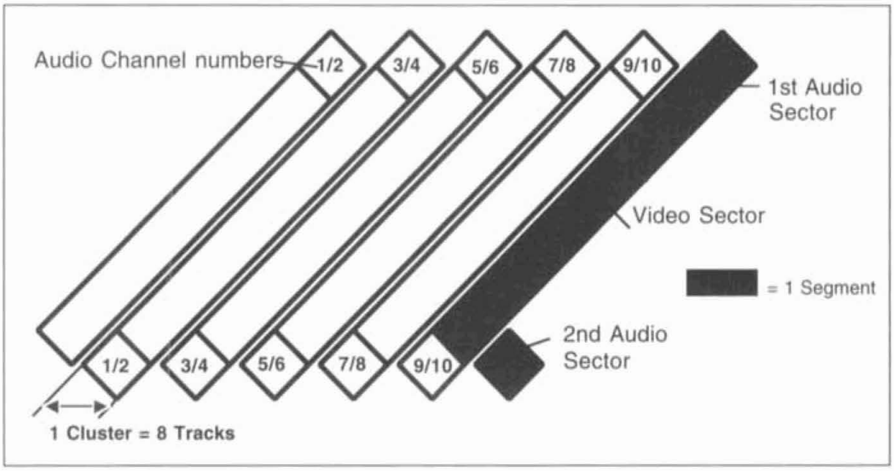

Figure 5. Distribution of audio channels within a data field with six segments (24-Hz, 25-Hz video standards).

Video Signal Intertrack Shuffling

The pixels of each video line are distributed equally over all eight tracks of a cluster. A distribution cycle repeats every eight luminance pixels and eight chrominance pixels. The sequence of tracks within a cycle is varied from line to line and is dependent on the data field number. An example for a distribution cycle is given in Fig. 6. The relation of record-

Table 5 — Distribution of Video Data Within a Cluster

Track 0	Luminance
Track 1	Chrominance
Track 2	Luminance
Track 3	Chrominance
Track 4	Luminance
Track 5	Chrominance
Track 6	Luminance
Track 7	Chrominance

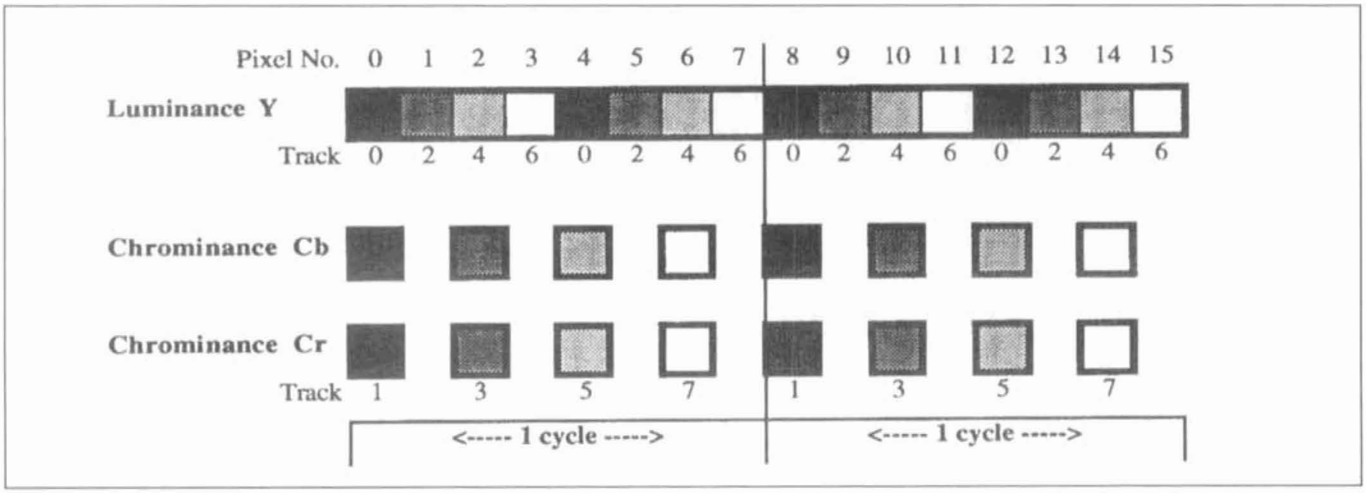

Figure 6. Intertrack shuffling for RLINE 0 and DFIELD 0.

Table 6 — Relation of Recorded Lines (RLINE) to Video Lines

No. Active Lines/frame	Frames/ Sec	First video line recorded [equivalent RLINE]	Last video line recorded	User lines recorded	Mfr. RLINEs*
Even Numbered DFIELDs					
1035	30	38 [0]	557	38-40	-
1080	30	18 [2]	560	18-20	0,1
1152	25	42 [21]	620	42-44	0-20, 600-623
1080	24	18 [2]	560	18-20	0,1, 545-653
720	60				
Odd Numbered DFIELDs					
1035	30	601 [0]	1120	601,602	-
1080	30	582 [3]	1123	582,583	0,1,2
1152	25	668 [22]	1245	668,669	0-21, 600-623
1080	24	582 [3]	1123	582,583	0,1,2 545-653
720	60				

* Manufacturer lines are internal to the recorder only.

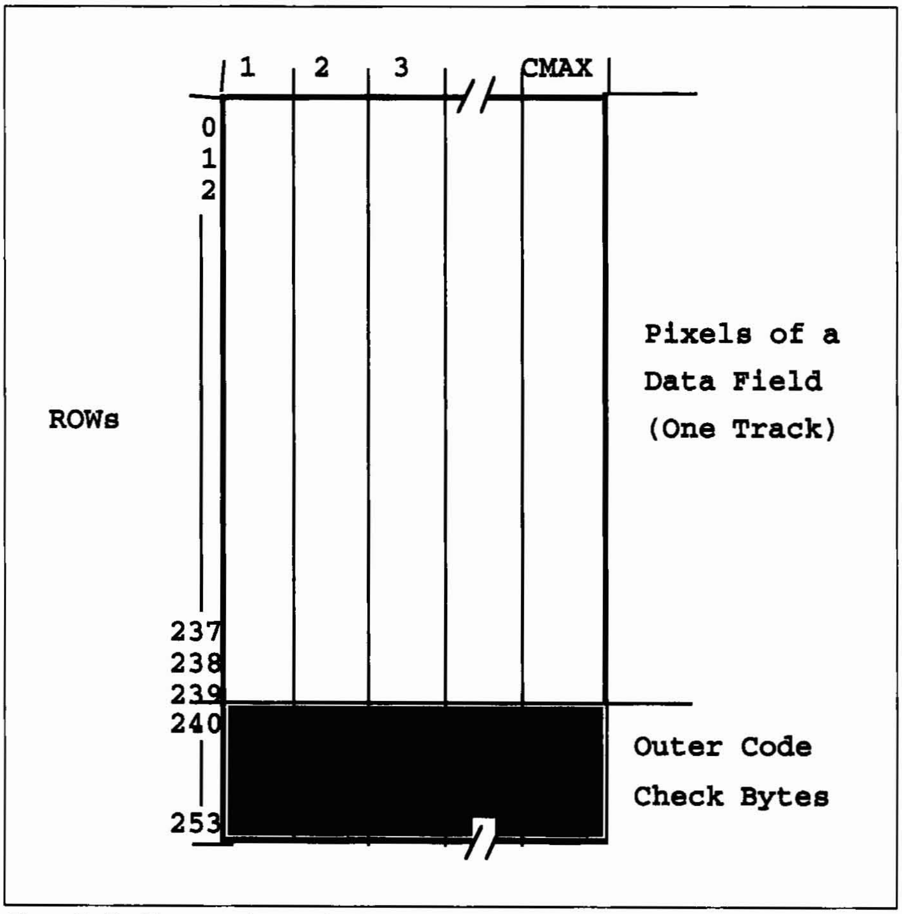

Figure 7. Shuffling array for standards with 30 frames/sec.

ed lines (RLINE) to video lines at the interface input is shown in Table 6 for various video interface formats.

Intrafield Shuffling

Data shuffling is performed over one data field. The shuffling sequence is created by writing to a shuffling memory array (Fig. 7) in a shuffling sequence and reading the array in a different shuffling sequence. The size of the array corresponds to 1/8 of the amount of data within one data field. There is an array for each track number. After writing to the array the outer error correction encoding is performed.

Error Correction

The error correction system is based on a Reed-Solomon product code formed by inner and outer code bytes. The inner error correction uses 16 check bytes, as described earlier. The outer error correction calculates 14 check bytes for the 240 data bytes shown in the columns of Fig. 7. The check bytes are appended to the end of the data bytes at the bottom of the shuffling array.

Figure 8 shows the relation between off-tape error rate and the error rate

Table 7 — Number of Audio Channels and Samples as a Function of the TV Standard

Active Lines/ Frame	Frames/ Sec	No. Audio Channels	No. Audio Samples/ Channel/Data Field
1035	30	10	800
1035	29.97	10	800/801
1080	30	10	800
1152	25	12	960
1080	24	12	1000
720	60	10	800

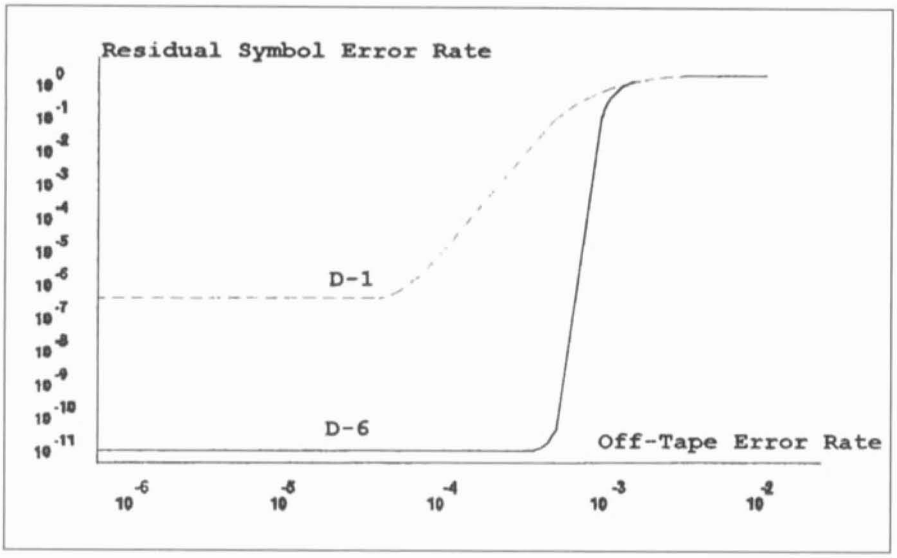

Figure 8. Error correction performance.

after correction. For off-tape error rates lower than 4 x 10^{-4} an output error rate of 1 x 10^{-11} can be achieved. With this powerful error correction system the recorded digital video signals are treated as data that makes it possible to record on D-6 even bit-rate-reduced video signals.

Audio Processing

The number of audio channels is determined by the recorded TV standard as defined in Table 7. Channels are processed in five or six pairs. Channels 1/2, 3/4, 5/6, 7/8, 9/10, and 11/12 form pairs that are independently and identically processed.

Audio words of the channel pairs are written into an array having the size of an audio sector. Control words are multiplexed with the audio words in the product block to provide housekeeping in the interface and in processing. After addition of 12 check bytes error correction data in the vertical direction, the audio data are shuffled using a different read sequence. Error correction in the horizontal direction is common with the video data. Figure 5 shows the distribution of audio channels within a data field with six segments (24-Hz, 25-Hz video standards).

Conclusion

The data recorded by the new D-6 standard may be digital video and audio of various image standards up to approximately 1 Gbit/sec. All image standards recordable by this new format employ identical track pattern, identical inner and outer error correction block structure, and identical modulation code. Parameters that vary for different interface formats are listed in tables. The later addition of any new interface format can easily be done by adding one more line with new parameters to these tables. The format is designed in such a way that it will ease implementations where the addition of any new interface format is done by exchanging EPROMs with software content.

The basic structure of the D-6 recording format is in fact that of a data recorder and not just that of a video recorder. This is reflected by the enormous power of the built-in error correction system. A residual error rate of 10^{-11} is reached. In combination with a method of rerecording data that could not be recovered error-free by read after write mode, residual error rates of approximately 10^{-15} can be reached.

THE AUTHOR

Jürgen K. R. Heitmann received his *Diplom Engineer* degree in communication technique at the Technical University Brunswick/Germany in 1972. The following year, he joined the Fernseh, which is now BTS, in Darmstadt, Germany. As head of development for magnetic recording systems, Dr. Heitmann was responsible for BTS's first digital recording products (D-1). Since 1993, he has held the post of senior manager, recording systems. Dr. Heitmann is an active member of the SMPTE's TRRT Technology Committee. He is also a Society Fellow and Chairman of the German Section.