VIDEO RECORDING

Long before television became a household word, man endeavored to capture and record visual images. By the time the first *electronic* television was introduced at the 1939 World's Fair, both still and motion photography were well established in black and white and in color. Motion pictures, such as *The Wizard of Oz,* had full color images and complete audio sound tracks. The following section will provide an overview of video recording progress (both visual and aural signals) over almost 50 years since that 1939 World's Fair demonstration (see Fig. 1).

CHRONOLOGY

After the development hiatus caused by the diversion of scientific talent and engineering skills to the war effort during World War II, 1947 saw the introduction of commercial broadcast television, and by the mid-1950s color broadcast TV was on the scene as well.

Virtually from its beginning, the television industry required a means of recording and storing the live video images that it was producing. In his famous *three wishes* speech in the fall of 1951, Brigadier General David Sarnoff, then chairman of RCA and founder of the National Broadcasting Company, called for the development of a device capable of recording television signals with a magnetic tape medium (1).

In 1951 the fledgling television networks relied on a photographic film process known as kinescope recording. This involved the transferring live television programming to motion picture film by photographing a high-intensity cathode ray tube and then reconstructing the video image by scanning the filmed image with a high-resolution camera tube called a *fly-*

1939	Introduction of *electronic* television
1947	End of wartime hiatus (WW II)
1948	B&W recording via kinescope
1956	First commercial videotape recorder (VTR)—Ampex
1970	First videocassette recorder (VCR)—Sony U-Matic
1975	First consumer videocassette recorder—Sony Betamax
1976	Introduction of VHS format consumer VCR—JVC et al.
1977	Videodisk players—RCA and Philips
1978	Laserdisk players—Philips et al.
1980	Commercial HDTV tape recorder (VTR)—Sony Hi-Vision
1985	Commercial, digital, component VCR—Sony, D-1 format
1989	Commercial, digital, composite VCR-Sony, D-2 format
1995	Digital versatile disk (DVD) Player—Sony, et al.
199?	HDTV digital disk (DVD) player

Figure 1. Video recording milestones—timeline.

ing-spot scanner. The resulting *kines* were often of poor visual quality due to the joint problems of loss of image definition during the filming and the reconstruction process and to synchronizing discrepancies caused by the difference between television's frame rate of 30 per second and the 24 frames per second rate of the normal movie camera. Notwithstanding these problems, the use of *kines* was immense. It was estimated that, during the 1950s, the television industry was a larger user of movie film than the movie industry itself (2).

Soon after Sarnoff's speech, in December 1951 a small group of engineers at the Ampex Corporation began a project to develop the prototype of the videotape recorder as we know it today. By 1956, Ampex had introduced a reel-to-reel, commercial model, using magnetic tape media supplied by the 3M company. For the next 15 years Ampex continued to provide the broadcast industry with ever more potent videotape recorders (VTRs) (3).

In 1970 the Sony Corporation, under license from Ampex, introduced the three-quarter-inch U-Matic, color videocassette player for the commercial market. In 1975 Sony established the basis for the home video recorder market by introducing the one-half-inch Betamax (SL-6300) consumer videocassette recorder (VCR). Both of these machines utilized tapes wholly contained within a cartridge, the cassette, which precluded the need to thread tape, as was the case then with the reel-to-reel machines (4).

In 1976 the Japan Victor Corporation (JVC), and others introduced a competitive and incompatible cassette recording format (VHS) for consumer use. Within a few years the VHS format became the dominant format, virtually eliminating Beta in the consumer marketplace. Despite this, as we shall see, Beta remains alive and well in the commercial realm to this day (5).

In 1977, the RCA Corporation and Philips Electronics each introduced a videodisk player to compete with the VCR in the consumer arena. Both of these machines employed analog recording schemes not to be confused with the digital laserdisk, introduced in 1978. None of these three formats permitted recording by consumers at home. They were offered only as prerecorded material, and they therefore had a difficult time competing with the VCR. Within a few years the first two fell by the wayside, leaving only the laserdisk, produced by Philips and others, with its inherently superior picture and audio quality to retain even a small foothold in the VCR-dominated consumer marketplace (6).

For almost a decade, until the 1995 announcement of the digital versatile disk, consumer video recording technology remained static.

Not so the commercial arena, which saw the transition of analog tape recording to digital component and then to digital composite formats. This has been followed by the application of high-density magnetic recording technology which has brought forth hard disk drives for video recording, in turn, leading to computer-based, nonlinear, *virtual video tape recorders* for commercial recording, editing and playback, and origination applications. (A brief description of this *nonlinear* video recording technology can be found at the end of this article, entitled *nonlinear video.* A more detailed discussion can be found elsewhere in this publication under the same title.)

It took almost 2 years from the initial announcement of the high-density digital versatile disk (DVD) for it to appear in 1997 in the consumer marketplace. Now it is only available in the *prerecorded* format, although the technology currently exists to produce a *recordable* disk, once the DVD format has become an established format. Even now, development is con-

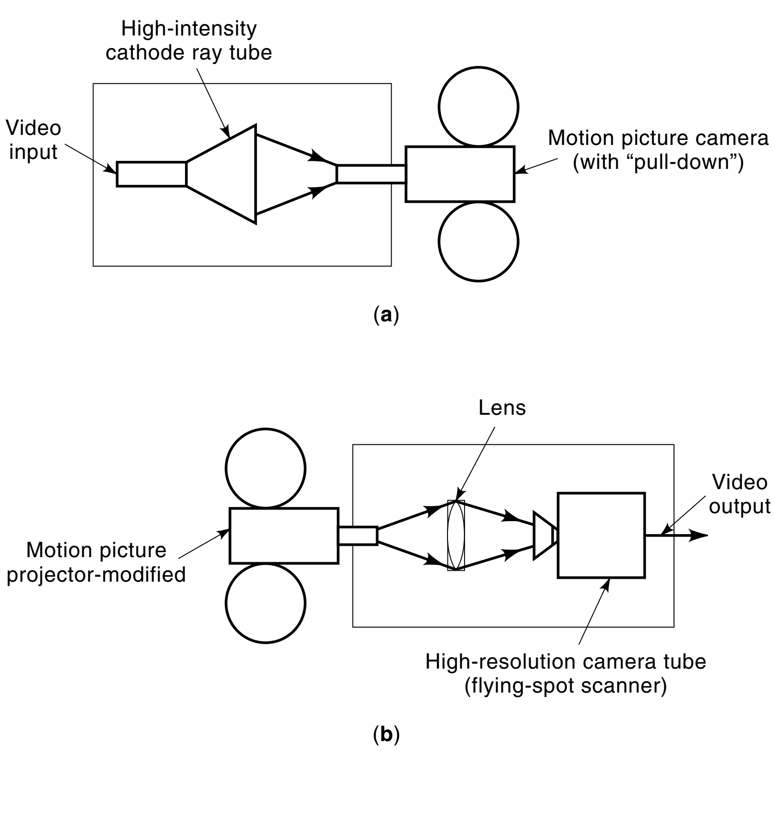

Figure 2. Basic kinescope (a) recording and (b) playback.

tinuing on an enhanced DVD capable of handling a digital, high-definition television signal (7).

DESCRIPTION OF THE TECHNOLOGIES

Throughout this article, the term *video* represents (except as specifically noted) a television signal consisting of program video, program audio (1, 2, or 4 channels) and a time-code channel.

For historical purposes we include a brief description of the kinescope process to provide a perspective on the more sophisticated magnetic and optical technologies which followed it and which dominate the video recording field.

Kinescope Recording

In its simplest form, kinescope recording involves filming a television image from a high-intensity picture tube and then playing it back by scanning the film with a *flying-spot* scanner to convert the filmed image to a standard video format (Fig. 2). This process allowed for time-delayed rebroadcast of television programming throughout the nation. It did so, however, at a high cost and significantly reduced picture quality.

Picture quality suffered for two reasons; the required image-to-film and film-to-image transfers were done with limited light levels, producing grainy images of low contrast. A second cause was the frame-rate difference between television (30 frames per second) and cinematography (24 frames per second). This latter problem was circumvented by using a "pull-down" mechanism in the motion picture camera which allowed exposing one film frame to multiple television fields (two or three) so that the 24/30 ratio was reversed. The resultant product was low in contrast and image stability.

Although the broadcast use of kinescope recording disappeared with the introduction in 1956 of the Ampex videotape recorder, there are still special situations where kinescopic recording is used. Most of the timing problems have been overcome through electronic time-base correction circuits and frame-storage techniques. As we shall see, however, the paramount technology in television storage from 1956 to the present has been magnetic tape recording (8).

Magnetic Tape Recording-Analog, Linear Transport

The first commercially practical video recorder was developed in the United States by the Ampex Corporation during the period 1951 through 1956. It recorded monochromatic (black and white) images from a National Television Standards Committee (NTSC), 525-line, 60 Hz signal with monaural sound. This machine, designated the VR-1000, achieved its breakthrough performance by using four moving recording heads, rotating in a plane transverse to the direction of (two-inch wide) tape motion. A second contributor to the success of the VR-1000 was its application of frequency modulation (FM) in the recording process (9).

Earlier efforts to produce a videotape recorder (VTR) were based on extensions of the magnetic tape technology developed for audio recording. This approach involved moving the magnetic tape longitudinally past one or more fixed recording heads and also the direct transfer of signal level through amplitude modulation of the magnetic field being applied to the tape (Fig. 3). These early systems failed to pass muster practically because they required excessive tape speed, as high as 20 feet per second, which resulted in limited recording times, and because their use of direct AM level transfer produced unstable record and playback performance due to the nonuniform magnetic characteristics of the tapes available then. Lack of stability in their tape transport mechanisms also contributed to recording artifacts, such as *jitter, flutter* and *wow* (10).

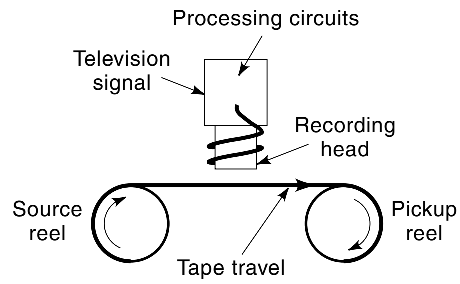

Figure 3. Linear transport; direct tape recording.

The Ampex machine resolved these issues in the following manner (Fig. 4). Four recording heads were mounted on a cylindrical drum which rotated at high speed (14,400 rpm) in a plane whose axis was at right angles to the motion of the tape. The tape speed was only 15 inches per second, a substantial reduction from the earlier British Broadcasting Company (BBC) and RCA designs which employed tape speeds of 200 and 3650 inches per second, respectively. In the Ampex machine, each of the four video recording heads laid down 16 horizontal television lines per revolution of the revolving head drum. Thus one drum revolution recorded 64 lines and only eight tape passes were required to complete the entire 525-line NTSC video frame.

Another significant feature of the VR-1000 was its use of FM technology for the signal-to-tape information transfer. This approach avoided the pitfalls of the direct methods used in the earlier VTRs because now the information was recorded in the frequency domain using incremental changes about a fixed carrier. The tape stock available then was much more uniform in its frequency-dependent characteristics than in its amplitude response to changing magnetic bias (11).

For almost two decades this Ampex *Quad* VTR, with minor refinements, was the commercial standard for television recording.

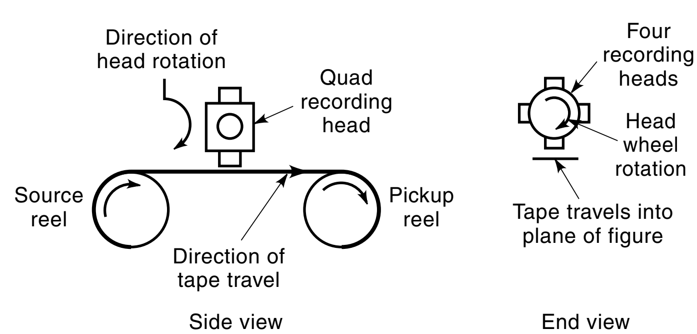

Figure 4. Quad-head tape recording.

Helical Scan and the Cassette Format

During the next 15 years, companies in the United States and Japan focused their attention on better media (tape stock), improved tape utilization (higher density recording), and a more convenient transport mechanism.

The Minnesota Mining and Manufacturing (later 3M) company was a principal provider of media for television recording in the United States during this period. The early product was a paper-backed tape with a magnetic coating on one side. By late 1947, 3M had converted to acetate film for base stock. By the time the VR-1000 was first commercially used by CBS on November 30, 1956), the tape was an improved acetate-based 3M product called *Scotch 179 Videotape* (12).

The next step in the evolutionary process focused on improvements in tape scanning. To improve the performance of its Quad machine, Ampex and its licensees (RCA and the Victor Corporation of Japan [JVC]) worked to develop a *helical* scanning format which effectively lengthened the scan distance per head pass by using a tangential rather than a simple longitudinal course (Fig. 5). This type of scanning has become the accepted standard for VTR in most applications (13).

In 1962 machines were introduced by Ampex, RCA, and JVC utilizing helical scanning with one-inch wide tape stock. The VR-1000 Quad machines used longitudinal scanning with two-inch wide tape. By the end of the 1960s, a helical scan VTR produced by the International Video Corporation (the IVC-9000), using two-inch tape, for the first time exceeded the performance of the Ampex Quad machine, then the broadcast industry standard. The final nail in the coffin of the Quad process came when digital time-base correction circuits were devised by the Japanese in 1968, which allowed the long-scan, helical process machines to exceed the stability performance of the shorter track Quad system (14,15).

The resulting improved helical scan VTRs became widely used in broadcast applications in 1970. These systems employed three-quarter-inch wide tapes as opposed to the one-inch tapes of their predecessors.

Until this time even the improved helical scan machines utilized open reel-to-reel tape formats. In 1970, Sony made a major breakthrough in VTR design by introducing the prototype U-Matic color video recorder. This was an analog, helical-scan machine which utilized three-quarter-inch wide tape packaged in a self-contained cassette. No longer did the tape installation process require careful and time-consuming threading of loose tape by a highly experienced technician. The cassette package contained both source and pickup reels with the tape installed at the factory. Tapes could now be changed in seconds by someone with virtually no prior experience (16).

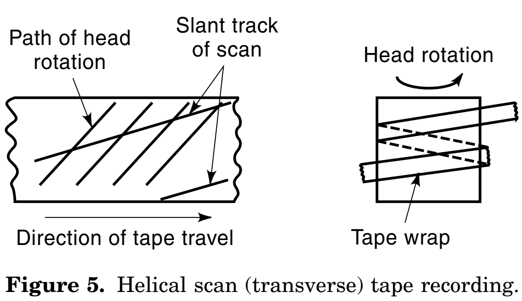

Figure 5. Helical scan (transverse) tape recording.

An improved, production version of the U-Matic recorder (the VP-1000) was offered for sale by Sony in 1972. Thus was born the video cassette recorder (VCR) and the groundwork was laid for a consumer product (17).

Video Cassette Recording (VCR)

The Ampex Quad machines had always been too complex and expensive to serve as a basis for translation to the consumer market. The Sony VP-1000 was initially conceived as just such a product because its cassette could be readily installed and removed and its use of advanced, lower cost solid-state technology was a further step in this direction. (Ampex had introduced the first fully transistorized VTR, the VR-1100 in 1962, but this machine was still large and cumbersome and had setup requirements too complex to be considered for consumer use.)

This prototype U-Matic machine was a cooperative effort of three Japanese companies, Sony, JVC, and Matsushita (known by its US trade name, Panasonic). For this reason, this three-quarter-inch format was termed *3C* in Japan. For its efforts in developing the VCR, Sony was awarded an EMMY in 1976 by the Motion Picture Academy of Arts and Science for technical achievement. In actuality, all three companies made significant contributions to the development of the VCR (18).

The early U-Matic helical scan machines were not an unqualified success for commercial applications. Their performance, as measured by resolution, signal-to-noise ratio (SNR), and stability, was not equal to the Quad machines then used by all broadcasters. The U-Matics, however, were compact, simple to operate, and inexpensive enough for field use, such as news gathering and other remotes. On the other hand, they were neither compact enough nor inexpensive enough to support their introduction as a consumer product. The three-quarter-inch cassette was still rather large and expensive. Another problem was their need for sophisticated time-base correction circuits to overcome the timing errors introduced by helical scanning of relatively narrow tape. Broadcasters eventually overcame these problems, first by introducing electronic time-base correction (TBC) in 1972 and later by using frame synchronizers in 1974 (19).

At this stage in 1974, the helical format machines were potential replacements for Quad machines in commercial applications, but not in the consumer market because they still cost too much.

Introduction of the Consumer VTR. Having achieved a somewhat competitive footing in the commercial marketplace, Sony and the other Japanese manufacturers again focused their attention on developing a consumer VCR. In 1970, Ampex and Toshiba jointly developed a one-half-inch cassette, monochromatic machine for the consumer market. It did not catch on! Neither did comparable machines introduced in 1972 by Panasonic and Philips (20).

During this period, JVC approached Ampex with a proposal to jointly develop a one-half-inch color VCR specifically for consumer use. To support their proposal, JVC had constructed a one-quarter-scale (one-half-inch format) working model based on the Ampex VR-1500 two-inch helical scan machine. The Ampex management was reportedly impressed with the prototype, but they gracefully declined to enter the world of consumer electronics at that time. Ampex, however, licensed JVC to use their technology in such an application. This was to prove a successful financial decision of momentous proportions for Ampex (21).

In 1975, Sony introduced a one-half-inch color consumer VCR using the Sony proprietary Beta (helical-scan) format. This machine, the Betamax SL-6300, was relatively compact and simple to operate. The Beta nomenclature was based on considering it a derivative of the U-Matic or Alpha format (22).

Within a year in 1976, JVC refined its prototype one-half-inch VCR, using its own, unique helical-scan format and proceeded to introduce it as the Video Home System (VHS). Thus did the *format wars* begin for the consumer market (23).

Although many technically astute persons believed that the Beta format was capable of performance superior to that of the VHS format, within a few years VHS had gained supremacy in the consumer marketplace. Many believe that this success was primarily due to JVC's decision to broadly license its format so as to encourage availability of a wide spectrum of prerecorded material to the consumer in a short time during which Beta titles were somewhat limited. Another drawback of the Beta format was its limited recording time compared to VHS. Even so, more than 20 years after their commercial introduction, U-Matic machines (Beta's origin) are still being produced and are widely used in the broadcast industry.

Early Disk (Nonmagnetic) Recording

In 1977, within two years after the introduction of the Sony Betamax, both RCA and Philips introduced a videodisk player for the consumer market. Both were play-only systems. The RCA version (called SelectVision) employed a capacitance pickup which monitored variations in a grooved, 12-inch diameter disk, rotating at 450 rpm. Each side provided up to 60 minutes of television programming (24).

The Philips version of the videodisk was quite different. It used a small laser to retrieve television information from a previously etched, grooveless, spiral track on a 12-inch disk. Philips called it the Video Long Play (VLP) system after the LP audio records current then. VLP played back previously programmed disks with a maximum program duration of two hours with the disk rotating at 150 rpm. A commercial version of the VLP system, offered by JVC and others as the Video High Density (VHD) system is still in use occasionally for special applications, such as institutional training programs and national sales promotions in the automobile business (25).

Because both SelectVision and VLP were play-only with no home recording capability, they did not receive significant consumer acceptance and were soon withdrawn from the marketplace.

The following year (1978) saw the introduction of the optical laserdisk, as we know it today. These units by Philips and others were playback-only machines using factory prerecorded material. However, they were digitally encoded and their reproduction performance was much better than that of the earlier VLP (analog) system and well above the performance of even today's VHS one-half-inch VCRs. A simplified description of the optical laserdisk recording and playback process is shown in Fig. 6. Many believe that this process led to the development of the audio Compact Disk introduced by Sony and Philips in 1982 (26).

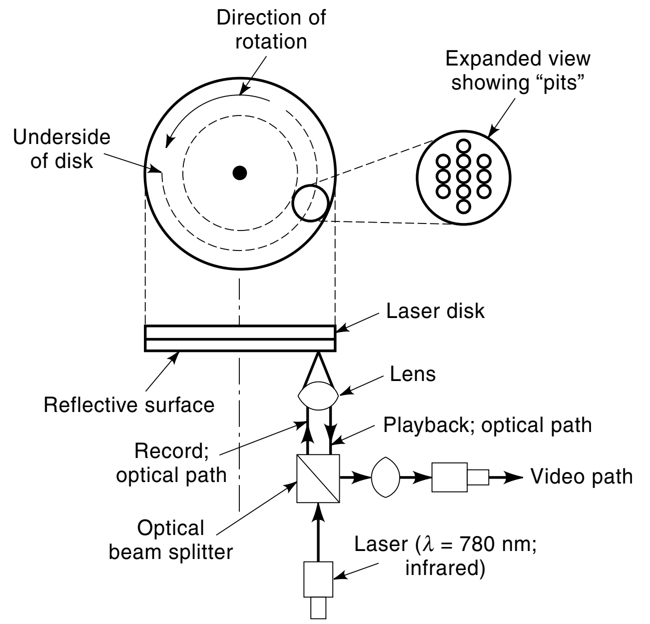

Figure 6. Laserdisk recording and playback (simplified).

For almost 20 years until the 1995 introduction of the DVD, the laserdisk has reigned as the gold standard for consumer video playback performance. Despite this reputation, the high cost of both the hardware and the software (discs) has limited its penetration into the U.S. consumer marketplace. This is not true in Japan, where virtually all new programming is made available simultaneously in both VHS cassette and laserdisk formats. In Japanese electronics outlets, both products remain equally competitive and laserdisk products are widely available. In the United States, after cumulative sales of more than 140 million VHS VCRs, the laserdisk has been virtually drowned in a sea of VHS tape as has the Beta tape format.

COMMERCIAL VTR EVOLUTION-COMPONENT AND COMPOSITE, DIGITAL TAPE RECORDING

Component Digital Tape Recording

Even as the consumer video industry was undergoing attempts to improve the playback performance of one-half-inch VCRs with optical and digital technologies, the commercial videotape recording field was experiencing a revolution of its own.

Until the mid 1970s, commercial videotape recording focused on handling the composite video signal which contained all elements, luminance (brightness), chromanance (color information), and synchronization and timing pulses, within a single envelope (Fig. 7). About the same time in 1978 as the consumer market saw the introduction of the digital laserdisk, the same signal processing technologies were being applied to commercial recording, first by separately processing the luminance and chromanance signals in the analog domain

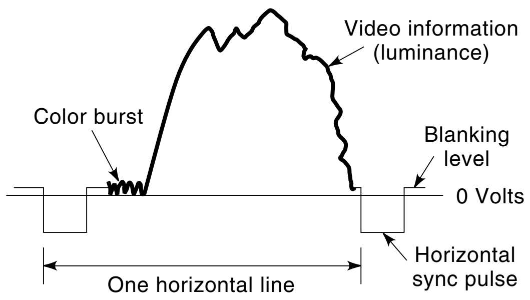

Figure 7. Composite television waveform.

and then, subsequently, by applying digital techniques to this process.

Recording these two analog signal elements on separate video channels was termed *component* signal recording. It offered the advantage of reducing color artifacts during playback. This process eliminates the use of the 3.58 MHz color subcarrier and therefore results in reduced susceptibility to cross modulation between component signals.

During the early 1980s two one-half-inch recording formats competed for market share for professional recording, the Sony Betacam SP (superior performance) and the Matsushita M-II formats. They were incompatible with each other because of significantly different signal processing techniques. The situation was reminiscent of the consumer format conflict (Beta versus VHS) of a decade earlier.

The Sony Betacam SP employed time-division multiplexing (TDM) to combine color component signals and record them alternately on a single color channel along with two stereo audio subcarriers at 310 kHz and 540 kHz, respectively. The luminance signal is recorded separately on a second channel (27).

The M-II format first sums the quadrature I and Q color elements into a single signal which is then recorded as the color track together with a pair of stereo audio subcarriers at 400 kHz and 700 kHz, respectively. A second channel contains the luminance information (28).

Composite Digital Tape Formats

As the analog component technology evolved, progress was being made in applying digital techniques, first employed in the consumer laserdisk, to commercial videotape recording.

In 1980, an international standards body, the International Radio Consultative Committee (CCIR), drafted Recommendation #601 which sought to define the characteristics of component digital recording. CCIR 601 was intended to be the recording standard for studios throughout the world. For many years thereafter, CCIR 601 was altered and modified. Finally, by 1985 the standards recommendations were firm enough for final approval. At this time Sony announced a digital component tape recording system based on the 601 recommendations. This D-1 system employed a 19-mm wide (approximately three-quarter-inch) tape in a cassette (similar to that employed in the U-Matic) and scanned in a helical manner with six tracks per field, two containing video data and four to support two pairs of stereo audio (29).

In 1987 Sony and Ampex working together brought forth the D-2 composite digital recording system. Like the D-1 format, the D-2 utilized a 19-mm tape and the same cassette as D-1 and provided four channels (two stereo pairs) of digital audio in addition to the video data. The scanning is also helical with six tracks per field (30).

The principal difference between the D-2 and D-1 formats is that D-2 is designed for a composite input signal which contains all of the color signal elements within a single envelope. Therefore the D-2 format is primarily for field recording whereas D-1 is for both studio and postproduction editing.

CONSUMER VIDEO-DIGITAL VERSATILE DISC (DVD)

For almost 20 years following its introduction in 1976, the VHS analog tape format remained preeminent in the consumer marketplace for video recording and playback. This was true, notwithstanding the ability of the laserdisk to provide much superior playback performance than even the enhanced VHS format, Super-VHS (S-VHS).

In 1995, barely 10 years after the highly successful introduction of the compact disk (CD) which provided digital, laser-scanned playback, an analogous versatile digital disk format (DVD) became available for video recording. Like the laserdisk before it, the DVD, as currently available, is a playback-only format.

The DVD is built on experience gained from the audio CD. However, it uses both a higher frequency (and shorter wavelength, red laser at 635 nm) and much more dense physical packing parameters (track spacing, groove width and length) to support an almost 6 : 1 increase in information storage capacity.

These improvements were not enough in themselves to provide the 10 : 1 storage improvement needed to go from 74 minutes of audio data (640–680 MB of information) to the 4000 MB needed to provide over two hours (typically, 135 minutes) of standard resolution (NTSC) television programming. Data compression is used as well.

As is the case for the audio CD, the laser scans the reflective surface of the DVD disk from below, and like the audio CD, the DVD (as available today) uses factory prerecorded programming on a CD-like media (12 cm = 5.25 in in diameter) (Fig. 8) (31).

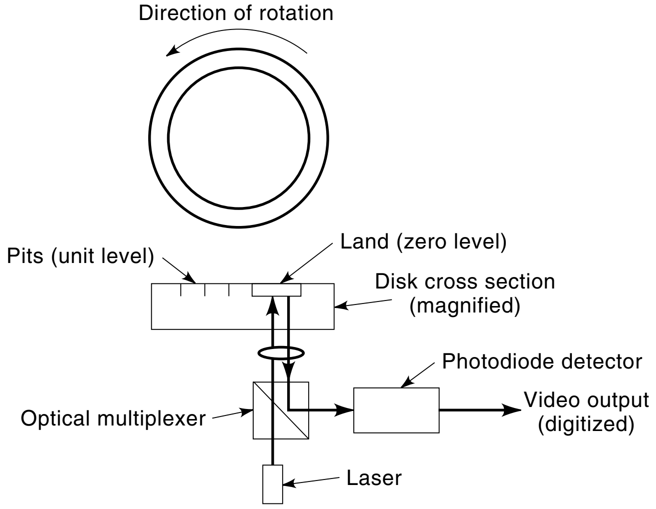

Figure 8. Digital versatile disk scanning (simplified).

FUTURE DVD ENHANCEMENTS

Even as DVD is being initially deployed in the marketplace, companies are investigating enhancement technologies to provide increased (double, quadruple, or higher) information storage capacity. One possible advance, derived linearly from present technology, seeks to replace the present binary digital encoding scheme with a multilevel scheme (nine states) which interprets the depth of the recorded *pits* to allow for coding beyond simply one or zero. The ability to read nine levels (from zero to eight) allows for a CD-sized disk capable of storing over two hours of HDTV-formatted television programming including three distinct stereo audio channels (32).

A second potential avenue of increased storage capability focuses on substituting a blue light laser at a wavelength of 390 nm for the red light laser at 635 nm currently employed in DVD recording. Because data storage capacity follows an inverse-square relationship with wavelength, this blue light technology could provide more than a 2.5 : 1 increase. Combining this with the use of smaller pit dimensions and closer track spacing, the total improvement could reach 4 : 1. This would lead to a storage capacity of over 15 GB on a 12 cm disk, enough capacity to provide five to seven hours of standard resolution (480 lines, NTSC) television or as much as two hours of HDTV (at 1080 lines) (33).

DVD HOME RECORDING

Even as the aforementioned investigations of increased capacity are being pursued, attention is also being given to technologies which address the ability of the consumer to record at home, thereby creating a real replacement for the VCR.

At least two main approaches are being followed at this time; optical phase change (OPC) and magneto-optical (MO). OPC technology exploits the heating effect of laser energy to alter the reflectivity of the DVD disk so that this change can be read optically as a phase difference. The current DVD technology reads the signal amplitude digitally as one of a pair of binary states, either one or zero.

Magneto-optical (MO) technology is not really new. It has been used for digital data storage for some time, and it is the basis of the recordable MiniDisc audio system introduced by Sony in 1992. As used in the MiniDisc (MD) system, virtually simultaneous erasure and recording is possible by having both a magnetic recording head and a *heating* eraser laser coaxially located, respectively, above and below the recording disk (Fig. 9).

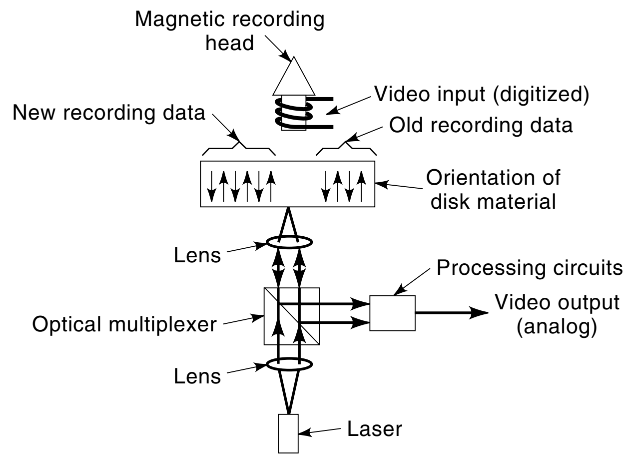

Figure 9. Magneto-optical recording.

To record, the laser first heats the disk to its *Curie point* (about 400 °F). This causes the magnetic orientation of that portion of the disk to become totally random. Next, the magnetic recording head above the disk reorganizes the magnetic particles on the disk to represent one of the two binary states, one or zero. Then this orientation can be read back during playback, analogously to the digital optical process used in the current DVDs (33).

Once the disk has cooled down, its magnetic orientation is firmly set, even in the presence of significant magnetic fields. It can be altered only by applying the equivalent of the laser heating cycle.

The OPC approach is quite attractive from a manufacturing perspective because it employs many of the components and circuits of the current DVD system. However it is slightly limited in the number of write/rewrite cycles (to between 100,000 and one million), whereas the MO system has virtually no limit on its rewrite capability (34).

NONLINEAR RECORDING-COMMERCIAL VIDEO SERVERS

A *video server* is a computer-based system which provides storage and playback of a variety of video formats. It consists of two major components (Fig. 10), the computer, which serves as an interface between the video environment and the storage device, and the hard disk storage device (35).

During recording, the computer converts the input video information (both video and audio) into a digital data stream formatted for storage on a hard disk storage array. The input can be either analog (NTSC or component) or digital (uncompressed or compressed) in format. The resulting digital data stream, delivered to the hard drive, can be either uncompressed or compressed. Compressing the data prior to storage provides for efficient use of storage capacity at the cost of minor reduction in video quality during playback.

During playback, the data file is retrieved from the storage device and converted back into a appropriate television format. This playback format may be either the same as, or different from, the input as the operator may desire. The process is termed *nonlinear* because video information can be accessed from any segment of the complete file rather than lin-

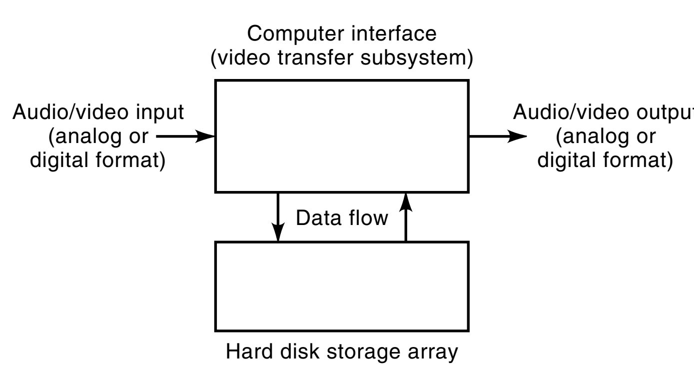

Figure 10. A basic video server.

early, starting from the beginning of the file, as is the case for tape.

Video server applications include broadcast editing, commercial insertion, and preparation of interstitial insertion material (clip reels). An aggressive adopter of this technology is the television news sector which employs the nonlinear instant access capability of the VS systems to enhance its creation of timely news programming.

Video servers can also be used to provide pay per view and near-video-on-demand (NVOD) type service to subscribers on a delivery system which has feedback capability from the subscriber's location to the server site (36).

Now, video server technology is in a period of rapid growth with the application of constantly improved technology. Philips, Sony, and Hewlett-Packard are some of the companies currently active in this field (37).

The storage array concept allows multiple diskrete disks to act as a single unit. The use of such multiple disks and drives provides redundancy in the event a single device (either disk or drive) fails. Even using compression of the storage data stream requires the use of multiple parallel drives to support the data transfer rate. A typical disk drive supports a data rate of three to five MB/s. A full digital component data stream can produce a rate of 35 MB/s. Multiple disk drives combined with parallel data paths can support up to 40 MB/s. Use of compression techniques can reduce the 35 MB/s stream to an effective rate of less than 20 MB/s which then can be handled by a single path storage array (38).

Because current storage technology is evolving at such a rapid pace, it is virtually impossible to predict the eventual structure of these nonlinear systems, even in the near future.

BIBLIOGRAPHY

1. S. Wolpin, The Race to Video, *Invention Technol.,* **10** (2): 52, 1994.
2. A. Abramson, A short history of television recording, *SMPTE J.,* **64**: 72, 1955.
3. C. Ginesburg, The birth of video recording, *SMPTE 82nd Convention,* San Francisco, CA: October 5, 1957.
4. R. Mueller, The first 15 years of 3/4-inch U, *AV Video,* **7**: 72, 1985.
5. J. Lardner, *Fast Forward,* New York: W. W. Norton, 1987.
6. D. Mennie, Television on a silver platter, *IEEE Spectrum,* **12**: 34, August 1975.
7. P. Lubell, The gathering storm in high density compact disks, *IEEE Spectrum,* **32**: 32, August 1995.
8. A. Abramson, A short history of television recording, *SMPTE J.,* **90**: 508, 1981.
9. Ref. 3, p. 74.
10. Reference 5, pp. 51–52, and N. Heller, Getting a grip on tape, *Video Systems,* **12**: 26, 1986.
11. Ref. 3, pp. 74–75.
12. D. Rushin, HiFi to high definition: Five decades of magnetic tape, *dB Magazine,* Jan./Feb. 1991.
13. R. Warner, Jr., Earl Masterson: A fresh slant on video recording, *IEEE Spectrum,* **33**: 51, February 1996.
14. A. Harris, Time Base Errors and Their Correction in Magnetic Video Recorders, *SMPTE J.,* **70**: 489, 1961.
15. C. Bentz, Inside time base correctors, *Video Systems,* **11**: 49 1985.
16. Ref. 4, p. 73.
17. S. Stalos, The real "U" in U-matic, *AV Video,* **7**: 75, 1985.
18. Ref. 17, p. 76.
19. C. Bentz, Avoiding a glitch in time: Inside TBCs, *Broadcast Engineering,* **27**: 80, 1985.
20. Ref. 2, p. 74.
21. Ref. 13, p. 57.
22. N. Kihara, and others, Development of a new system of cassette type consumer VTR, *IEEE Trans. Consum. Electron.,* **26**: 56, 1976.
23. Ref. 5, pp. 145–149.
24. W. Workman, The videodisk player, 25/4, Session 25, *ELECTRO/81 Prof. Program Session Record,* New York: April 1981.
25. K. Compaan and P. Kramer, The Philips 'VLP' system, *SMPTE J.* **83**: 564, 1974.
26. P. Rice and R. Dubbe, Development of the first optical videodisk, *SMPTE J.* **91**: 237, 1982.
27. K. Sadashige, Video recording formats in transition, *SMPTE J.* **98**: 25–31, 1989.
28. J. Roizen, Standards: Where do we go from here, *TV Broadcast,* **8**: 68, 1985.
29. R. Hartman, Electrical system design for SMPTE D-1 DTTR, *SMPTE J.* **95**: 1215, 1986.
30. D. Brush, Design Considerations for the D-2 NTSC Composite DVTR, *SMPTE J.* **95**: 1215, 1986.
31. Ref. 7, p. 33.
32. T. Wong and M. O'Neill, 15 GB per side and no blue laser, *Data Storage,* April 1997, pp. 80–83.
33. MD, Rainbow Book Sony Standard, San Francisco, CA: 1991.
34. *Phase-Change Rewritables,* Sony Product Release, Palo Alto, CA: September 1997.
35. C. Bernstein, Media pool-flexible video server design for television broadcasting, *SMPTE J.* **106**: 511–518, 1997.
36. P. Hejtmanek, Video servers, *Broadcast Eng.,* **38**: 27, 1996.
37. P. Hejtmanek, Video disk recorders, *Broadcast Eng.,* **39**: 36, 1997.
38. Digital video servers for on-air broadcast use, *SMPTE Seminar NAB Convention,* Las Vegas, NV: April 1997.

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