How the Videotape Recorder Works

Many TV programs are now on tape. Here's the recorder responsible for this revolution in TV broadcasting.

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SINCE the advent of magnetic tape recording in the audio field and as its inherent advantages of good quality, immediate playback, and tape reusability were recognized, the possibility of utilizing the same process for recording television images has stimulated engineering minds.

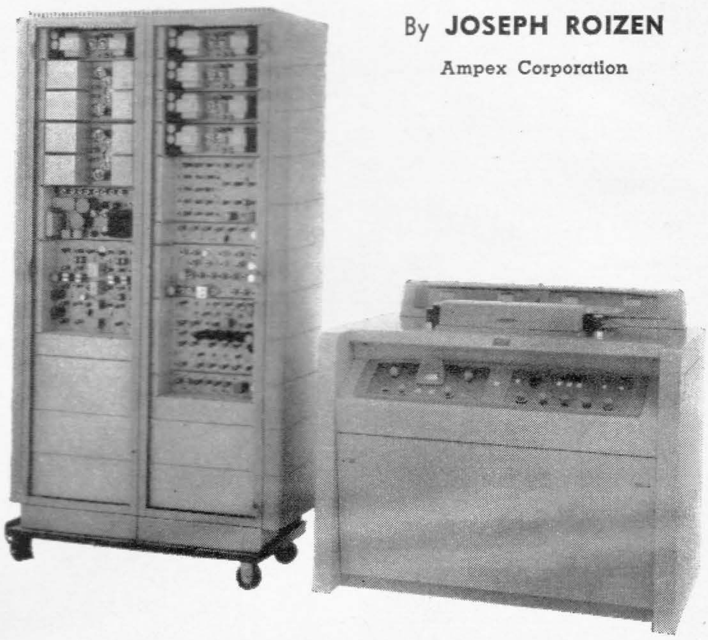
As video and audio information are both made up of varying electrical voltages, differing only in the frequency ranges involved, it would seem that a simple extension of audio recording techniques would serve to put pictures on tape. This, unfortunately, is not the case and we must examine the fundamentals of magnetic recording to understand the problems involved.

It is a paradox of magnetic recording that you cannot put both a very high and a very low frequency on the same tape and expect to get good output and adequate signal-to-noise ratio from both. The range of audio signals (30 to 15,000 cycles) represents about the maximum latitude possible. But video frequencies extend from nearly d.c. to above 5 megacycles!

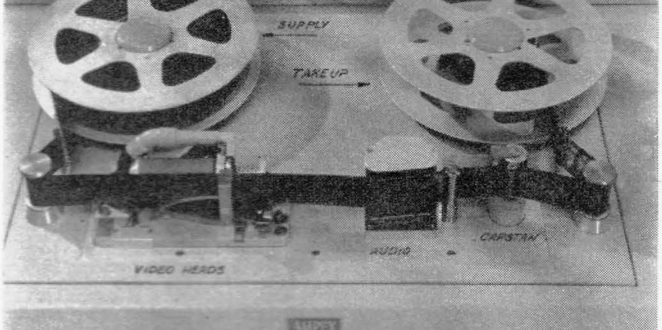
The diagram of Fig. 1 shows that the maximum frequency you can record and play back is controlled by head gap size and tape velocity. When the tape velocity is such that a full wavelength (1 cycle) of the recorded signal is approaching or is equal to the gap dimension, no output is possible. If the head instantaneously sees equal amounts of positive and negative flux density on the tape, then they cancel. A range of frequencies before this upper limit and spanning approximately 10 octaves represents the usable spectrum and even though the output from the head drops in amplitude proportional to the reduction in frequency, an equal and opposite response curve of the amplifier following the head will correct for this condition and give usable output over this range.

Since the head output is dependent on the *rate of change* of flux density, we soon reach a low limit where the rate becomes so slow that no useful output can be obtained and the signal-to-noise level becomes prohibitive. The *Ampex* VR-1000 "Videotape Recorder" solves the various problems in recording television signals by these three methods:

1. The video signal is altered, in form, from an AM signal extending from 0 to 5 megacycles to an FM signal containing the same inherent information but transposed into a spectrum of 1.5 to 6.5 megacycles. This meets the basic requirement of having upper and lower frequency limits within the conditions as specified.
2. To get adequate playing time from a compact reel of tape, the system utilizes a 2-inch wide tape (compared to ¼-inch used in audio recording) and a rotating head assembly with heads spaced 90° apart which provides the high head-to-tape velocity (1500 ips) necessary for recording the very high frequencies involved.
3. Precision-made head assemblies and a very accurate servo system make it possible to play tapes made on one machine on any other machine adjusted to established standards. This allows for interchangeability of tapes between users in the United States and

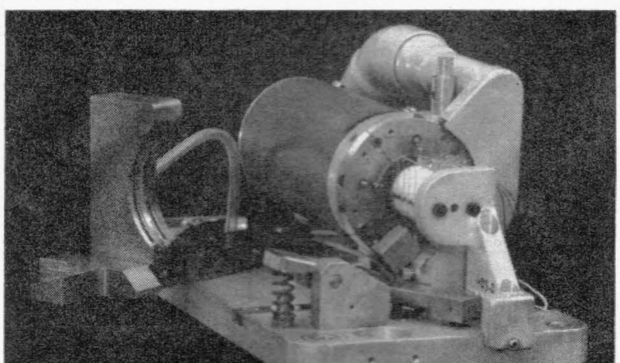


The complete machine comprises two racks and console.



Close-up view of transport with cover plate removed.

This is what the video head assembly looks like.



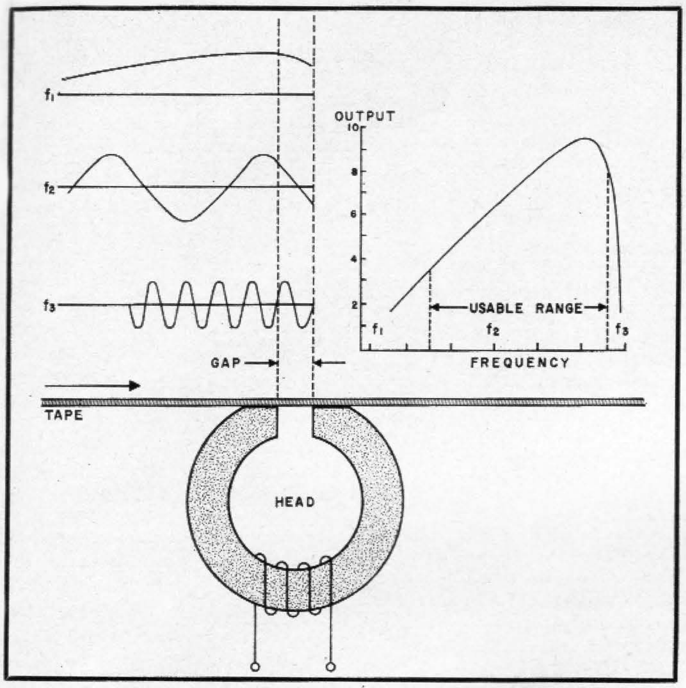


Fig. 1. Maximum frequency is controlled by gap and tape speed.

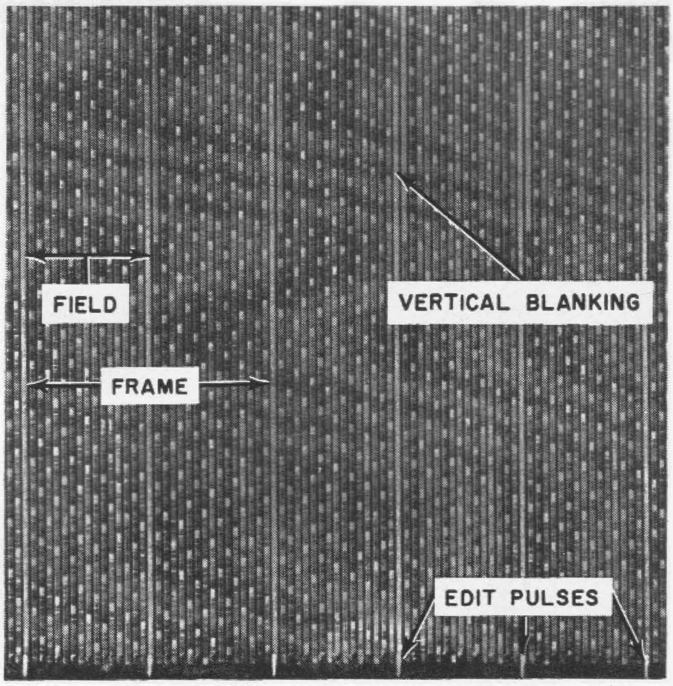


Fig. 2. A "visualized" tape with a monoscope pattern recorded.

Canada and, in some cases, even with foreign countries. It also permits commercials made on different machines to be spliced in with program material recorded at a different locale.

The "Videotape" unit is capable of recording for indefinite storage or immediate playback (without processing) a complete television program of up to 90 minutes in length, including both picture and sound. A standard one-hour reel is 12 inches in diameter and holds approximately 4800 feet of tape. The tape consists of a specially manufactured Mylar base, 1 mil thick, coated with oxide on one side. It can be re-recorded over 100 times. Tape speed is the standard 15 inches-per-second employed in professional audio recording equipment.

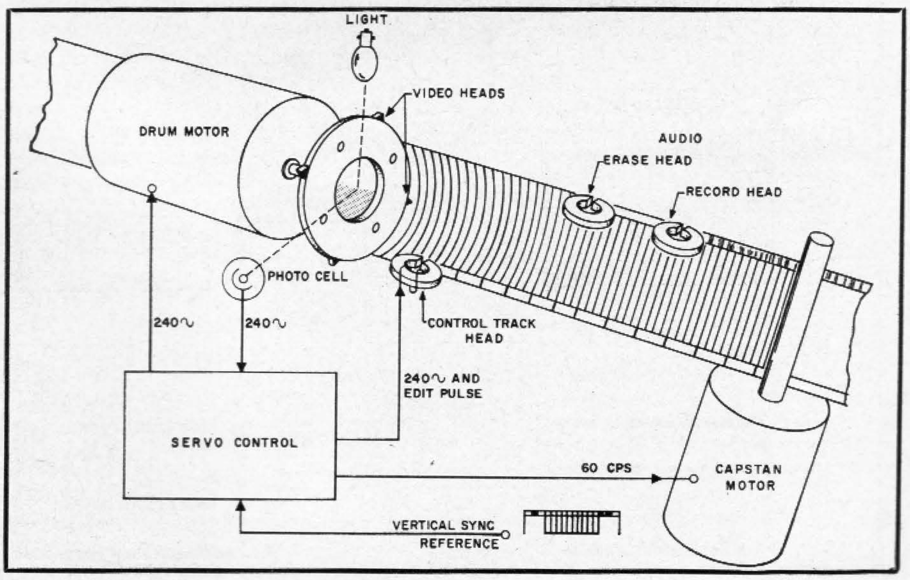
The recorded signals include the picture information (video) laid down at right angles to the tape by the rotating head assembly. The sound portion is recorded along the upper edge of the tape with the timing reference signal (control track), the cue track, and edit pulses recorded at the lower edge. Although these signals are invisible to the naked eye, it is possible to bring them up for editing and splicing purposes. Fig. 2 shows a "visualized" tape which has a monoscope pattern recorded on it. The transverse lines carrying the video signal are 10 mils wide with a 5 mil spacing between them. Each scan of one head in the drum assembly covers 16 to 17 active television lines. Enough overlap of video information is available so that there is ample time for switching from head to head while maintaining proper continuity.

Fig. 3 is a simplified diagram showing the "Videotape Recorder" in the "record" mode. Vertical sync signals derived from incoming video information are used as a reference for maintaining the rotational speed of the drum motor at exactly 240 revolutions-per-second (14,400 rpm). The servo loop picks the signal from the head assembly off a photocell and feeds it back to the servo control unit for comparison with vertical sync. The resultant is used to control the speed of the drum motor. The photocell signal is also recorded on the bottom edge of the tape by the control-track record head as a timing reference to be used in playback and the edit pulses are superimposed on it. Two binary counters reduce the 240-cycle signal to 60 cycles—the frequency used to drive the capstan motor pulling the tape.

The same video signal that controls the drum servo is fed to a modulator which transforms it to FM and is then applied through four identical channels to the individual heads on the drum. A slip ring and brush assembly serve to transfer the signal to the head drum. Since only one head at a time is in contact with the tape, each head lays down its track in sequence. To maintain a perfect pressure gradient across the tape in contact with the revolving heads, the tape is held in a concave guide by an applied vacuum. This guide can be minutely adjusted to make playback time exactly equal to record time even when the head wear has somewhat reduced the diameter of the head drum assembly. The average life of a head drum assembly is in excess of 100 hours and they are refurbished on a rotational exchange basis.

Fig. 4 shows the test pattern which results when the guide is slightly misadjusted. This demonstrates the group of picture lines each head covers and the result of a timing error which was

Fig. 3. Simplified diagram showing "Videotape Recorder" in the "record" mode.



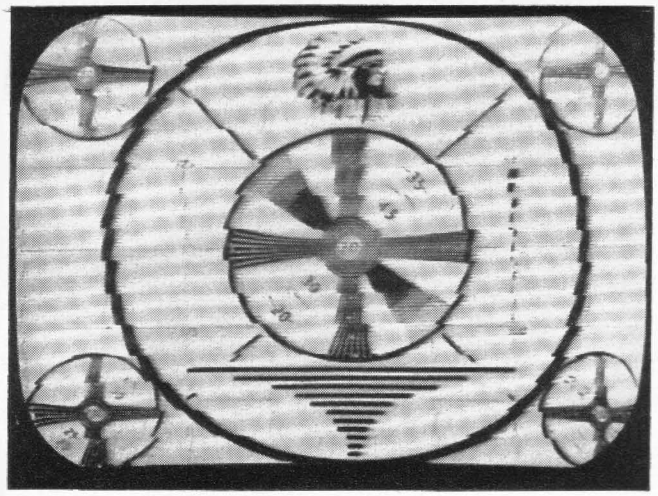


Fig. 4. Test pattern resulting from slight guide misadjustment. This shows the group of picture lines each head covers and the result of a timing error which was purposely induced in this case. This condition is called "picture skewing" and it is corrected for by automatic compensation.

purposely induced in this case. We refer to this condition as "picture skewing" and an automatic compensating device corrects for it.

The edit pulses along the bottom edge of the tape are referenced to vertical sync and serve to locate the exact point at which a splice can be made so that it will occur during vertical blanking and be invisible to the viewer. An accessory precision splicer performs this function very simply and with the required amount of accuracy.

We will now follow the path of a standard television picture signal which would normally be obtained from a live camera chain, film chain, or microwave source as it goes through the processing required to have it recorded on video tape and then played back for previewing or air transmission. Fig. 5 is a simplified block diagram of the video signal path. In the "record" mode a video AM signal of approximately 1.4 volts peak-to-peak is applied to the input of a multivibrator type modulator whose normal rest frequency (4.75 mc.) is made to deviate approximately 2 mc. by variations in the video voltage. The output of this modulator is now an FM signal whose frequency is proportional to the original video amplitude. This FM signal is further amplified and applied, through four identical drivers, to the video record heads on the drum assembly. The signal is then laid down on the tape as previously explained. In the "playback" mode the servo control system insures that each head will follow closely the tracks that have been recorded and the sequenced, overlapping outputs of these heads are fed to individual preamplifiers and into the switching system.

The "switcher" is a fairly complex electronic device capable of precisely sequencing the FM signal from the tape in such a way that no overlap or absence of signal occurs and that switching transients are timed by horizontal sync and do not appear in the picture. The now continuous FM signal is then channeled through a demodulator chassis which applies considerable amplitude limiting (to make up for variations in head outputs). The signal now has a constant amplitude and is applied to a delay-line slope detector and a full-wave rectifier where it is converted back to an AM video signal. Although the output of the demodulator can be used to provide high-quality television reproduction, the degradation of the sync signals is such that the composite video would not meet FCC requirements for commercial re-broadcast. To overcome this deficiency a processing amplifier, somewhat similar in action to stabilizing amplifiers used by television stations, is utilized. The processing amplifier regenerates new blanking signals and amplifies, clips, and gates synchronizing pulses. The newly blanked video is combined with the noise immune, as well as cleaned up sync signals and the resultant composite video output is now acceptable for standard transmission.

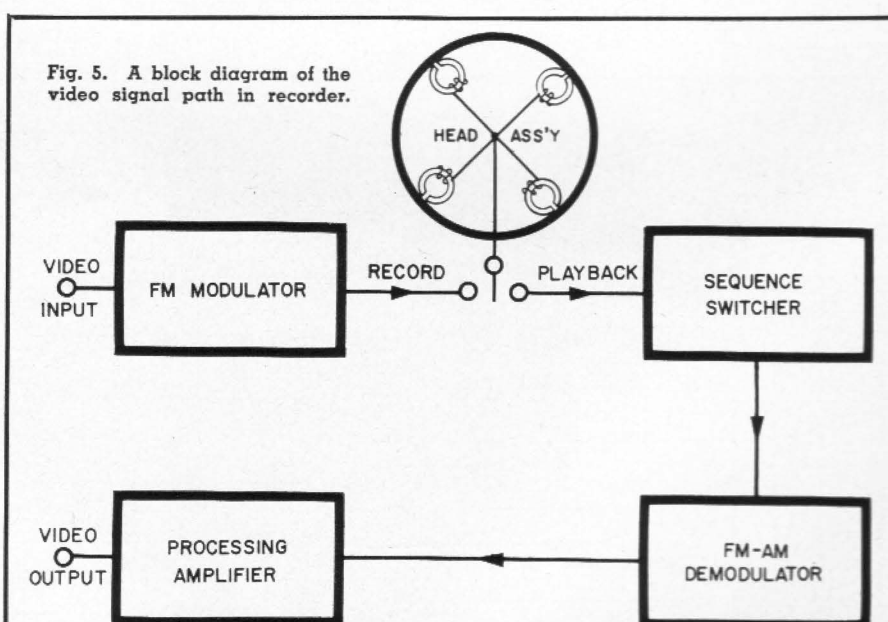


Fig. 5. A block diagram of the video signal path in recorder.

Because of the inherent linearity of the system there is no expansion or compression of the gray scale and the reproduced images are almost indistinguishable from the original on the home receiver. The over-all bandwidth allows an off-the-tape picture of better than 400 lines resolution with a standard monoscope pattern to be played back. The major limiting factor in video tape recording today is the maximum signal-to-noise ratio that can be achieved. At the present state of the art, between 33 and 36 db of signal-to-noise appears to be the maximum. This permits commercially acceptable third-generation copies (a copy of a copy of a copy).

At the present time, to make high-quality copies it is necessary to utilize the original tape feeding a group of "Videotape Recorders" in parallel, each of which is recording the duplicate on a one-to-one time basis. Network tape centers equipped with batteries of these recorders are located in New York, Chicago, and Los Angeles as well as at independent stations all over the world. Foreign stations in Canada, Mexico, Japan, Great Britain, Germany, Australia, and France are using these recorders for day-to-day programming.

The recording of color television signals on video tape, although presenting a much more difficult technical problem, has been successfully demonstrated and its adoption is just a matter of time. A group of *Ampex* VR-1000's has already been converted by *NBC* engineers to record and play back its major color shows (Steve Allen, etc.) and the company is now delivering color conversion kits to its "Videotape Recorder" customers.

A tremendous variety of non-broadcast uses have been opened up by video tape recording. At the AMA convention in San Francisco, in co-operation with *Smith, Kline and French* whose color facilities were being used to telecast surgical operations, color recordings and repeated playbacks served to demonstrate the potentialities of the medium as a medical training tool. The applications of video tape recording to educational and closed-circuit work are being expanded while modified versions of the technique are finding gradual acceptance in the instrumentation field. —30—