A SYSTEM FOR RECORDING AND REPRODUCING TELEVISION SIGNALS*

By

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Summary—*A system for recording and reproducing television signals by means of magnetic tape has been developed. This system will accommodate both monochrome and color pictures. For monochrome pictures, two channels are used, one for the video signal and one for the sound signal. These signals are recorded as two tracks on ¼-inch magnetic tape. For color pictures, five channels are used: video channels for the color signals red, green and blue and the synchronizing channel and an audio channel. These signals are recorded as five tracks on ½-inch magnetic tape. An electronic servomechanism provides the speed constancy required for the reproduction of television signals from magnetic tape. The present tape speed is 30 feet per second. The recorded and reproduced frequency band is over 3 megacycles. There is a description of a demonstration which included side-by-side showing of a direct picture, and the same picture recorded and immediately played back.*

INTRODUCTION

A SYSTEM for recording and reproducing television signals by means of magnetic tape has been developed. This system will handle both monochrome and color pictures. The elements of the system and several demonstrations are described in the sections which follow.

TAPE

The tape used in this development consists of a cellulose acetate base coated with a red iron oxide. The acetate base is .0017 inch in thickness. The iron oxide coating varies among different makes from .0004 to .0007 inch in thickness. The width of the tape for color television is ½ inch, and that for monochrome television is ¼ inch. In the case of monochrome, ½ inch tape may be used with two parallel programs on one tape. The coercive force of the tape used in the demonstration is 250 oersteds. The residual magnetization is 770 gausses.

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Tape Transport Mechanism

The tape transport mechanism has been designed to limit any sudden speed changes to a very minute quantity and thereby prevent jitter in the pictures. The order of constancy required can be illustrated by stating that a sudden speed change of one part in a million

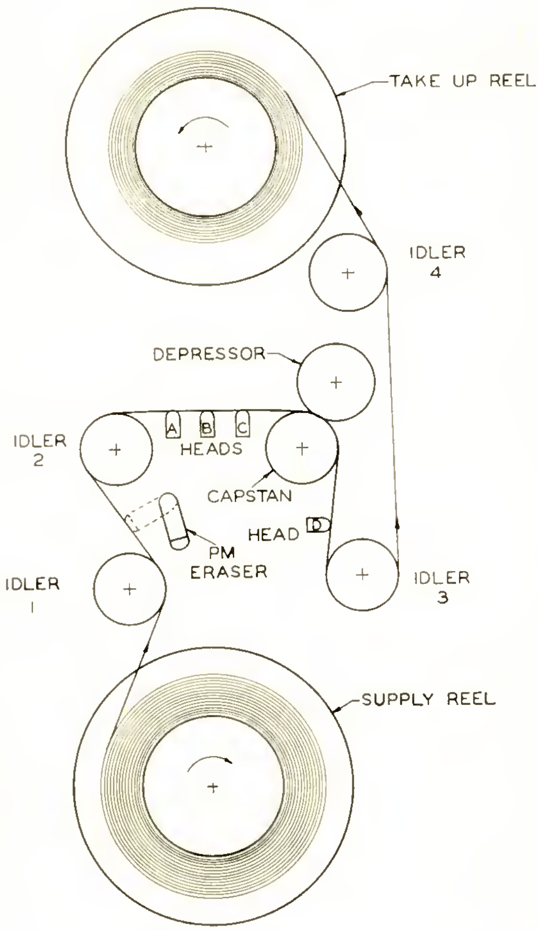

Fig. 1—A schematic diagram of the tape transport mechanism.

will put a jog of about 1/5 inch in the picture on a 12-inch kinescope. In addition, any slow drifts in speed have to be limited to considerably less than one picture element per scanning line.

A schematic diagram of the tape transport system is shown in Figure 1. A photograph is shown in Figure 2.

The basic speed of the tape feed is determined by a capstan driven at approximately 30 revolutions per second and having a circumference of one foot. Sudden changes in capstan speed are filtered out by a flywheel. Bearings on this capstan-flywheel assembly must be

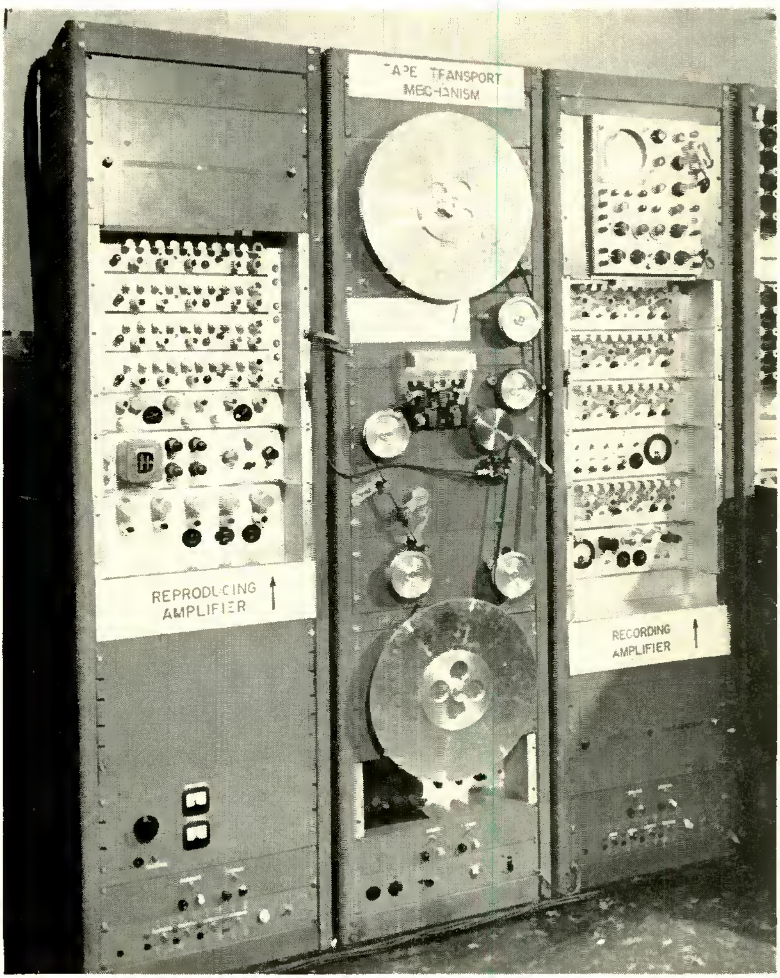

Fig. 2—The system for recording and reproducing television signals by means of magnetic tape.

very smooth and perfectly aligned, and both static and dynamic balance of all parts must be precise.

Even with accurate tape speed established by the capstan, tension in the tape supply and take up must be held very exact or momentary changes in tape position will be introduced by stretch in the tape.

Tension is maintained constant on the supply by driving a generator from the supply reel shaft, and using feedback to control the generator load to a constant tension load. The control must hold over a speed range of from 400 revolutions per minute (with a full reel) to over 860 revolutions per minute (when reel is empty).

The take up reel is motor driven and has its feedback circuit arranged so that a constant tension on pull-out is obtained. Both supply and take up tensions are held constant whether the reels are empty or full.

Figure 1 shows a diagram of the complete transport mechanism. Four fixed idler pulleys are used to guide the tape from supply reel over the heads and capstan, and onto the take up reel. A rubber surfaced idler is sprung against the capstan to act as a depressor in holding the tape on the capstan for speed determination.

The tape reels are an important part of the tape transport mechanism. The reel must not have excessive inertia if a practical starting time is to be achieved. The reel must be accurately balanced if full advantage is to be had from the constant tension reel drives.

The playing time of a reel full of tape is dependent on the diameter of the reel, the thickness of the tape, and the speed of the tape. The present reels shown in Figures 1 and 2 are 17 inches in diameter and have a hub 8 inches in diameter. The present tape is .0021 inch in thickness. A full reel contains approximately 7000 feet of tape. This length of ½ inch tape weighs 4.3 pounds and will play approximately 4 minutes at 30 feet per second. An objective of current research is to handle 15 minutes of program time using reels 19 inches in diameter. A fifteen minute reel could be considered a unit reel for television programing. Longer shows would be handled by using two reproducers alternately, as is done in motion picture theater presentations.

Recording and Reproducing Heads

The enormity of the problem of recording video signals on magnetic tape is obvious to anyone acquainted with the art of recording sound on magnetic tape. Application of the techniques employed for recording sound on tape seems almost futile when the demands of video recording are enumerated. To be more specific, a simple calculation will show that a frequency of 4 megacycles per second recorded on a tape traveling at 30 feet per second results in a wave length, on the tape, of less than 1/10,000 of an inch. Quite obviously the effective gap length of the recording and reproducing heads must be considerably less than the wave length to be recorded. One must accept the problem of producing heads having exceedingly small effective gap lengths.

Further thought will point out the fact that the head gaps must be straight if the tape is to be recorded on one head and reproduced on another head, without loss of over-all performance.

The electrical and magnetic performance of the heads is all the more formidable for the reason that some 16 to 18 octaves of frequency range must be covered. The magnetic path of the heads must be made of a material that will maintain a high permeability over the entire frequency range. The coil which surrounds the magnetic path of the head must produce a reasonable electrical impedance over the frequency range. It is particularly important that the electrical impedance be free of resonances in the higher frequency range.

The physical configuration of the heads must satisfy a number of conditions. Firstly, the assembled head must be stable with time

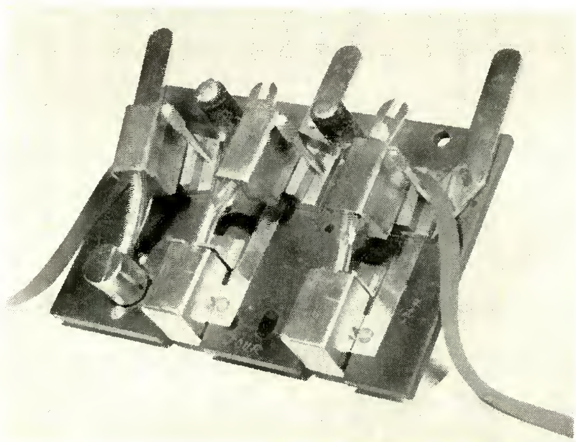

Fig. 3—The sound and video magnetic recording and reproducing heads.

against such adversities as temperature and humidity cycles. Secondly, the head must have good wear resistance to the abrasive effect of the passage of tape. Thirdly, the head must be physically small to allow for the grouping of multiple channels, such as in the color recording and reproducing procedures. Finally, there are numerous other mechanical requirements such as mounting of the heads, shielding of the electrical connections, head position adjustments, etc.

Redoubtable as the above requirements may be, it has been possible to develop a set of heads that appears to be a reasonable solution to all the problems. Figure 3 is a photograph showing the present arrangement of the head assembly for recording the color video signals on tape. The left-hand head is for recording the sound. The central head is the video recording head, which is made up of four elemental heads to provide four channels. The right-hand head is the video reproducing head, which also contains four elemental heads. The sound reproducing head is placed at a point following the tape drive capstan, for the sake of expediency only. In a final design, both video and sound heads would probably be incorporated in a single unit. It may be noted that the sound recording head is positioned so that the sound track is centered between two of the video tracks.

Tests have established that the frequency response of the heads is uniform with a reasonable signal-to-noise ratio up to approximately 3.5 megacycles per second. The impedance of the elemental head is substantially free of resonances to the highest frequency. The wear properties of the heads, although not completely examined, have been satisfactory.

Audio System

In conventional magnetic tape recording systems used for audio frequency work, the tape usually moves past the recording and reproducing heads at a speed in the neighborhood of 1.25 feet per second. With such systems, careful design and adjustments are necessary if one is to succeed in recording and reproducing the higher audio frequencies, say above 10,000 cycles, because of the extremely short wave lengths of these higher frequencies. In the video tape recording system where the tape speed is 30 feet per second, the situation with respect to recording audio frequencies is reversed. It is now more difficult to record and reproduce the lower audio frequencies at useful levels above noise because of the extremely long wave lengths of the lower frequencies. For example, a 100-cycle tone recorded by the video tape system has a wave length of nearly 4 inches, while the same tone recorded on a conventional audio tape recorder has a wave length of only 1/10 inch or less.

A consideration of the problem of recording and reproducing the lower audio frequencies, together with the requirement of a complete absence of cross talk between the audio track and the adjacent video tracks recorded on the tape, led to the use of a modulated-carrier method of recording the audio signals in the present system. Thus, the audio frequencies are not recorded directly on the tape. Instead, a high-frequency carrier signal is recorded, and this carrier is amplitude modulated by the audio-frequency signals. Upon playback from the tape, the modulated carrier is amplified and demodulated to give the reproduced audio signals.

A block diagram of the audio recording and playback system is shown in Figure 4. The frequency of the carrier is 150 kilocycles. The recording and reproducing amplifiers both employ tuned circuits having a pass band centered at the carrier frequency. The audio recording and reproducing heads are essentially the same as those used in the video channels. A switching arrangement not shown in the block diagram can be used to connect the audio amplifier input directly to the audio input of the modulator. This permits listening to the audio program without first passing the signal through the tape system.

VIDEO SYSTEM FOR COLOR

The block diagram of Figure 5 shows the basic components required

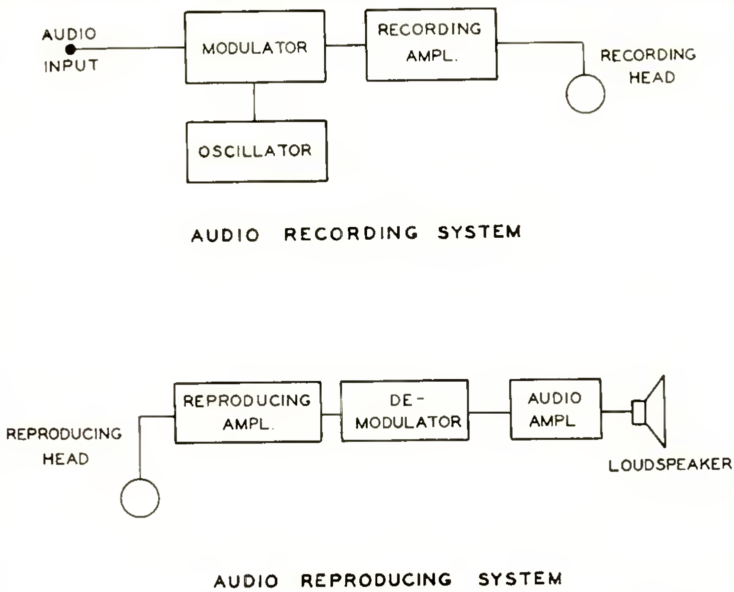

Fig. 4—A schematic diagram of the electronic elements used in recording and reproducing the audio signals on magnetic tape.

for recording a composite color video signal such as obtained from the video output from a television receiver or microwave radio relay.

As shown, the composite color video is coupled to a color demodulator which produces, on separate outputs, the three color video signals (red, green, and blue), and the separate synchronizing components. The four signals thus obtained are coupled to their respective recording heads through four recording amplifier units.

The sound or audio signal which may be obtained from the audio output of a television receiver is coupled to the audio recording head through a fifth recording amplifier unit as described in the preceding section.

The recording amplifier units provide both phase and frequency compensation in order to obtain the desired flux pattern on the tape.

The signals, as shown in Figure 5, are recorded on five separate tracks on the magnetic tape. There is one track for each of the primary color video components (red, green, and blue), one for the associated synchronizing information and one for the audio or sound signal.

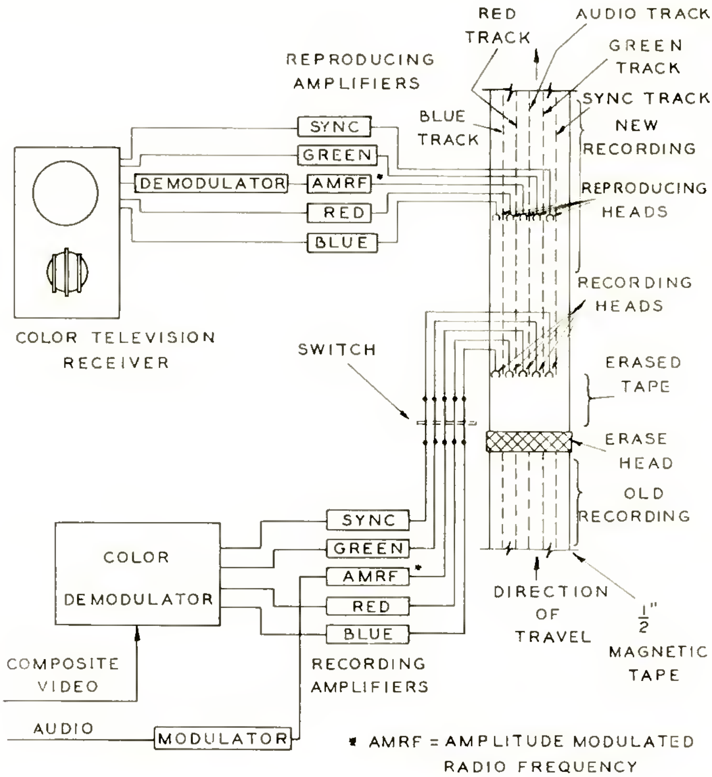

Fig. 5—A schematic diagram of the electronic elements used in recording and reproducing the color video signals and audio signals on magnetic tape.

Referring again to Figure 5, as the tape travels in an upward direction, the erase head first removes all previous information from the tape and conditions the tape for recording. The tape then travels past the recording heads where new information is impressed. The information is stored on the tape in the form of a flux pattern which corresponds to the signal.

The energized tape then travels past the five reproducing heads which are used for reproducing or monitoring purposes. The reproducing heads generate electrical signals which correspond to the flux patterns stored on the tape.

Since the reproducing heads do not change the flux pattern on the tape, any desired number of reproductions may be had by merely running the tape through the machine with the erase and recording heads de-energized.

The erase head is a specially designed permanent magnet which subjects the individual elements of the tape to reversing magnetic fields and leaves the tape in a fixed magnetic condition. This head is physically removed from the tape path when the erasing operation is not desired.

In order to de-energize the recording heads, there is provided an on–off switch which permits the removal of all signals from these units.

Each of the recording amplifiers contains a special biasing unit. This unit applies an appropriate signal to the tape so that the full magnetic amplitude range may be used for the video signal. That is, the "black" level of the video wave is made to occupy a particular value on the magnetic characteristic of the tape. The "white" signal components then vary the magnetic pattern relative to this value.

The output signals from the magnetic tape are essentially in the form of the output signals from a television color camera. To use these signals to modulate a television transmitter, it is necessary to form a composite signal of FCC Standard Signal Specifications just as is done with camera signals at a studio. One difference exists in the use of magnetic tape output, for here the synchronizing signals are reconstituted and related to the information recorded on the tape.

Video System for Monochrome

When black and white television signals are to be recorded on magnetic tape, only two tracks on a ¼-inch tape are required. As shown in Figure 6, one track is used to carry the complete video signal and the other is used for the associated audio signal.

The video signal is coupled to the video recording head by means of a recording amplifier. This amplifier inserts the required phase and frequency compensation to permit the desired flux pattern to be formed on the tape.

The audio signal is coupled to the audio recording head by means of an audio recording amplifier. The audio system consists of a carrier generator, modulator, and amplifier as described earlier.

As in the case of color, any previously recorded information is removed from the tape by a specially designed permanent magnet erase and conditioning head. The tape then travels past the recording heads and on to the reproducing heads. The recording heads record the video and sound signals on the tape in the form of a flux pattern which corresponds to the signal as described for the color system.

The reproducing heads generate a signal which corresponds to the flux pattern on the tape. The video signal, generated by the video recording head, is coupled to a video reproducing amplifier where amplitude and phase correction is applied. The output from the reproducing amplifier is the complete video signal which may be applied to

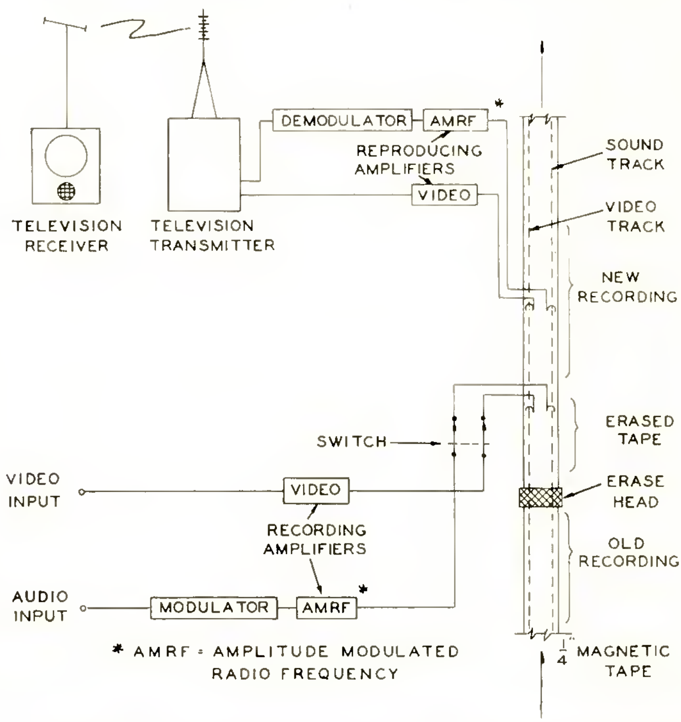

Fig. 6—A schematic diagram of the electronic elements used in recording and reproducing the monochrome video signals and audio signals on magnetic tape.

a television transmitter as shown.

The signal from the audio reproducing head is coupled to a demodulator and amplifier as described in a preceding section.

The complete video and sound signals may then be transmitted in a standard television channel and may be received by conventional black and white television receivers.

Comparison of Photographic Film and Magnetic Tape Systems

In conventional kinescope recording methods, the television picture is displayed on a kinescope. A special motion picture camera photographs the kinescope image and records the program sound. The film negative is chemically processed and the desired number of prints made. In order to reproduce the television signal, another apparatus is required. This apparatus includes a special television camera that picks up the image produced by a motion picture projector. A diagram of the kinescope recording method is shown in Figure 7.

Figure 8 shows a diagram of the magnetic tape recording method. The television picture and sound signals are fed directly to the record-

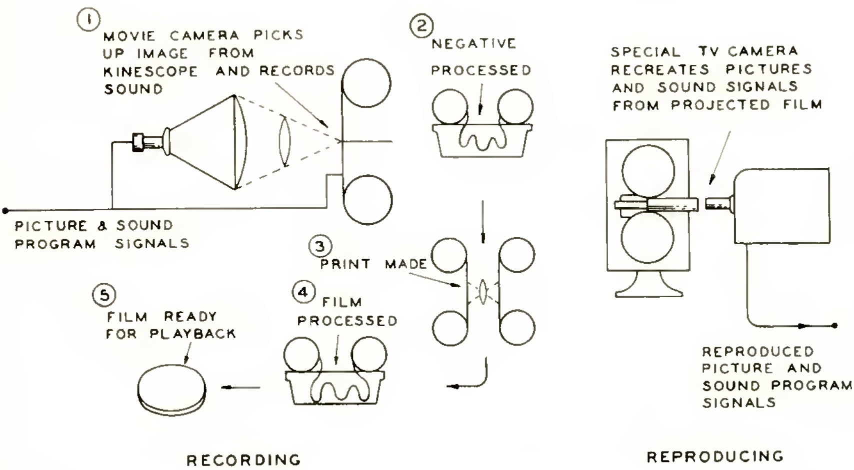

Fig. 7—A schematic diagram of the system for recording and reproducing a television program by means of photographic film.

ing system where the electrical signals are stored on tape in magnetic form. The magnetic tape requires no processing. The program may be reproduced from the tape by using the same unit which recorded it. As in motion picture practice, when a lengthy program is to be recorded and reproduced, two tape transport units with suitable switching may be used.

Description of the System Used for Demonstration

The schematic diagram of Figure 9, shows all of the essential elements used in the demonstrations of the recording and reproduction of color television signals by means of magnetic tape. All of the program material originated in a television studio in New York. The picture was picked up by means of a color television camera. The output of the camera was fed to standard studio-type video equipment to produce a composite video color signal. The output of the microphone was fed to standard studio-type audio equipment. The audio signal was carried by a telephone line from New York to Princeton. The composite video signal was carried by microwave radio relay from New York to Princeton. The audio signal was fed to the modulator of the recording equipment. The composite color video signal was demodulated into the red, blue, and green video signals and the synchronizing signal by means of a color demodulator. These signals were sent to the input of the recording system. The outputs of the synchronizing, red, blue, and green video recording amplifiers and the sound modulator were

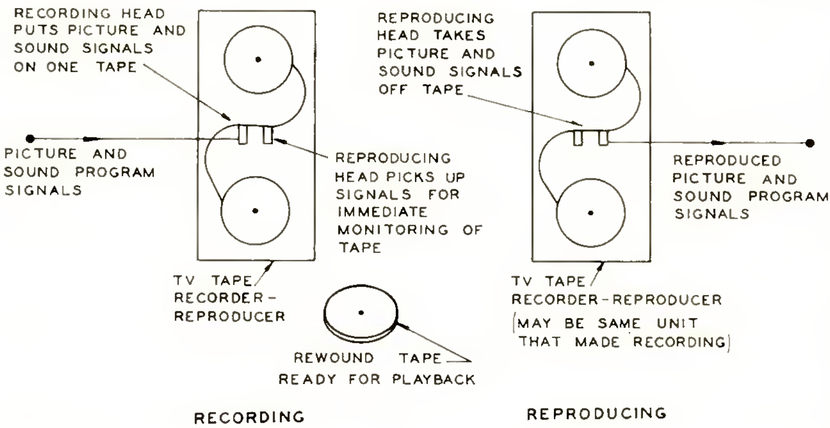

Fig. 8—A schematic diagram of the system for recording and reproducing a television program by means of magnetic tape.

fed to the recording heads. In reproducing, the outputs of the reproducing heads were fed to the synchronizing, red, blue, and green video amplifiers and the sound demodulator. The outputs of the amplifiers correspond to the direct red, blue, and green video signals and the audio signal. The direct signals and the reproduced signals were fed to a switch gear. The output of the switch gear was fed to two color television receivers. Each of the color receivers was equipped with a tri-color kinescope for the reproduction of the picture and a loudspeaker for the reproduction of the sound. By means of the switch gear it was possible to switch both receivers to the direct signals or both receivers to the reproduced signals or one to the direct signal and one to the reproduced signal.

THE DEMONSTRATIONS

Four similar demonstrations were given, one in the morning and one in the afternoon of December 1 and 2. All of the program material originated in a television studio in New York. The actress was Margaret Hayes. The direction was by Herbert Swope, Jr.

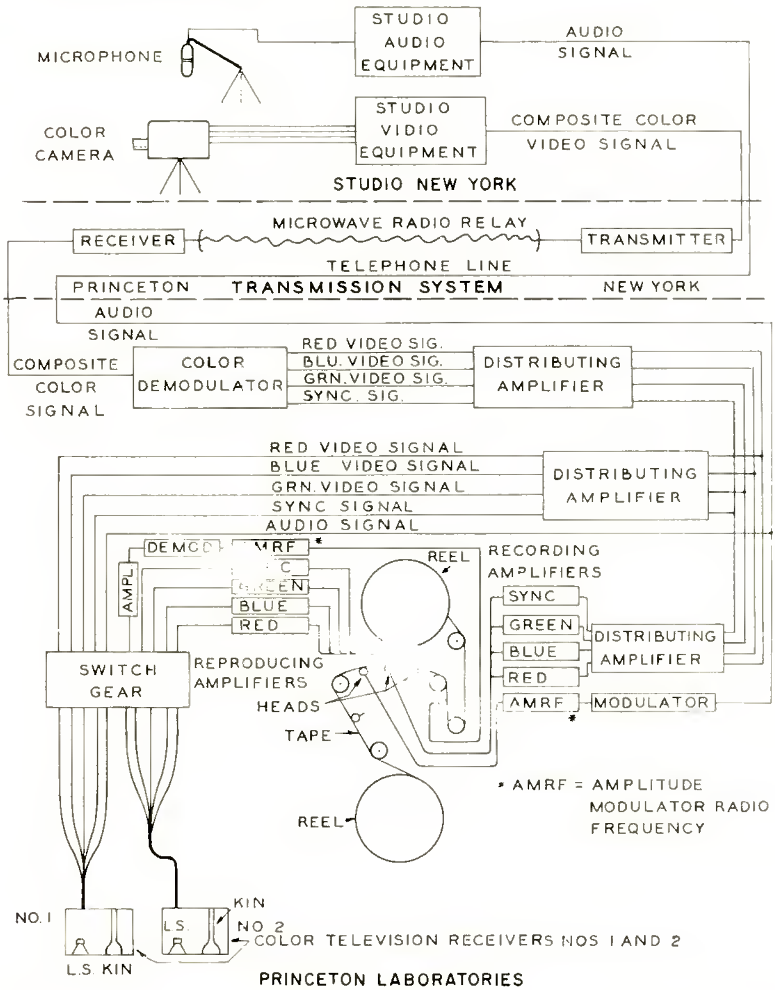

Fig. 9—A schematic diagram of the elements of the system used in demonstrating the recording and the reproducing of television signals by means of magnetic tape.

The following program was presented:

1. The reproduction of a magnetic tape recording of a monochrome

television signal containing an introductory message by Margaret Hayes. The tape was recorded several days before the demonstration.

2. The reproduction of a magnetic tape recording of a color television signal containing a Christmas sketch by Margaret Hayes. The tape was recorded several days before the demonstration.
3. The reproduction of a magnetic tape recording of a monochrome television signal containing a Victorian sketch by Margaret Hayes. The tape was recorded several days before the demonstration.
4. In this part of the demonstration, a live program from the studio, consisting of a Victorian sketch by Margaret Hayes, was fed by microwave radio relay to both receivers. Halfway through the sketch, one receiver was switched to the signal reproduced by the magnetic tape so that a comparison could be made of the direct and reproduced pictures. The delay introduced between the direct and reproduced pictures was the time required for the tape to travel from the recording to the reproducing head. Since this is only 4 milliseconds, the delay is imperceptible. This test demonstrated the fidelity of the reproducing system.
5. The tape recorded in Part 4 was rewound and played back.

Results

In a complex operation such as video recording, it is difficult to derive a figure of merit which will permit an objective evaluation of the system. The opinions of a sufficiently large number of observers, however, give a good indication of the success of the system. The demonstrations described above were shown to several hundred members of the press, industry, and other diverse interests. The magnetically reproduced monochrome and color pictures were considered to be very nearly as good as the pictures received by direct transmission.

In addition to the quality of pictures, the magnetic system has two other notable advantages over the more conventional film recording. These are reduced costs and the fact that instantaneous playback is possible. It has been estimated that the cost of recording a monochrome program on tape will be about 10 per cent of what it would cost to record the same program on film. The corresponding figure for a color program would be about 5 per cent. This difference in cost is due in part to the fact that the tape may be erased and reused a great number of times.

In kinescope recording it is necessary to process the film before the recorded pictures can be viewed. This usually requires several hours. The instantaneous playback feature of the tape system permits simultaneous recording and monitoring of the recorded picture. The advantages of such a feature are self evident.