Television with Cathode-Ray Tube for Receiver†

Special Tube, Called the Kinescope, Eliminates Usual Scanning and Synchronizing Apparatus and Provides Larger Picture with Better Detail

By V. Zworykin*

THE problem of television has interested humanity since early times. One of the first pioneers in this field, P. Nipkow, disclosed a patent application in 1884[1] describing a mechanical scheme for television. It involved a scanning of the object and picture, for which purpose the familiar perforated disk was employed. The scanning disk is used even now, almost without alteration, in all practically-developed schemes of television apparatus. However, Nipkow's ingenious invention could not materialize in his day because of the lack of powerful modern aids—the photo-cell and radio amplification. At present, the rotating disk is giving excellent results within the mechanical possibilities of our time.

Out of a number of other methods which have been proposed for the solution of television by various inventors, the author[2] has been attracted by the application of the cathode ray for scanning purposes. This method was proposed for the first time by Boris Rosing, professor of physics in Petrograd, in 1907[3]. The same reasons which handicapped Nipkow prevented Rosing from achieving practical results. Later Belin and Holweck,[4] Douvillier,[5] and Takayanagi[6] were working in the same direction with various degrees of success, striving to develop television reception by means of cathode-ray tubes. The cathode-ray tube presents a number of distinct advantages over all other receiving devices. There is, for example, an absence of moving mechanical parts with consequent noiseless operation, a simplification of synchronization permitting operation even over a single carrier channel, an ample amount of light for plain visibility of the image, and indeed quite a number of other advantages of lesser importance. One very valuable feature of the cathode-ray tube in its application to television is the persistence of fluorescence of the screen, which acts together with persistence of vision of the eye and permits reduction of the number of pictures per second without noticeable flickering. This optical phenomenon allows a greater number of lines and, consequently, better details of the picture without increasing the width of the frequency band.

This paper will be limited to a description of an apparatus developed in Westinghouse Research Laboratories for transmission by radio of moving pictures using the cathode-ray tube for reception.

In the author's opinion, if a receiver is to be developed for practical use in private homes, it should be designed

Fig. 4. A general view of the television transmitter.

Fig. 3. A view of the projector, showing the vibrating mirror.

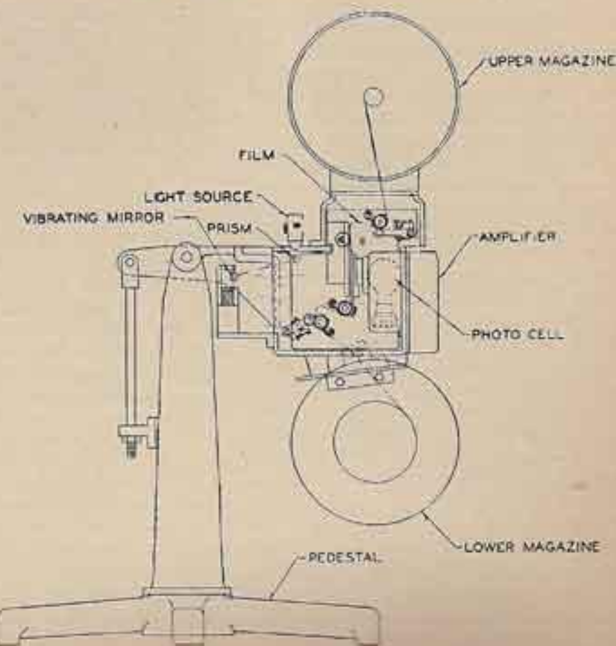

Fig. 1. Details of the modified standard moving-picture projector — a part of the television transmitter — showing the location of the photo-cell, light source and vibrating mirror.

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* *Engineering Department, Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.*

[1] *P. Nipkow, English patent No. 30,105, January 6, 1884*

[2] *U. S. Patent application, March 17, 1924. U. S. Patent No. 1,691,324, July 13, 1925.*

[3] *English Patent No. 27,270, December 13, 1907.*

[4] *Belin et Holweck, Bull. No. 243 de la "Societé Francaise de Physique," p. 35, S, March 1927.*

[5] *A. Douvillier, "Revue General de L'Electricite," p. 5, January 7, 1928.*

[6] *K. Takayanagi, "Jour. I. E. E.," Japan No. 482, pp. 932, Sept. 1928.*

without any mechanically moving parts. The operation of such a receiver should not require great mechanical skill. This does not apply to the transmitter, since there is no commercial difficulty in providing a highly trained operator for handling the transmitter at a broadcasting station.

The Transmitter

The transmitter consists of a modified standard moving-picture projector. The intermittent motion device, the optical system, and the light source are dismantled. The film is caused to move with a constant speed downward, this motion providing the vertical component of scanning.

The construction of the transmitter is shown in Fig. 1. A light source is provided by an ordinary 6-volt automobile lamp. The light is focussed by a condensing lens *L* upon a diaphragm *D* with a small orifice. From there the beam of light emerging through the orifice is reflected from a vibrating mirror *M* and focussed into a sharply-defined spot on the moving film *F*. With the mirror vibrating at a frequency of 480 cycles about a vertical axis, the light spot sweeps the film horizontally. This vibration of the mirror combined with the downward movement of the film causes the light spot to explore the whole surface of the pictures as shown in Fig. 2. After passing the film, the light enters a photoelectric cell *C* which transforms the variations of optical density in the film into a variable electric current.

The vibrating mirror is shown in Fig. 3. It consists of a small steel rod with a vane placed between the poles of an electromagnet. The poles are *U*-shaped and each leg is provided with a coil. An oscillating current of the same frequency as the natural frequency of the rod is supplied to the coils, thus causing the rod and the mirror to oscillate about the axis of the rod. In order not to depend upon the uniformity of sensitivity over the cathode area of the photo-cell, an additional lens L_2 is provided between the film and photo-cell. This lens is so situated that the mirror and sensitive surface are at conjugate foci.

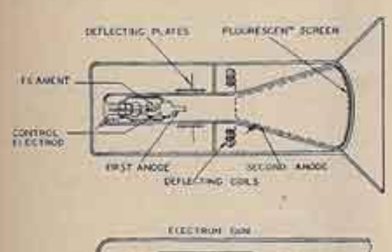

Fig. 5. Details of the special cathode-ray tube described in this article.

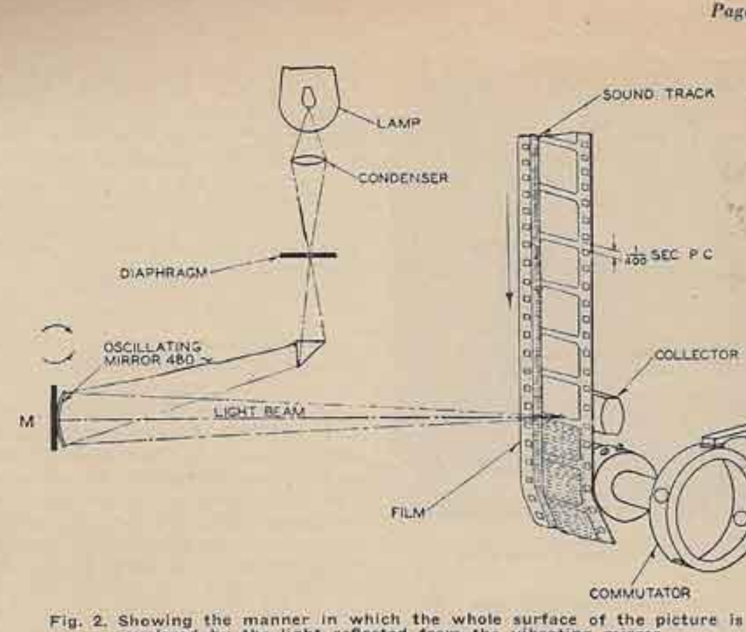

Fig. 2. Showing the manner in which the whole surface of the picture is explored by the light reflected from the vibrating mirror.

Thus, the scanning beam is always focussed upon a stationary spot in the cell.

From the fact that the horizontal scanning is produced by a sinusoidal current, it follows that the velocity of the beam across the picture is not uniform. The velocity in the center is about 57 per cent higher than that of a spot scanning at uniform rate a picture the same width. Before work was started on the machine, it was anticipated that the feature would be found objectionable and correction by optical filter was planned. Practical tests, however, indicate that the non-uniform distribution of light across the picture is not readily apparent to the eye, and, therefore, no precautions are now used. A general view of the transmitter is shown in Fig. 4.

The Receiver

The receiver consists of a cathode-ray tube especially designed for the purpose. The principles of the cathode-ray tube are well-known from their application for oscillographs. In their ordinary form, however, they cannot be used for picture reception, because although they have scanning arrangement in two dimensions they do not have means for varying the intensity of the picture. Moreover, neither of the main types of oscillographs is suited for television purposes. The high potential type which would give a sufficiently brilliant spot, is always operated in connection with a vacuum pump. Such a pump is impractical for a home television receiver. The low potential type of cathode-ray oscillographs is of the sealed-off type but the amount of light available from the screen is far too small. In order to give sufficient brilliancy for the picture of 5-in. size, the tube should operate at least at 3000 volts. For larger pictures still higher voltage is required, since the brightness increases with the accelerating voltage. According to these requirements, a new type of cathode-ray tube was developed. This is shown in Figs. 5 and 6. An oxide-coated filament is mounted within a controlling electrode *C*. The cathode beam passes through a small hole in the front part of the controlling element and then again through a hole in the first anode *A*. The first anode accelerates the electrons to a velocity of 300 to 400 volts. There is also a second anode consisting of a metallic coating on the inside of the glass bulb. This second anode gives to the electrons a further acceleration up to 3000 or 4000 volts. The velocity of the electrons at this voltage is about one-tenth that of light. An important function of this second anode is also

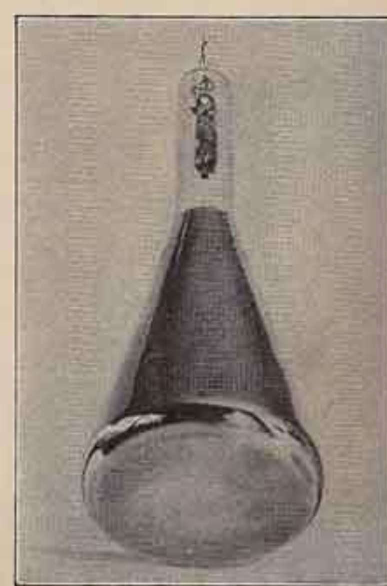

Fig. 6. The special cathode-ray tube, or Kinescope, as it is called.

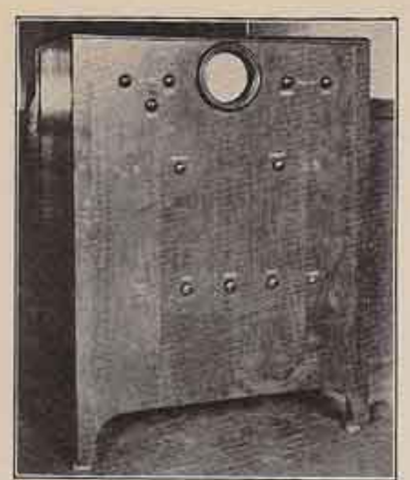

Fig. 7. A view of one of the laboratory television receivers.

to focus electrostatically the beam into a sharp spot on the screen. The target wall of the bulb is about 7 in. in diameter and is covered with a fluorescent material such as willemite prepared by a special process so as to make it slightly conductive. Conductivity is required to remove the electrical charges from the screen supplied by the electron beam. This tube will be referred to hereafter in this paper as the kinescope.

The beam of electrons can easily be moved across the screen either by an electrostatic or an electromagnetic field, leaving a bright fluorescent line as it passes. For this purpose a set of deflecting plates and a set of deflecting coils are mounted on the neck of the kinescope, outside the tube. The plates and coils are adjusted in the same plane, so as to give vertical and horizontal deflection at right angles to each other. As a result of the location of the deflecting elements between first and second anode, the deflecting field is acting on comparatively slowly moving electrons. Hence the field strength required is much less than that which would ordinarily be used to deflect the beam under the full acceleration of the second anode voltage.

The brightness of the line can be controlled to any desired extent by a negative bias on the controlling element. The bias controls the mean intensity of the picture whose lights and shadows are superimposed upon this mean intensity. It is evident that if we apply to this controlling electrode the amplified impulses from the transmitter and at the same time deflect the beam to synchronism with the motion of the light beam across the picture on the film, the picture will be reproduced on the fluorescent screen. Figs. 7 and 8 show a general view of two types of receivers.

Synchronization

If separate channels are available for each of the synchronizing signals, the problem of synchronization of the receiver with the transmitter is very simple. For horizontal scanning, it is necessary only to transmit the scanning frequency, operating the mirror as a sinusoidal voltage and to impress it on the deflecting coils of the kinescope. The cathode beam will follow exactly the movement of the light beam across the film.

For the framing or picture frequency, a voltage is generated at the receiving end and merely controlled by signals from the transmitter. A condenser is charged at constant current through a current limiting device, such as a two-electrode tube, so that the voltage at the condenser rises linearly. The deflecting plates of the kinescope are connected in parallel to this condenser, and, therefore, when the condenser is charging, this cathode beam is deflected gradually from the bottom to the top of the fluorescent screen at constant speed. This speed is regulated by the temperature of the filament of the charging tube to duplicate the downward movement of the film. An impulse is sent from the transmitter between pictures, which discharges the condenser, quickly returning the beam to the bottom position, ready to start upward and reproduce the next picture.

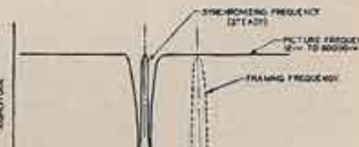

Fig. 10. The spectrum used to modulate the radio-frequency carrier.

Fig. 8. The television receiver built into a Radiola cabinet.

For transmission of the complete picture, three sets of signals are therefore required: picture signals, horizontal scanning frequency, and impulses for framing. It was found that it is possible to combine all of these sets of signals into one channel. In this case the photo-cell voltage of the transmitter is first amplified to a level sufficiently high for transmission. There is then superimposed upon the series of high audio-frequency impulses lasting a few cycles only and occurring when the light beam passes the interval between the pictures. (Fig. 9.)

The picture frequencies together with the framing frequencies are then passed through a band-eliminating filter, which removes the picture component of the same frequency as that of horizontal scanning. Following this, a portion of the voltage which drives the transmitter vibrator is impressed upon the signals, passed through the filter, and the entire spectrum is used to modulate the radio-frequency carrier. (Fig. 10.)

At the receiving station the output of the local radio receiver is amplified

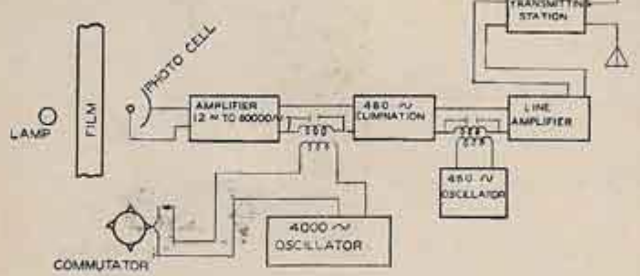

Fig. 9. Sketch showing the general transmission arrangement.

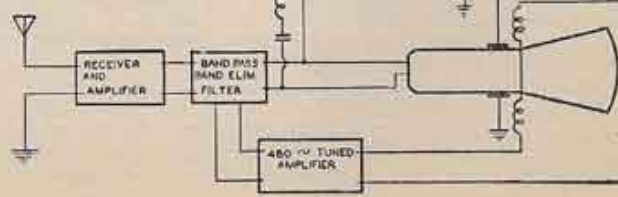

Fig. 11. Sketch showing the general reception arrangement.

and divided by a band-pass band-elimination filter into two parts: one the synchronizing frequency, and the second the picture frequency plus the framing frequency. The synchronizing frequency is amplified by a tuned amplifier which supplies current to the deflecting coils of the kinescope. (Fig. 11.)

The picture and framing frequencies are applied directly to the control electrode of the kinescope.

The same voltage which modulates the light is impressed upon a band-pass filter, which is tuned to the frequency of the a-c. voltage used for the framing impulses. The output of this filter is amplified, rectified, and used to unbias a discharging triode which is normally biased to zero plate current, and which takes its plate voltage from the condenser which provides the vertical scanning voltage.

Thus, the picture signals and both synchronizing and framing frequencies are transmitted on one channel, and fully automatic synchronization is obtained.

The amplification problem in this case does not differ from that of the amplifier for mechanical television of the same picture frequency. The frequency band for which the amplifier should be constructed is much lower for the same number of lines due to the smaller number of pictures per second.

Conclusion

Those who are accustomed to the conventional scanning disk type of television notice a number of differences in the appearance of the picture as viewed on the end of the cathode-ray tube. The picture is green, rather than red (as when a neon glow tube is used). It is visible to a large number of people at once, for an enlargement by means of lenses is unnecessary. There are no moving parts, consequently, no noise. The framing of the picture is automatic; and it is brilliant enough to be seen in a moderately-lighted room.

Technically, the kinescope type of receiver presents added advantages. The high-frequency motor for synchronization, together with its power amplifier, is not required. The power required to operate the grid of a kinescope is no more than that for an ordinary vacuum tube.

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