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The practical operation of a complete television system‡

By ALLEN B. DUMONT*

MANY writers and philosophers have envisaged the day when it would be possible for people to look into a magic crystal and see events taking place in some other part of the world. Today, thanks to the many technical advances that have taken place, it is not only possible to *see* events at a distance but to *hear* them as well.

For the past fifty years, one system after the other has been introduced for transmitting pictures from point to point. Some of the systems attempt only to transmit still images such as photographs, drawings or written messages, recording them at the receiving point in facsimile form. Other systems aim to transmit simultaneously the actual events taking place, in animated form, utilizing suitable apparatus at a remote point to receive and reconstruct such events so that they may be seen by a group of persons. Both classes of systems may employ either wire lines or the radio ether as the transmission medium. That class of systems in which the events are transmitted instantaneously over the air is the one which holds the greatest fascination and likewise represents the more difficult problems. Commonly known as television, and more specifically as radiovision when employing the radio transmission medium, this class is of particular interest today when a new entertainment vehicle is now in the making.

In this paper a practical system for accomplishing radio television or radiovision will be described as well as demonstrated. Before going into details, however, it might be well to state the general problems and to give a brief résumé of the inventions which have made a practical television system possible.

The Nipkow Disc

To start with, we must have a suitable method of analyzing the event to be transmitted. The most satisfactory method for this purpose at present makes use of the Nipkow disc, invented by Nipkow in 1884. This consists of a disc in which a number of holes are punched to form a spiral. The disc is mounted on the shaft of a motor. For picking up outdoor events where the intensity of illumination is considerable, the image is usually focused on the disc by means of lenses, so that it may be analyzed in its reduced form. Fig. 1 shows the Jenkins outdoor pickup camera in which this principle is employed. For studio pickups, however, it is generally advantageous to reverse this process. Instead of focusing the image on the disc, a powerful beam of light, properly guided by the disc, is projected on the subject to be analyzed. An example of this system is shown in Fig. 2, which depicts the Jenkins flying spot pickup. The lenses in front of the disc may be shifted to take care of a larger or smaller field, while the adjustable mirrors in front of the lenses permit of shifting the light beam up or down for any desired height of subject. After the event has been analyzed, it is necessary to translate the varying light waves picked up, into varying electrical impulses. This translation is accomplished by means of a light sensitive or photoelectric cell. As the light waves fall on the cell, the current passing through the cell is proportionately varied.

Going back a bit in television history, it is interesting to note that only as recently as the past five years have suitable photoelectric cells been available. For television work, the photoelectric cells must be sufficiently sensitive and possess a satisfactory frequency response. Prior to five years ago, the available photoelectric cells were either too sluggish to transform faithfully the high-frequency light variations into corresponding electric variations, or lacked the necessary sensitivity. At present the potassium hydride cell and the caesium sub-oxide cell are available for this work, and, while by no means the ultimate cells, they are successfully employed with proper associated apparatus. We are

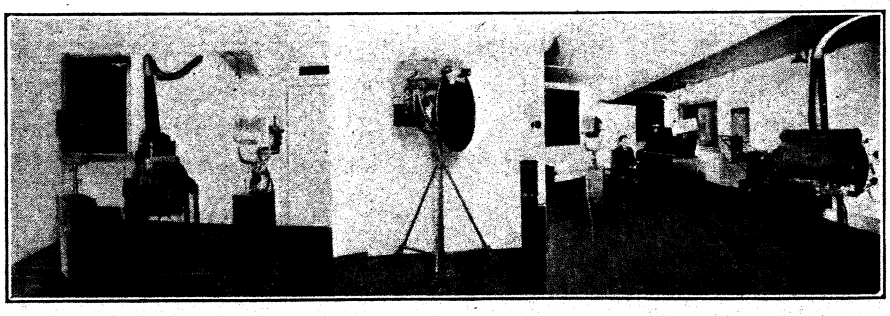

Fig. 1. Fig. 2. Fig. 3.
Fig. 1. Jenkins outdoor pickup camera. Fig. 2. Jenkins flying spot pickup. Fig. 3. Direct pickup studio.

‡ *Presented before the Club, April* 8, 1931

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now employing the DeForest type 668 photoelectric cells of the caesium suboxide type in our work.

The Amplifier

Having obtained weak electrical variations as the result of the light translation process, it is now necessary to amplify those variations several million times without distortion. This step is accomplished by a carefully designed resistance-coupled amplifier employing a number of Audions. After the electrical variations are amplified, they are put to work modulating or regulating a radio transmitter similar to the usual broadcast transmitter but designed to pass the far wider band of frequencies required for good pictorial detail in television work.

We have, so far, briefly discussed the method employed in picking up the event and starting it on its way through the ether. No mention has been made of the voice or sound pickup apparatus, frequently employed in combination with television programs, but since such apparatus is quite similar to that employed in sound broadcasting work, no further mention is required.

In order to visualize the layout of a sight and sound television transmitter, we refer to Fig. 3, depicting the direct pickup studio, Fig. 4 showing the film and synchronized sound apparatus.

In the station studio a reception room is provided for artists who are to appear before the direct pickup camera. In this room a radiovisor or "looking-in" device is provided so that the artists may see for themselves the programs on the air and how they are being received. Looking through a window on one side of the reception room, the artists and studio visitors may see the other artists as they are being televised. A loudspeaker is also installed in this room, operated by the voice transmitter.

Pickup Studio

Adjoining the reception room is the direct pickup studio. As the voice as well as the actions of the artists must be picked up in this studio, the treatment is along the same acoustic lines as that of a modern sound broadcasting studio. The flying spot pickup apparatus as well as the two photoelectric cell units are much in evidence. Each photocell unit comprises four photoelectric cells mounted on cushioned supports and placed at the focal point of individual spherical mirrors that collect and concentrate the reflected light from the subject. As an integral part of the unit, there is the head amplifier which amplifies the current from the photoelectric cells and feeds it to the main picture amplifier. The main purpose of the head amplifier is to raise the level of the current from the photocells sufficiently so that the ratio between this current and any extraneous or parasitic currents will be such as to overcome any streaks or lines in the picture. The photocell pickup units are mounted on rubber-tired wheels so that they may be moved about readily. Also, the mounting is such that they may be raised or lowered to follow the motions of the artist. The photocells are screened electrically to prevent any feedback from the transmitter. It might be well to state at this point that extreme care must be taken in the layout of the unit to prevent microphonics. We have found that in addition to the cushioned supports of the photocell, sound-absorbing material behind the photocell mounting helps considerably. If only the picture is being transmitted, without sounds to contend with, no difficulty is experienced with microphonics.

The flying spot pickup makes use of a 3.7 kw. arc mounted on a movable

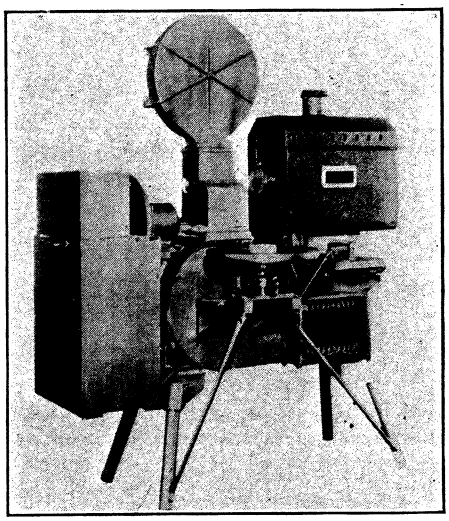

Fig. 4. Film and synchronized sound apparatus.

stand, together with the scanning disc and motor. As already mentioned, several lenses make possible the televising of either closeup or long shots. Mirrors in front of the lenses enable the operator to shift the scanning beam up or down in following the artist in a close-up shot. The studio includes a radiovisor so that an artist or the pickup operator may occasionally "look in" and check up on the program being transmitted.

Sound Pickup

Next to the direct pickup studio is the mechanical pickup room, containing the film-pickup apparatus and the synchronized sound accompaniment. A non-synchronous sound pickup is also provided and is employed when films without their own sound are being transmitted. The main picture amplifier is also in this room. This amplifier takes the signal either from the direct pickup head amplifiers or the film pickup amplifiers and increases it so as to feed directly into the modulator tube of the transmitter. The head and main amplifiers have a practically flat characteristic from 15 to 100,000 cycles. The main picture amplifier increases the voltage of the incoming signal approximately 2,000,000 times.

In the film pickup apparatus, the film feeds through continuously or without the intermittent motion of the usual motion picture projector. The holes in the scanning disc are arranged in the form of a circle rather than as a spiral. At present we are employing sound on disc, but a film pickup has been designed and is being built, which will permit us to employ either sound-on-film or sound-on-disc presentations. Also, at the present time, it is necessary to employ special records, because all records available are for 24 pictures a second, whereas we are transmitting only 15 pictures per second. Our new pickup is so designed that standard 24 pictures per second recordings can be run through at any desired speed for perfectly synchronized sight and sound presentations.

The voice and the picture transmitters are contained in a separate room adjacent to the film pickup room. Special precautions have been taken to prevent modulation of the voice transmitter by the picture transmitter, or vice versa. The picture transmitter operates on a frequency of 2035 kc., and the voice transmitter on a frequency of 1604 kc.

Control Room

The control room is so located as to face the three rooms already mentioned, namely, the direct pickup studio, the film pickup room, and the transmitter room. Windows are provided so that the control room operator can see into each room at all times.

In front of the control room operator is a control board. Before describing the apparatus in this room, it might be well to point out the greater number of details to be watched in the radiovision station, as compared with the usual sound broadcaster. Following are the duties of the various operators at Station W2XCD.

Control Operator

1. Monitor picture over line for quality.
2. Keep picture level constant.
3. Synchronize film and direct pickup.
4. See that film and sounds are synchronized.
5. Monitor pictures over air for quality.
6. Monitor sound or voice for quality.
7. Keep sound or voice level constant.
8. Shift from films to direct pickup.
9. Shift from microphone to phonograph or synchronous phonograph turntable.

Fig. 5. Fig. 6. Fig. 7.
Fig. 5. Radio receiver. Fig. 6. The radioviser. Fig. 7. Scanning drum and mechanical shutter radiovisor.

Radio and Film Pickup Operator

1. Check operation of picture transmitter.
2. Check operation of voice transmitter.
3. Operate film pickup.
4. Change phonograph records.
5. Operate synchronous record drive.
6. Keep film pickup in focus.

Direct Pickup Operator

1. Keep artists in field of direct pickup.
2. Keep direct pickup in focus.
3. Keep photocell units adjusted.
4. Check arc and change carbons.

Announcer and Studio Director

1. Make announcements.
2. Instruct artists.
3. Locate artists and instruments.
4. Have acts ready to go on.
5. Shift properties.

It will be noted that there are twenty-four duties listed. Nine of these duties are necessary in sound broadcast operation, namely: Monitor voice for quality; keep voice level constant; check operation of voice transmitter; change phonograph records; make announcements; instruct artists; locate artists and instruments; have acts ready to go on; and shift properties. It will also be noted that the control operator must keep the other operators informed as to what is going on and what is desired so that the program may move along without a hitch.

The control panel consists of two televisors employed as monitors for both the picture on the line and the picture on the air. Beneath the line monitor is a level indicator and beneath this is a level control for the picture over the line. By varying the level control the signal to the modulator tubes is varied. Beneath the air monitor are switches to turn on or off the televisor. Between the air and line monitors is a frame control which is simply a switch controlling the scanning motor on the film drive. In order that the "lookers-in" may only have to frame the picture once, we start the direct pickup scanning apparatus before the program starts and allow it to run throughout the program. The air and line monitors are then framed by snapping on and off the switches under the air monitor until they are in frame. We now have both monitors in synchronization with the direct pickup scanner, and they are bound to stay in step until the station is closed down following the completion of the program.

Pickup

When we shift from direct pickup to films, the frame control between air and line monitors is turned on and off until the picture is framed, before the picture is put on the air. This calls for one adjustment at the studio instead of an individual adjustment at each receiving location.

Beneath the frame control is the voice level indicator, and beneath this is the voice level control. To the left of the central panel just described is the voice control panel. The four divisions vertically are, in turn, the order control, the main control, the order lamps and the answer lamps. The same arrangement also applies to the picture control which is to the right of the central panel. With regard to the voice controls, the four divisions horizontally are, in turn, the voice carrier, the studio microphone, the non-synchronous pickup, and the synchronous pickup. On the picture controls the three divisions are, in turn, the picture carrier, the flying spot pickup, and the film pickup. This control arrangement enables the control operator to direct and to monitor the programs. He can indicate to the various operators what is desired, and he is notified when the order has been carried out. Signal lights in the three rooms notify the operators what is desired and also what is going on.

While further improvements are being made in the control room, the arrangement referred to has proved satisfactory in maintaining a smooth flow of program features.

Reception

To receive the radiovision programs, we have developed several models of radiovisors and also several models of television receivers. Without going to details, it may be stated in a general way that the receiving problem is practically the reverse of the transmitting problem. The modulated radio wave is received on a radio receiver of a sensitivity of about 10 microvolts per meter, capable of passing frequencies of from 15 to 100,000 cycles with fairly flat characteristics. In this regard, we have developed an inexpensive receiver that can be assembled by the average experimenter. It is of the tuned r-f. type with a resistance-coupled audio amplifier including a power tube, and also a self-containing power pack for a-c. operation.

Really good half-tone pictures may be obtained with this receiver when employed in conjunction with one of the several models of radiovisors which we are producing. The receiver appears in Fig. 5. We have also developed a radiovision receiver of the superheterodyne type which has somewhat better characteristics but is considerably more expensive to produce.

It might be interesting to note at this point that the proper receiver has been a minor problem. At no time have we been unable to duplicate the results obtained in the studio.

The Radiovisor

The radiovisors employed in combination with the television receivers, all operate with the DeForest type 601 neon glow lamp. The small model radiovisor is sold assembled and unassembled, being in stripped form or without an enclosing cabinet. It provides a two-inch square picture. See Fig. 6. The motive force of this radiovisor is furnished by an eddy current motor comprising four electromagnets acting on a copper disc fastened to

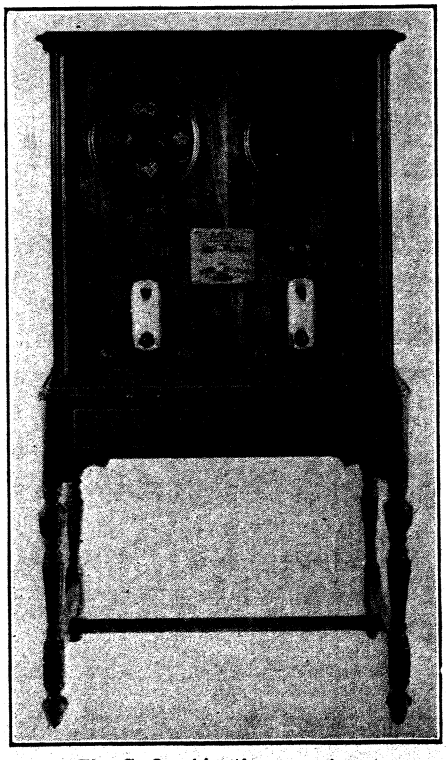

Fig. 8. Combination sound and picture receiver.

the scanning disc which is mounted on a ball-bearing shaft. Synchronism is obtained by means of a toothed rotor that rotates between a pair of magnets energized by the 60-cycle current. The radiovisor will keep in step only with stations on the same power system. However, due to the close regulation of frequency which is maintained today on power systems, it is feasible to maintain approximate synchronism on signals from a station outside the power system employed. Where fully automatic synchronization is desired on signals from stations outside the power system zone, a simple synchronizing device is added. This unit comprises a laminated 60-tooth rotor which fits on the motor shaft, together with an electromagnet fed by the 1200-cycle component filtered out of the intercepted carrier wave. The 1200-cycle is a dominant frequency in the present 60-line 20 pictures per second signal (60 x 20=1200). The receiver is provided with an additional tube to amplify the 1200-cycle component so as to feed the automatic synchronizer. It will be noted that while the usual 60-cycle current is used to keep the radiovisor approximately in step with the intercepted signal, the 1200-cycle synchronizer adds the necessary acceleration or braking effect so as to complete the synchronization. With this automatic synchronizer, it is possible to hold the signals from stations several hundred miles distant in perfect step for an entire evening.

A larger radiovisor providing either a 4 x 4 or an 8 x 8 picture, depending upon the lenses employed, is also being manufactured. This model does not employ a scanning disc. Instead, it makes use of a scanning drum and a mechanical shutter, permitting a relatively large picture to be obtained from an 8-inch drum. At present, this model is made up with a synchronous motor (see Fig. 7). Another model now in production contains practically the same mechanism as the stripped radiovisor models already referred to, with automatic synchronizer. Still another model, shown in Fig. 8, provides the highly desirable combination of voice receiver with loudspeaker and picture receiver with radiovisor.

The radiovisors just described are no more difficult to operate than the present-day broadcast receiver. They are intended for home use. For theatre purposes, where a larger picture must be thrown on a screen so as to be seen by a large group of people, several experimental models have been made up. One model employs a lens disc and a crater lamp, while another employs a lens disc and a Kerr cell.

The programs now on the air which can be received in the New York metropolitan area are as follows:

Station	Location	Programs	L.P.P.	P.P.S.
W2XCD	Passaic, N. J.,	syn. films and direct pickup....	60	20
W2XCR	New York City,	syn. films and direct pickup..	60	20
W3XK	Washington, D. C.,	syn. films and direct pickup	60	20
W1XAV	Boston, Mass.,	direct pickup.....	60	20
W2XR	New York City,	silhouette films.....	60	20
W2XBS	New York City,	call letters of station.....	60	20

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CONTRIBUTORS to the Proceedings, by bearing in mind the points below, will avoid delay and needless expense to the Club.

1. Manuscripts should be submitted typewritten, double-spaced, to the Chairman of the Papers Committee.* In case of acceptance, the final draft of the article should be in the hands of the Chairman on or before the date of delivery of the paper before the Club.

2. Illustrations should invariably be in black ink on white paper or tracing cloth. Blueprints are inacceptable.

3. Corrected galley proofs should be returned within 12 hours to the office of publication. Additions or major corrections cannot be made in an article at this time.

4. A brief summary of the paper, embodying the major conclusions, is desirable.

5. The Club reserves the right of decision on the publication of any paper which may be read before the Club.

* For 1931 the Chairman of the Papers Committee is Mr. F. X. Rettenmeyer, 463 West Street, New York City.