The Scanning Disc, Television's Canvas

The Simple Device by Which a Moving Scene of Action Is Built Out of Radio Impulses Before the Observer's Eyes

By C. P. Mason

OF the four devices which are required to adapt the art of radio to television, two—the photoelectric cell and the neon "flash" lamp—are the "eye" and the "paintbrush," respectively, of the radio television apparatus. Two others, the scanning mechanisms of the transmitter and the receiver, respectively, must be considered together; for they must perform similar duties, though perhaps in very different ways, mechanically.

While it is very probable that new devices may be invented to take the place of the scanning discs, which will be as much superior to the latter in operation as the vacuum-tube receiver is to the old "coherer," the work which they perform must be the same—that of breaking up into points the image which is to be televised, and restoring it again, point by point, into a perfect whole at the receiving end.

The reason for this is found in the nature of the human eye. We *hear* in one dimension—one impulse at a time. A single point, moving back and forth with varying speed, will convey sounds to the ear—as shown by the old, but simple, "string telephone." The most complex sounds can thus be conveyed in their fullness over a single wire circuit, or a single radio carrier-frequency.

NATURE'S ELABORATE APPARATUS

But our sight demands thousands of simultaneous impulses to build up a picture. Thousands of nerves carry them from our eyes to the brain, which thus receives at one instant the impressions of form, color and distance.

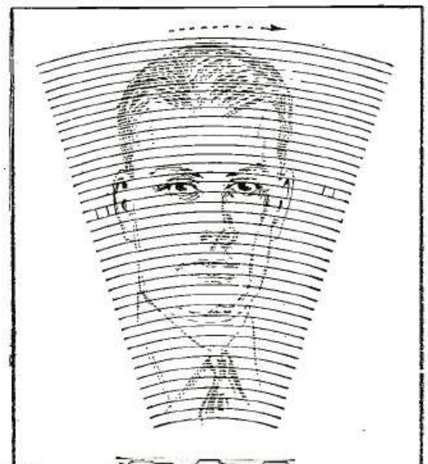

Fig.1

The fast-flying holes divide the image into slightly-curved strips—exaggerated here. Each dark spot—like the eyes in this picture—causes a drop of current in the photoelectric cell and a darkening of the flash lamp's plate.

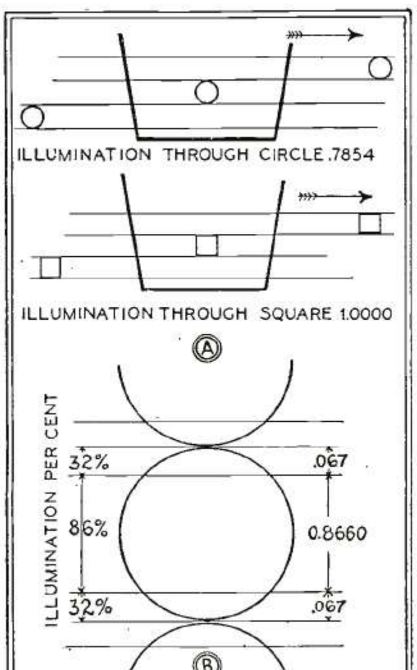

FIG.2

A circle passes only 78% as much light as a square—at its edges only a third as much. Dark bands are thus caused by the use of circular holes.

It is conceivably possible that, by utter disregard of expense, we might build equally-complicated apparatus for television. Thousands of miniature photoelectric cells, corresponding to the "rods" and cones at the back of the eye, would receive as many fragments of the scene before our transmitting device. Thousands of miniature flash lamps would reproduce them as an enormous whole at the receiving end. But all the radio transmitters now in the world would be needed to send such a picture; all the radio channels at present available would be needed for its transmission; and comparatively few of the complex receivers needed could be assembled out of all now in existence.

We are therefore compelled to break up the picture into little pieces, as we have said before, and send it bit by bit. This is easily done in sending a photograph by radio, when we can take, comparatively speaking, unlimited time; but in television we are limited also by the fact that we must reproduce the entire picture with all its changes as fast as they can occur.

"PERSISTENCE OF VISION"

Fortunately, however, we are aided by the fact that the eye, with all its breadth of vision, is comparatively slow in discarding impressions. A flash of lightning lasts for an imperceptible fraction of a second; but it will leave the impression of its path on the eye for a minute. If, therefore, we can build a picture out of points of light, it is necessary for each one to be in its place but a slight instant to give the impression that it is standing there. Everyone knows the impression of a continuous curve given by whirling a single spark in the dark.

If, therefore, we could whirl this point over a regular track, one line so close to another that the space between them could not be seen, back and forth from the bottom to the top of a considerable area, we could apparently fill the space, with the effect of an unbroken illuminated surface. This task exceeds the deftness and speed of the best-trained hand, but it is not impossible with machinery. Now then, if we can also *vary the brilliancy of this spark*, certain parts of our illuminated surface will be darker than others; if we can turn it on and off quickly enough, we will have patches of blackness and patches of light. This is what the television apparatus of the present accomplishes.

THE NATURE OF SIGHT

While we are accustomed to think of the images present to our eyes as even, unbroken, uniform scenes, such is not the case. There are minute holes in our field of sight, which is composed of a multitude of little impressions fitting closely together. At twenty to thirty inches from our eyes a crack 1/100th of an inch wide will vanish, unless it is illuminated much more brightly than its edges.

Advantage is taken of this fact in making illustrations for printing purposes. They are photographed through screens which are ruled at distances of from 1/60th to 1/300th of an inch apart. For ordinary magazine work, such as this, divisions of from 1/110th to 1/120th of an inch are used. The picture thus made presents the effect of surfaces of light and dark grays over an unbroken

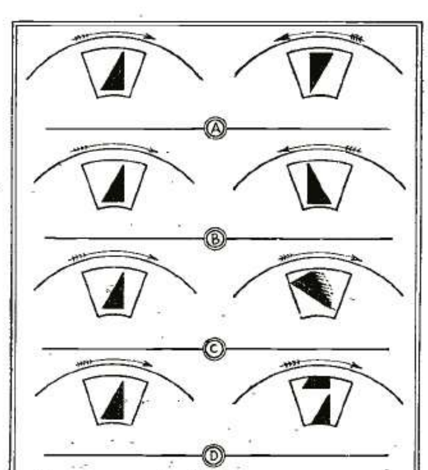

FIG.3

If the receiving spiral is run backwards, the image is upside down (A); if it is left-handed, the image is mirror-like (B); if its speed is wrong, the image is twisted, blurred and drifts (C); if it is steadily out of phase, the image is out of "frame" (D).

area; but examination of the reproductions of photographs in these pages ("halftones") will show that they are composed of dots of varying sizes, each occupying the same amount of space and separated from its companions. Where they are large and close together, the surface appears nearly black; where they are small it is nearly white. Yet, viewed at ordinary reading distance, no single dot is visible separate from the others.

If, therefore, we can break up a scene before our television transmitter into similarly small dots, and reproduce each according to its corresponding brightness, in the same *relative position* at our receiver, we can reproduce the picture with such accuracy that it will be acceptable to the eye. If we can do this at the rate of about fifteen times a second, we can present a continuous moving picture at the receiving end. This is television.

THE PERFORATED DISC

We have, in the photoelectric cell, a device which will emit electric current proportioned to the amount of light which falls upon it. We have in the neon flash lamp a device which will emit light in proportion to the current passing through it. We have radio amplifiers, transmitters and receivers which will reproduce small current variations as very large ones, and this through almost unlimited space. We have only to adopt a mechanism which will break up the image—"scan" it—at the transmitting end, and put it together again at the receiving end. It is not necessary that the mechanism at both ends be alike—in fact, in several television systems, it is not—but it is necessary that each part of the picture corresponding to one transmitted impulse shall be reproduced in identically the same *relative* position as that part of the image which caused the impulse.

Many mechanical systems have been made for this purpose; but the first one proposed, forty-odd years ago, even before the birth of radio, is the simplest and involves the least difficulty in operation. It is simply a disc, perforated spirally by small holes. Each of these holes is as far from the next one as the *width* of the picture; the distance of each from the center differs from that of the next by the *width of the hole* itself.

Let us suppose that, with the aid of a camera lens, we reduce the image at the transmitter to an inch wide. The disc is placed between this image and the photoelectric cell and starts to turn. (See Fig. 1.) The hole in the disc which is farthest from the center crosses the image, in almost a straight line, at the top. If it enters upon a part of the image which is bright, a ray of light passes through into the photoelectric cell, which emits a throb of current. This is amplified and transmitted to the receiver, where it lights up the neon lamp.

From a photograph of a subject being televised by the Ives system. The dark bands caused by the edges of the circular holes are visible.

The scanning disc at the receiver is turning in exact synchronism with that at the transmitter. Just as the hole in the latter crosses the edge of the image, that at the receiver comes into the "frame" at the top of the plate of the neon lamp—and the observer sees a point of light which is moving very rapidly.

"DECOMPOSING" THE IMAGE

The transmitting disc strikes a dark spot in the image; the photoelectric cell, relieved from the bombardment of light, stops its emission of current, and this reversal is felt electrically all the way to the receiver. The neon lamp goes out, and the moving point of light disappears under the eye of the observer. The process is repeated, and the progress of the hole in the first disc across the televised image is registered in a broken line of alternating light and darkness before the eye at the receiver. *The spinning disc is the canvas upon which a pencil of light is painting the received picture.*

At the instant the first hole clears the image at the transmitter, the second one starts just below the first, and records the variations of light and darkness in a second line; this is repeated until the last hole has run across the bottom line of the image. If we should take one of the illustrations in this magazine, and cut it across from side to side into many narrow strips, then paste them together end for end, we would have the picture "decomposed" into a single line of light and dark spots which, obviously, could be telegraphed or sent by radio. This is what the scanning mechanism at the transmitter does. We have described here the picture as composed of light and darkness (like a "black-and-white" drawing) but many shadings are possible by varying the current at the neon lamp.

The precisely-corresponding mechanism at the receiver is also passing an endless series of holes over the rapidly-flickering neon lamp, each hole tracing a single line of alternating light and darkness, and the lines are so close together that the eye cannot see between them. Every fifteenth of a second, the picture is completed at the bottom, and the outermost hole starts at the top of the frame to "paint" a second picture, which the transmitter is beginning to send.

It will be noticed that the bottom of each picture is reproduced 1/15th of a second later than the top. This differs from the motion-picture method by which each picture is taken simultaneously, with a perceptible interval between. In the moving pictures, we may see the "stroboscopic" effect by which an automobile's wheels turn backward, apparently. In the television apparatus, we might see the automobile's wheels persistently keep a foot or so ahead of its body—unless some method can be devised of fixing an instantaneous image be-

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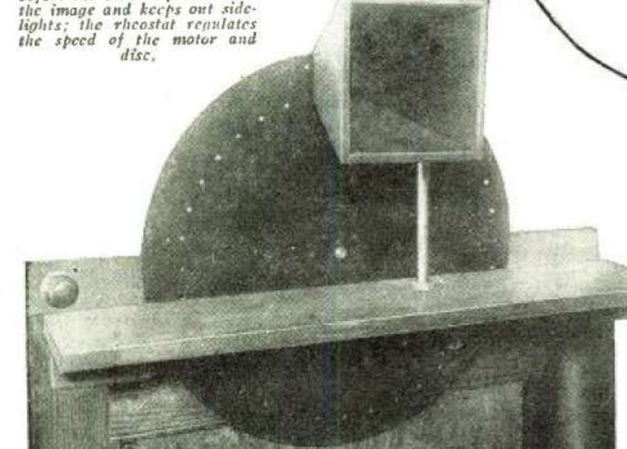
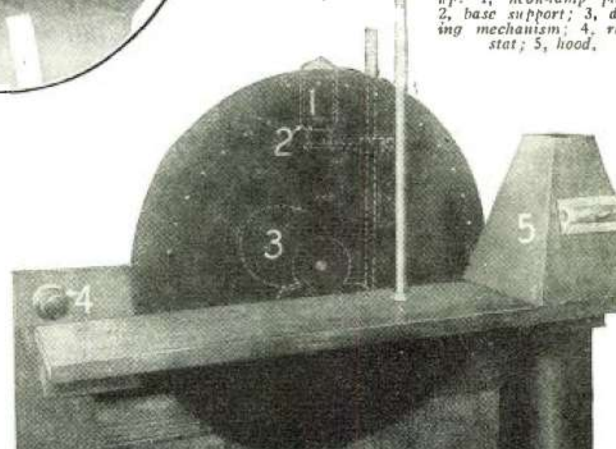


An experimental receiving television set-up. The hood before the disk helps to define the image and keeps out side-lights; the rheostat regulates the speed of the motor and disc.



The disc whose size is shown at the center has small square holes through the larger white dots, which are the aluminum exposed. (Courtesy of Lexington Television Corp.) Below, the arrangement of the set-up: 1, neon-lamp plate; 2, base support; 3, driving mechanism; 4, rheostat; 5, hood.

The Scanning Disc

(Continued from page 223)

fore the television transmitter for the period necessary to transmit it.

PROBLEMS OF THE APPARATUS

So far as we have dwelt on the simple theory of the television apparatus; but there are many practical problems which make its operation more difficult, or the theory would have been put into practice many years ago.

If we should adjust the scanning disc at the transmitter to the object glass of a telescope, with proper precautions, we could transmit very readily an image of the disc of the sun, with a large sunspot or two, if they were in sight. With a very large telescope, we could send pictures of a region of the night sky, with its stars. But scenes on the earth are not lit as brightly as the sun or stars, and it is exceedingly difficult to get enough reflected light from a spot a quarter of an inch in diameter, through a hole 1/48 of an inch in diameter, to produce the slightest effect on a photoelectric cell.

It is true that we are not limited to a small disc at the transmitter; we can use a larger one than is possible for reception, if it is magnified *exactly in proportion.* But the amount of energy sent out from the photoelectric cell is exactly proportioned to the amount of light falling on it; and is very small at the best.

Enormously-powerful lights have been turned on the objects to be televised; but if they are human beings, there is a limit to the amount of light and heat they can endure, and they are poor reflectors at best. Another solution of the difficulty, which is meeting with much favor, is that of using the scanning disc to pass a beam of very intense light, which travels over the object televised. It dwells on a single spot only 1/35,000 of a second at a time, so that it can be borne by a human subject; and its reflection can be received by several very large photoelectric cells at once. The problems, however, which would arise if this method were to be used on objects at varying distances from the photoelectric cell are many; because of the various angles of reflection of the light. It is probable that the apparatus which will be necessary to take outdoor and moving scenes will be electrically, if not mechanically, far more complicated than that at the receiver.

DESIGNING THE DISCS

We are also faced with the problem of the size of the holes in our scanning mechanism. The smaller they are, the finer the picture which we will produce, and the better its detail—IF they will pass the needed amount of light to register on the photoelectric cell. But, as we increase the number of these holes, we increase the number of impulses per second which our apparatus must register, we increase the speed which is required of our photoelectric cell—and we increase the width of our radio channel. A 200-kilocycle channel has been authorized for television; this gives us 13,333 modulating vibrations for each television image, or about the number of distinct impulses that are required for dots in one square inch of a halftone in RADIO NEWS.

It would also require, for an image one inch square, 116 holes in a scanning disc 37 inches in diameter at the receiving end; and this revolving at 900 revolutions per minute, to take full advantage of this channel with the system we have mentioned. Such an image, of course, could be magnified several times, if the neon lamp gives sufficient light.

It is difficult to make very small *square* holes in a metal plate; nevertheless, the value of a square hole, as compared with a round one, may be seen by comparing their area. A square hole contains 27 per cent more area than a circle of the same width, and will pass, therefore, 27 per cent more light. (See Fig. 2.) With circular holes, dark bands are visible on the enlarged images. On page 223 they may be seen on the face of a young woman who was being televised in demonstrations at Schenectady; this is reproduced from an unretouched photo. With square holes, this defect would be overcome; and some experimenters make round holes slightly oversized, so that they will lap. This, however, to some extent confuses the distinctness of the various lines, if the overlap is sufficient to compensate for the loss of light by the roundness of the holes.

It will be seen that both discs must revolve very truly on their centers, and that the holes must be bored very accurately. A vibration of as much as a hundredth of an inch, in a 50-hole disc, would be fatal to the picture. For that reason a home constructor cannot attempt to drill his own disc, unless he has measuring tools of great precision. A motor of great steadiness, also, must be used.

GETTING THE DISCS INTO PHASE

It is necessary, not only that the scanning mechanisms shall be constructed with similar proportions, but that they shall be operated exactly alike, with reference to the television impulses.

For instance, suppose that our receiving disc, with the same spiral of holes, is run *backward* compared with the sending disc. The image will not be reversed from right to left, as in a mirror—it will be reproduced upside down! The backward-running disc builds up the picture *from the bottom to the top*. (Fig. 3A.)

Suppose that we have a counter-clockwise spiral of holes in the sending disc, and a motor turning it accordingly. The motor at the receiving end runs clockwise—as common motors do—and its disc is drilled accordingly. Then the picture will be reversed, as in a mirror—from right to left.

In fact, this is just what happens if the discs are alike on the side turned toward the person being televised and the side turned toward the observer. *The photo-electric cell is the electric eye, which takes the place of the observer's;* and if it is placed back of the disc, instead of in front of it, the image will be reversed. (Fig. 3B.)

Suppose that our two discs are both properly placed, at the beginning of a transmission, but that the receiving disc is running very slightly faster toward the right. The image in reproduction will be shifted to the right and down; it will be twisted out of shape toward the lower right, and it will move downwards to the right at a rate depending on the extent to which the motors differ in speed. This is because the series of points which reproduce the image is moving further and further along in their course down the image, and toward its right, at every revolution. (Fig. 3C.)

When the image drifts down to the bottom, and sinks below it at one corner, the bottom of it will reappear at the opposite corner above. It is obvious that if the sending disc were just beginning on the top of the image when the middle holes of the spiral on the receiving disk were passing the plate of the neon lamp, the received image would be like a moving picture out of its "frame"—the top half and bottom halves reversed.

ADJUSTMENT OF SPEED

In the early experimental transmission of photographs by wire, very odd results were obtained before the synchronization of the apparatus was accomplished. The upper right corner of a photograph would be reproduced in the lower left corner and *vice versa,* before the correct adjustment was made. Similar effects must be expected at first in television. While it is possible to send synchronizing impulses which will automatically regulate the receiving machinery (mechanism suited to this purpose will undoubtedly be a feature of the finished commercial receiver) the complicated controls which it involves are unnecessary for the experimenter in these early days of television.

It is apparent that it will be desirable to establish some standard geometrical image to be transmitted for preliminary adjustment of the receiver. An excellent one for this purpose would be a white X, running from corner to corner of the field and crossed at its center. Practice will very quickly teach a "looker-in" to adjust the speed of his motor to bring such a figure back to shape.

It is probable, however, that each broadcast station will adopt its own special figure for this purpose; such a figure gives a characteristic note during its transmission, which would identify the station for a listener-in through a loud speaker. After a reasonable period for adjustment of the image, which will enable the receiving operator to bring his motor into phase with that of the transmitter, the reflecting surface carrying the figure at the studio will be withdrawn, and the "program" acted before the "electric eye." It will be transmitted through the ethereal medium, received, and the "electric paintbrush" will write it in rosy fire on the black rim of the scanning disc—the canvas of television.

HE TUNED IN CUBA INSTEAD

TEACHER (to geography class): "What was Columbus trying to find in 1492?"

BRIGHT PUPIL: "A short-wave hook-up to get India."—*A. E. Hauser.*