Radio Vision Demonstrated in America

By H. WINFIELD SECOR

FOR the past several years RADIO NEWS has been describing various television systems, all more or less in an incomplete state. That described by Mr. Secor, however, is a real development, by means of which clear and recognizable images are received. We are sure all our readers will be interested in reading the details of its operation.—EDITOR.

APRIL 7, 1927, will always be a memorable day in the annals of science, for on that day, before a group of invited guests, the experts of the Bell Telephone Laboratories demonstrated in New York the first, practically perfect reproductions of the living image of Mr. Herbert Hoover and other speakers at the Washington end of a telephone circuit; and secondly, similar images transmitted by radio from Whippany, N. J., thirty miles away.

To make the subject more interesting, it is well to state at the outset that at the transmitting end of the circuit the image of the moving object was reproduced in two forms. In the smaller receiving instrument the size of the image is about 2½x2 inches, and here the likeness was very perfect; Mr. Hoover's face appearing in a photographic reproduction against a rose-pink background. This color is due to the use of neon gas in the glow-tube, which is placed behind a revolving disk in the small machine. The larger reproduction apparatus, used to show the built-up image before the assembled guests, had a screen approximately 24 inches wide by 36 high. Here also the general color of the background was pink, due to a grid of evacuated glass tubing containing neon gas, which formed a surface on which the picture was built up by means of 45,000 light-flashes sweeping over the screen every second.

HOW IMAGE IS TRANSMITTED

Referring to the diagram (Fig. 1, A, B and C), we shall first consider how a concentrated light-beam from an arc lamp is caused to sweep across the object, a human face for example, in a series of small spots and at the rate of 900 light-flashes per second. The light from the arc is concentrated through a condensing lens upon the back of the rotating perforated disk shown in the figure. There are 50 small holes drilled through this disk, these being laid out in a spiral; it rotates eighteen times per second, or 1080 revolutions per minute. As the three stages of the process, (Figs. 1A, B and C), demonstrate, and thanks to the slit or diaphragm placed behind the disk, one hole only

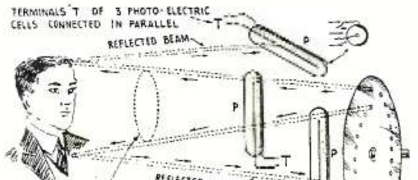
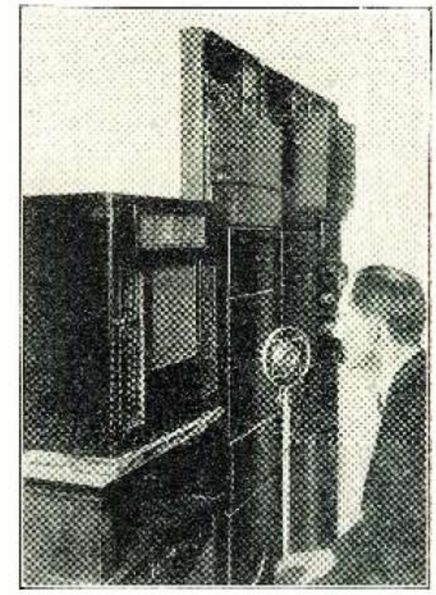


FIG. 2

How the extreme positions of the succeeding pencils of light exploring the object at the transmitter are enabled to pick up the whole image. The solid angle of vision is made up of rapidly moving beams of light.

is permitted to pass a light beam at a time. Look at Fig. 1A; then note that at B the second hole in the spiral has reached the vertical position and a small beam of light passes through and sweeps across the image in the second lower position. Look at Fig. 1C, and it becomes evident that No. 3 hole has reached the vertical position, and the third pencil of the beam sweeps across the image in the third position from the top of the face or other object at the transmitter.



Close-up of microphone and the three large photo-electric cells behind grille doors. the light rays coming through the square opening between the latters. The apparatus in the background comprises amplifiers and other devices used in the transmission.

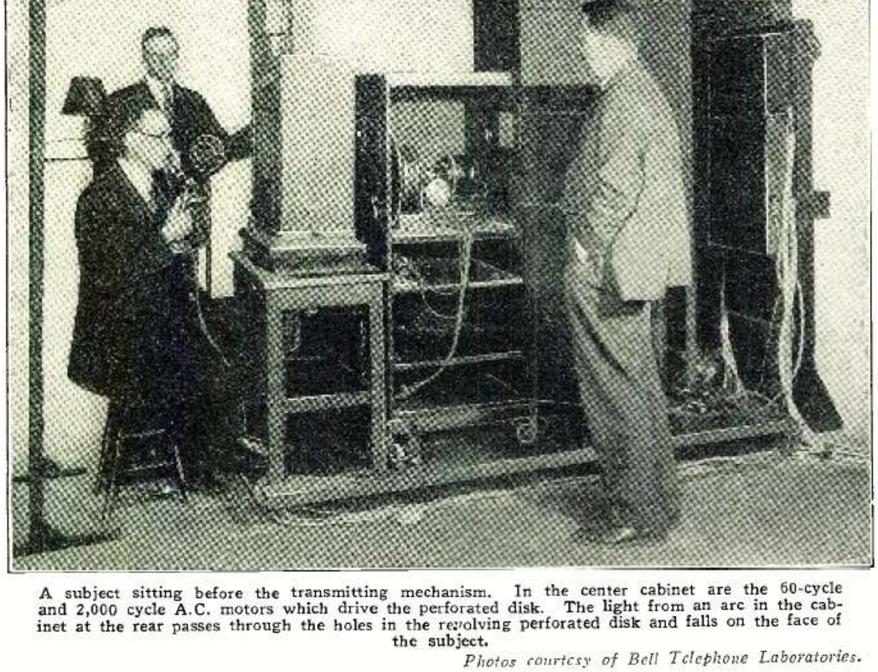
This action is repeated, as becomes clear, so that when the 50th or innermost hole of the spiral on the disk comes into position before the diaphragm, a pencil of light pass through, sweeping the bottom of the image. This is clear on inspection of Fig. 2.

It is well known that the motion picture of today is possible only because of the *retention of vision* by the human eye. That is, sixteen slightly-different pictures are jerked, one after another, in front of the lens and flashed on the theatre screen every second. Due to the "lag" of the human eye, the individual pictures overlap and give the illusion of a perfect moving image. The same thing occurs in this television system; but instead of flashing each light across the face sixteen times per second, the engineers who developed this system of television in the Bell Telephone Laboratories cause the light-beams to travel across the image at a speed of eighteen times per second. As there are fifty light-beams, due to the fifty perforations in the rotating disk at the transmitter, there are 18 times 50, or 900 light-targets traveling across the image every second!

It might be thought that such a strong concentrated pencil of light, when it traveled across the eyes, for instance, would prove unbearable; but such is not the case. The effect when looking toward the opening in the transmitting machine is like looking into a camera lens with a fairly strong light behind it. The light beams change place so fast that the final result is a slightly flickering bluish light which seems to bathe the face or other object at the transmitter.

The next very important point to note is that, as the light-beam (at Fig. 1A for instance), moves across the top of the man's face, a ray of light with a constantly-changing angle of incidence is reflected from the face and impinges on some part of the three large photo-electric cells used in this perfected system of television.

Looking at Fig. 2 we see how the three large photoelectric cells of new design are arranged in front of the image. In the pictures you will note that these three photoelectric cells, each of which measures about



A subject sitting before the transmitting mechanism. In the center cabinet are the 60-cycle and 2,000 cycle A.C. motors which drive the perforated disk. The light from an arc in the cabinet at the rear passes through the holes in the revolving perforated disk and falls on the face of the subject.

Photos courtesy of Bell Telephone Laboratories.

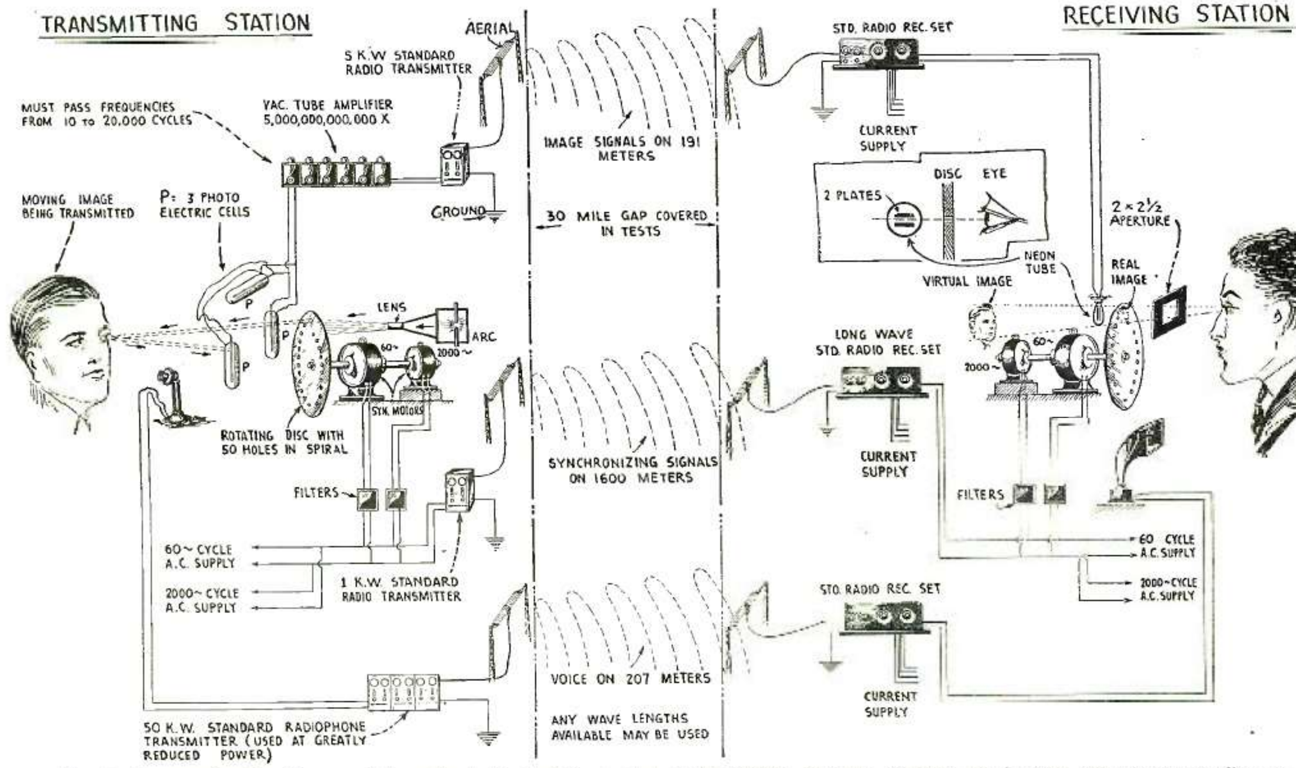


Fig. 3. A comprehensive diagram of the entire radio television apparatus; the subject, an image of whose face is being transmitted by radio, appears at the left, while the person observing the transmitted and reproduced image appears at the right. The perforated disk causes rapidly moving targets of light to sweep across the face; the reflections fall on photo-electric cells, P. The light fluctuations are thus transformed into minute electric currents, and these are amplified 5,000,000,000,000 times. The radio image signals are picked up by a standard receiving set, and after amplification, the image signals pass into a neon glow-tube placed behind a second revolving disk, driven in exact synchronism with that at the transmitter. The observer looking through the small aperture sees the image built up on a plane behind the whirling disk. The voice is transmitted and received in usual manner; while a third radio wave transmits synchronizing signals for the motors.

14 inches long and 4 inches in diameter, are placed inside three metal boxes provided with wire-grille doors to protect them from breakage. The doors are kept shut, even when the machine is in operation. These photoelectric cells, which were devised under the direction of Dr. Herbert E. Ives of

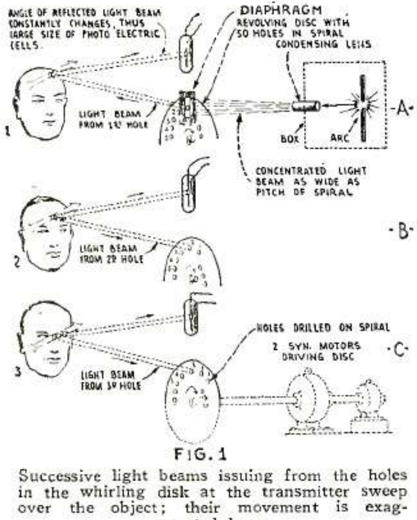


FIG. 1

Successive light beams issuing from the holes in the whirling disk at the transmitter sweep over the object; their movement is exaggerated here.

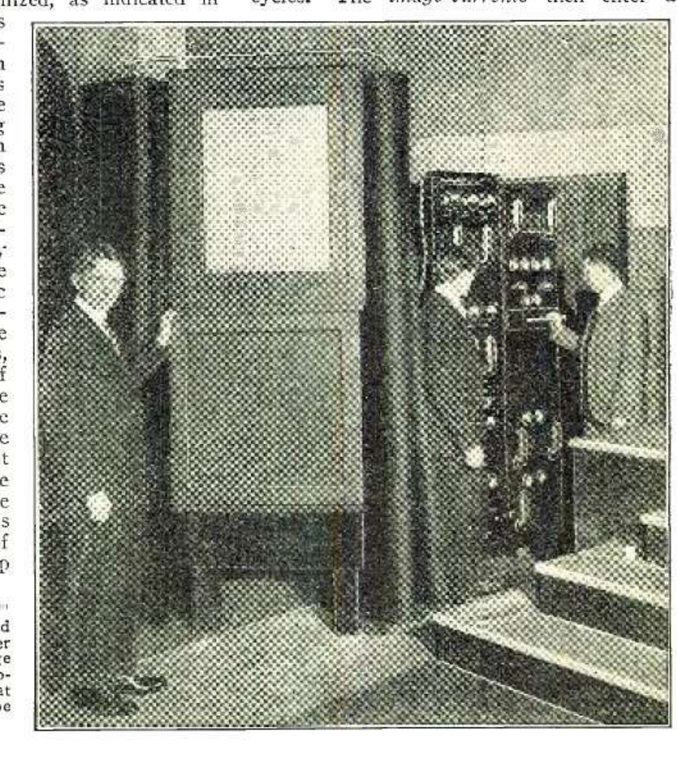
the Bell Telephone Laboratory staff, comprise a central electrode running the length of the tube, while the rear inside half of the tube all the way up is coated with a metallic deposit. The tubes are then exhausted and the proper gas introduced. These photoelectric cells have practically no lag whatever, and their action is therefore instantaneous.

As Fig. 2 shows, there is a constant *solid angle* of vision, filled with a constantly-moving series of light-beams. As becomes evident, the angles of the reflected beams will be constantly changing as the initial beams shoot forth from the apertures in the rotating disk. This is one of the main reasons why such large photoelectric cells are required. These are undoubtedly the largest ever used. The terminals of the cells are connected in parallel, so that their action is all concentrated in one circuit, as becomes clear from an inspection of the diagram, Fig. 3.

RADIO TRANSMISSION OF IMAGE

Instead of using three telephone circuits, in the radio transmission three different wavelengths were utilized, as indicated in Fig. 3. Looking at this we see how a concentrated light beam from the arc shoots through one of the holes in the revolving disk, which is driven by two synchronous motors; thence to the face, from which the light beams are reflected progressively upon one of the three large photo-electric cells. By the instantaneous action of the photo-electric cells, every gradation of tone or color upon the face or other image encountered by the spot of light as it sweeps across the face is transmitted to the receiver. For this reason the spots of light, as they build up the image at the receiving instrument, give a very faithful reproduction of the image at the transmitter.

A special vacuum-tube amplifier of several stages serves to magnify the very minute fluctuating currents coming from the photoelectric cells five thousand, thousand, million (5,000,000,000,000) times. It is interesting to note that this vacuum-tube amplifier had to be designed to amplify all frequencies from ten up to twenty thousand cycles. The *image-currents* then enter a



The glass screen and front of the loud-speaker horn used. The large image reproduced appeared on the screen at the top. Vacuum-tube amplifier at right.

5-kilowatt standard radio transmitter of the vacuum-tube type, and leap across the thirty-mile gap between Whippany and New York City on a wavelength of 191 meters.

In New York a standard receiving set picks up the 191-meter image-signal, and after amplifying it sufficiently, passes it into a neon tube, placed directly behind a second revolving disk having the same speed and number of perforations as the disk at the transmitter station. The person at the receiver simply looks through a small aperture at the swiftly-moving pulses of light as they become visible through the whirling holes in the spinning disk. He sees the real image build up apparently at the position of the disk, while the virtual image is of course considerably behind the disk, as the drawing shows.

mitter and receiver, this motor being designed for a frequency of 2,000 cycles per second. As will be seen, a slight variation at this frequency is much less noticeable than it would be at 60 cycles; and so, between the two motors, the synchronous speed is maintained practically uniform at all times.

Note particularly how the 2,000-cycle alternating current supply is connected in

ceiving set, and then passed into a loud speaker placed alongside of the picture-reproduction mechanism.

REPRODUCTION OF IMAGE

Sufficient has been said to give an insight as to how the image is reconstructed or built up by light pulses, rapidly following one another at the receiving instrument.

At the right: The large exhibition screen, built up of a continuous length of glass tubing, along the rear walls of which are cemented 2,500 tin-foil segments. The tube is filled with neon gas; light spots appear opposite each segment when electrically energized.

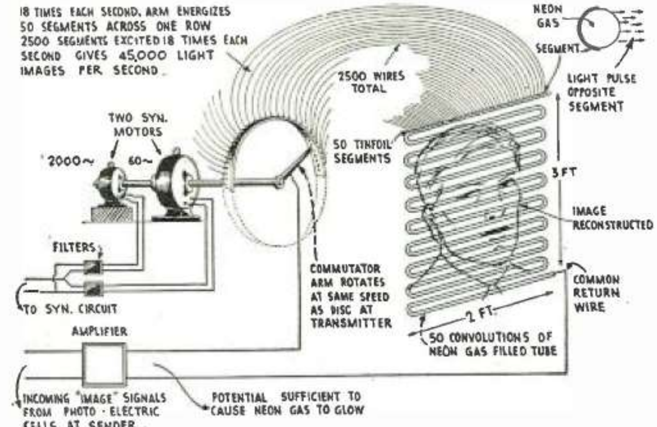


FIG. 5

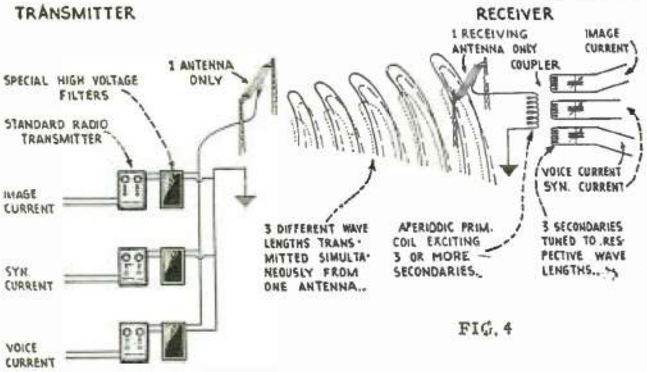


FIG. 4

Left: Simplified system, whereby three transmitters, tuned to different wavelengths, are joined to a common antenna through suitable filters.

Referring to Fig. 3 once more, we note that the neon glow-tube, placed behind the revolving perforated disk, is about the size of a 75-watt electric light bulb; it contains two flat metal plates a short distance apart. The detail sketch in the upper right-hand corner of Fig. 3 shows the relative position of the eye, the perforated disk and the neon glow-tube when viewed from the top. Usually a curtain is drawn around the person looking through the aperture. The remarkable thing is that no screen of any kind is here used, and we might say the person at the receiving instrument sees the likeness

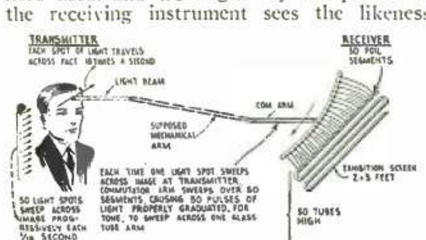


FIG. 6

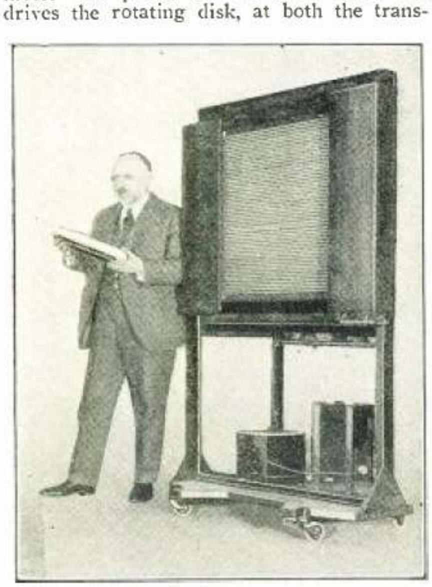
How the image on the large receiving screen is built up. 45,000 light pulses flash across it every second.

of the person at the transmitter actually reconstructed in the air.

HOW SYNCHRONISM IS ESTABLISHED

It required much special research work and clever designing of the synchronizing circuit and motors used for this perfected television scheme; and to Mr. H. M. Stoller is due the credit for the special synchronizing means finally adopted.

This very important part of the system of television has several new aspects. Due to the high speed of the light-image transmission and reception, quite necessary to produce a practically perfect image at the receiving end of the line, it was soon found that ordinary 60-cycle synchronous motors would not do. Synchronous motors, as is well known, have the habit of *hunting;* that is, they will swing a little below or a little above their true normal speed at times. To reduce the degree of this variation resulting from hunting, a second synchronous A.C. motor was placed on the same shaft that drives the rotating disk, at both the trans-



Dr. Herbert E. Ives is shown holding one of the giant photo-electric tubes. At his left, the screen on which the large television image was reproduced.

parallel to the 60-cycle A.C. supply circuit. Suitable filters made up of inductances, resistances and condensers are placed in each pair of leads running to the synchronous motors, as Fig. 3 shows. Where television takes place over three telephone circuits, the action is quite simple; while with radio transmission, the insertion of a standard transmitter of the vacuum-tube type is necessary to transmit the synchronizing signals to the receiving instrument.

In the demonstration recently conducted, these synchronizing signals were transmitted to the receiving station by a one-kilowatt transmitter, on a wavelength of 1,600 meters. It should be noted at this point that no such high power is necessary, and all of the units were operated at considerably less than normal capacity. The reason that these particular transmitters were used is the fact that they happened to be available and handy at the experimental station.

In radio transmission of the television image, the sychronizing signals were picked up on a standard receiving set fitted with suitable inductances and condensers for tuning at 1,600 meters; and the amplified synchronizing signals were then fed into the circuit supplying the 60-cycle and 2,000-cycle A.C. to the two synchronous motors driving the revolving disk in the receiving instrument.

HOW VOICE WAS TRANSMITTED

Referring to Fig. 3, we see that the voice of the subject before the television transmitter at the receiving station was picked up by a standard microphone, fed into a standard radiophone transmitter (a 50-kw. set was here used at greatly reduced power), from whence it leaped across the 30-mile gap to New York on a wavelength of 207 meters.

The wavelengths used were purely arbitrary and chosen because of their freedom from interference at this time. Any wavelengths available can be used, so long as the three are sufficiently separated to be tuned in clearly and without any overlapping at the receiving station.

The radio waves carrying the voice were picked up on a third and independent antenna amplified by means of a standard re-

The image at the receiving instrument is built up by reproducing the same number of light pulses per second, as those flashed across the face or other object at the transmitter. That is, the eyes of the person gazing through the aperture at the receiver witness 900 flashes of light per second, each of which carries the proper tone of some part of the image. The revolving perforated disk at the receiver rotates at the same speed as that at the transmitter, and like it has also fifty perforations. One of the wonderful things accomplished at this juncture is the perfection of the synchronization between the two revolving disks. Another very important contribution to the science of television is of course the special photoelectric cells used at the transmitting instrument.

SIMPLIFIED RADIO TRANSMISSION

Where the picture is transmitted and received over telephone circuits, four circuits would ordinarily be required; but, thanks to the ingenuity of the scientists who worked on this problem in the Bell Telephone Laboratories, this has been reduced to three circuits by combining the 60-cycle and 2,000-

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cycle alternating current circuits feeding the synchronous motors. Where regular wire circuits are to be used, there can be a still further reduction to one full-metallic circuit of two wires; as it is perfectly feasible now to transmit the three distinct currents for the image, for synchronism, and for the voice, by utilizing three carrier-frequencies. These must have a value above an audible frequency, in order not to interfere with the voice transmission. With voice transmission over special telephone circuits, the engineers have for several years been able to transmit six telephone currents over one circuit simultaneously, by using carrier-currents of different frequencies; in the case of multiplex telegraphy they are now transmitting ten different signals over a two-wire circuit simultaneously by the use of suitably graduated carrier-currents.

Looking at Fig. 4 we see how it is possible to simplify the radio transmission of picture images by this or any other system, and where three different wavelengths have to be transmitted simultaneously for the image, synchronism and voice transmission. As pointed out in an interview of the writer with one of the scientists of the Bell Telephone Laboratories, who is familiar with this remarkable achievement by their engineers, it is possible, if occasion required it, to connect the three standard radio transmitters shown in Fig. 3 to a single antenna as shown in Fig. 4. This can be accomplished by connecting special, high-voltage filters comprising suitable inductances, condensers and resistances, in series with the respective radio transmitters and the common aerial and ground. In the recent demonstration and tests leading to it, it was found much cheaper and more convenient to use three separate transmission antennas and also three separate and independent receiving antennas. These special filters required where three radio transmitters are to be connected to one antenna, are quite expensive, and ordinarily it does not pay to use them.

There are several ways in which the three wavelengths being transmitted simultaneously can be picked up and passed into the three independent circuits, for the image, synchronism and voice circuits. One of the simplest ways of picking up and sharply tuning the three desired wavelengths is shown in diagram at Fig. 4. Here an aperiodic primary winding on a special coupler transfers the aerial energy to three or more independently tuned secondary windings. All the operator has to do is to tune the respective secondary circuits to the desired wavelengths. This is the system used for reception of transatlantic radio telegraph messages. The more elaborate system of Dr. A. Hoyt Taylor of the Navy (see page 1421) can be used; as well as numerous others which have been patented and described in the technical press.

DETAILS OF LARGE-IMAGE SCREEN

These details have probably made fairly comprehensible how at last it has become possible for a person at one end of a telephone or radio circuit, to actually see the moving image of the person at the other end, but the mind fairly staggers at the results obtained in reproducing a larger television image on a screen measuring two by three feet, such as that demonstrated before the audience which attended the introduction of this system of television.

Imagine for a moment what a problem the engineers had to solve, when it became evident that to properly build up the image of a face for example, on a screen as large as two by three feet, that not less than 45,000 light images or pulses per second, must occur! This meant, for one thing, that the synchronism between the two rotating elements at the transmitter and receiver must not be out of step by more than one ninety-thousandth of a second. As one of the scientists connected with this work pointed out to the writer, if either one of the revolving elements slipped out of synchronism by one-half a cycle, it would result in a *negative* image being received instead of a *positive*. In other words, you would see a white man with a black face and white hair. This problem, therefore, was one of the hardest ever placed before electrical engineers.

Other phases of the research problem were encountered in the development, by Dr. F. Gray, of the large neon tube used for the production of an image large enough to be viewed by a considerable audience. The development and use of such a tube, with its present total of 2,500 external electrodes, required the construction of a current-distributor from which 2,500 wires, like a gigantic optic nerve, extended to the tube. When the front of this tube is observed, its whole area appears to glow at once; so rapidly does the instantaneous spot travel from one electrode to another that the eye does not appreciate its successive positions.

Referring to Fig. 5 we see that, instead of the revolving disk previously used for reproducing the image, we here use the two synchronous motors on a common shaft to rotate a commutator arm, and this arm passes over no less than 2,500 compactly-arranged metal segments, cemented along the rear walls of the 50 convolutions of the neon tube. These are correctly and progressively energized. Note that the incoming image signals, instead of passing into a single glow-tube, as in the simple apparatus for the small image, are now amplified to a sufficiently high potential to cause the neon gas in the large grid-tube to glow at the spot corresponding to any one of the 2,500 tinfoil electrodes.

The man who built the commutator needed lots of patience, a good hot soldering iron, and also plenty of time. He had to connect the 2,500 insulated wires running from as many tinfoil segments, cemented on the back of the neon tube, in exact order to their respective segments around the stationary commutator frame. When he had connected 50 wires from the 50 segments along the top glass arm for example, he then repeated this with the 50 wires coming from the 50 tinfoil segments along the second leg of the neon tube, etc. The action taking place in the magnified image on this large exhibition screen is made a little clearer perhaps by looking at the mechanically analogous diagram in Fig. 6.

Referring to Fig. 6 for the moment, let us note that as one of the fifty pencils of light at the transmitter sweeps across the face for example, it, by analogy, causes a mechanical arm, corresponding to the commutator brush, to sweep across the fifty metal segments, and has therefore caused fifty spots of light of varying intensity or tone to sweep across this top leg of the glass neon tube. As the commutator has 2,500 segments, it will be seen that, while the fifty light beams passing through the transmitter disk cause 900 spots of light to traverse the face or other object each second, the number of light pulses, all properly graduated reproduced on the large glass tube screen will be 45,000. In other words, 2500 light pulses appear 18 times every second on the 2 x 3-foot exhibition screen; this is sufficient to give a satisfactory image, owing to the retention of vision by the human eye, as described in the first part of this article.