Transmission of Pictures over Wires

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For many years, scientists have been interested in the possibilities offered by the electrical transmission of pictures over wires. As early as 1847, an attempt was made at picture transmission and this was followed by several other experiments. Naturally, these early methods were all rather crude, but they served as a basis for further investigation. The research laboratories of the American Telephone & Telegraph Company and the Western Electric Company took up the problem some years ago and met with considerable success, but no news of the experiments reached the public until the company officials were satisfied that a method had been devised which would satisfy practical requirements and, at the same time, be of real commercial value.

In May, 1924, the first public demonstrations were given and the practicability of the method for newspaper work was at once established. Pictures were then sent between Cleveland and New York, and further demonstrations followed at the time of the Republican and Democratic national conventions. Experiments continued over longer and longer distances and, early this year, transmitting and receiving sets were placed in San Francisco.

The new method transmits pictures which may be reproduced perfectly, and requires a sending time of but seven minutes. Other methods previously devised have required as much as an hour or an hour and a half for transmission. The apparatus represents the association of many recent inventions by telephone engineers, together with standard types of telephone and telegraph apparatus which have been readapted to this new use.

The simplicity of the method is such that a positive transparency film is suitable for transmission. The picture is received in such form that, after photographic development of the usual sort, it is practically indistinguishable from an ordinary photograph, and is ready for newspaper or other reproduction. As films can be used for transmission while still wet, the system eliminates the delay which would otherwise be caused by drying, or by making special sending plates.

The time element is a most important phase of telephotograph transmission. It takes only about three-hundredths of a second for the electrical waves to reach San Francisco from New York. The seven minutes required for transmission of a complete 5-by-7-inch picture is the time consumed in tracing over the picture, point by point, on the sending machine. The film is inserted in the transmitter simply by rolling it up in a cylindrical form. During the operation a very small but intense beam of light shines through the film into a photoelectric cell within the cylinder. The film is rotated at a uniform speed and, by means of a screw mechanism, is caused to advance parallel to the axis of the cylinder. Each minute portion of the picture, in turn, affects the intensity of the light reaching the photoelectric cell, the variation of the amount of light striking the sensitive surface of the cell giving rise to the current which, through the agency of a vacuum tube amplifier and modulator, controls the current flowing over the telephone line (Figure 1).

The photoelectric cell consists of a vacuum tube in which the cathode is an alkali metal, such as potassium. Under illumination, the alkali metal gives off electrons so that, when the two electrodes are connected through an external circuit, a current flows. This current is directly proportional to the intensity of the illumination, and the response to variations of illumination is practically instantaneous (Figure 4).

At the receiving end, an unexposed photographic film has been placed in the machine, and this also rotates under a beam of light in a manner similar to that of the transmitting equipment. The two films are caused to rotate at exactly the same rate of speed, by means of small motors controlled by electrically operated tuning forks (Figure 2).
By means of a new device known as a light-valve, the fluctuating currents received from the line are transformed into corresponding variations in the intensity of the beam of light focused on the sensitized film. The light-valve consists essentially of a narrow ribbon-like conductor lying in a magnetic field, in such a position as to cover entirely a small aperture. The incoming current passes through this ribbon which is, in consequence, deflected to one side by the inter-action of the current with the magnetic field, thus exposing the aperture beneath. Light passing through this aperture is thus varied in intensity (Figure 5).

Due to the impinging of the light beam on the rotating cylinder, the film is exposed by amounts varying in proportion to the lights and shades of the original picture.

In the simple scheme of picture transmission outlined in the preceding section, the photoelectric cell gives rise to a direct current of varying amplitude. The range of frequency components in this current runs from zero up to a few hundred cycles. Commercial long-distance telephone circuits are not ordinarily arranged to transmit direct or very low frequency currents, so the photoelectric currents are not directly transmitted. Moreover, these currents are very weak in comparison with ordinary telephone currents. On account of these facts, the current from the photoelectric cell is first amplified by means of vacuum tube amplifiers, and then is impressed upon a vacuum tube modulator jointly with a carrier current whose frequency is about 1,300 cycles per second. What is transmitted over the telephone line is, then, the carrier wave modulated by the photoelectric wave, so that the currents, in frequency range and in amplitude, are similar to the currents corresponding to ordinary speech. Were it possible to have two forks at widely separated points running at exactly the same speed, the problem of synchronizing would be immediately solved. Actually, this is not practical, since variations of speed with temperature and other causes prevent the two forks from operating closely enough together for this purpose. If the two cylinders are operated on separate forks, even though each end of the apparatus runs at a uniform rate, the received picture will, in general, be skewed with respect to the original.

The method by which this difficulty has been overcome in the present instance is due to Mr. M. B. Long. Fundamentally, the problem is solved by controlling the phonic wheel motors at each end by the same fork. For this purpose, it has been found desirable to transmit to the receiving station impulses controlled by the fork at the sending end. The problem of transmitting both the fork impulses and the picture current simultaneously could be solved by the use of two separate circuits. It would not, however, be economical to use two separate circuits for the picture and synchronizing channels; consequently, the two currents are sent on the same circuit. In order to accomplish this, the picture is sent on the higher frequency carrier, approximately 1,300 cycles per second, and the

Figure 2. Receiving End of Apparatus, Showing Light-valve and Observation Microscope

Figure 3. Schematic Diagram of Apparatus. Left—Sending End; Right—Receiving End
synchronizing pulses are sent on the lower frequency carrier, approximately 400 cycles per second, both lying in the range of frequencies readily transmitted by any telephone circuit. These carrier frequencies are obtained from two vacuum tube oscillators. The two currents are kept separate from each other by a system of electrical filters at the sending and receiving ends so that, while the current on the line consists of a mixture of two modulated frequencies, the appropriate parts of the receiving apparatus receive only one carrier frequency each.

The origin and nature of the microscopic structure characteristic of pictures transmitted by the present process is illustrated by the diagrammatic presentation of Figure 9, which may serve at the same time to give a review of the whole process. We will assume that the original picture consists of a test object of alternating opaque and transparent lines. Such a set of lines is shown at A. The lines are assumed to be moving from left to right across the spot of light falling on the film. The width of the spot of light (corresponding to the pitch of the screw) is represented by the pair of dashed lines. If the spot of light were infinitely narrow in the direction of motion of the picture film, the photoelectric current would be represented by diagonal lines as shown at C. Due to the unavoidable reactances in the amplifying system, there is introduced a certain rounding off of the signal, so that the variation of potential impressed on the modulator tube follows somewhat the course shown at D. The alternating current introduced by the vacuum tube oscillator is, then, given the characteristics shown at E, the envelope being a close copy of D. Passing out to the transmission line, the fact that a band of frequencies transmitted by a telephone line is limited in extent results in a certain further rounding off of the envelope of the picture current as shown in F. The ribbon of the light-valve, when traversed by the alternating current from the line, performs oscillations to either side of the center of the aperture, consequently opening first one side of the aperture and then the other. The two curves of sketch G represent the excursions of the light-valve ribbon, with time, past the edges of the aperture, which latter are indicated by parallel straight lines. Owing to the fact that the light-valve aperture must have a definite length in the direction of rotation of the cylinder (indicated by the small rectangle in the center of the sketch), there is a certain overlapping of the light pulses on the film. (This is, in fact, necessary for the production of solid blacks.) These are indicated diagrammatically at H. In sketch I, are shown, from an actual photomicrograph, the variations in the image as formed by one rotation of the receiving cylinder. It will be noted that the images due to the opening of the light-valve in each direction form a double, beaded line. The double lines are juxtaposed, so that the right-hand image due to one rotation of the cylinder backs up against the left-hand image due to the next rotation, thus forming on the film a series of approximately symmetrical lines of variable width. These are exhibited clearly in the enlarged section of a picture, Figure 7.

There are, in general, two methods by which a transmitted picture may be received. One of these is to form an image of the light-valve aperture on the sensitive photographic surface. When this is done, the picture is made up of lines of constant density and varying width. A picture of this sort is shown in Figure 6. A merit of this kind of picture (when received in negative form) is that, if the structure is of suitable size (60 to 65 lines to the inch), it may be used to print directly on zinc and thus make a typographic printing plate similar to the earlier forms of half-tones, whereby the loss of time usually incident to copying a picture for reproduction purposes may be avoided. A disadvantage of this form of picture is that it does not lend itself readily to retouching, or to change of size in reproduction.

Another method of picture reception is to let the light from the light-valve fall upon the film in a...
diffused manner through an aperture of fixed length, so that lines of constant width (exactly juxtaposed) but of varying density are produced. A photomicrograph of a variable density picture of the opaque line test object previously discussed is shown at J, Figure 9. Prints made from film negatives received in this way, if the structure is chosen fine enough (100 lines to the inch or more), are closely similar in appearance to original photographic prints and may be reproduced through the ordinary half-tone cross-line screen. They may be retouched or subjected to special photographic procedures in any way desired. An enlargement of a portion of a variable density picture is shown in Figure 8, and an example of a complete picture so received is shown in Figure 10.

Electrically transmitted pictures are, in general, suitable for all purposes for which direct photographic prints are used. Such uses include halftone reproduction for magazines and newspapers, lantern slides and display photographs. Among these uses may be mentioned, as of some interest, the transmission of the three black and white records used for making three-color printing plates.

Some practical details of the procedure followed in transmission of pictures by the apparatus described may serve to clarify the foregoing description. The picture to be transmitted is usually provided in the form of a negative, which is apt to be on glass and of any one of a number of sizes. From this a positive is made on a celluloid film five inches by seven inches, which is then placed in the cylindrical film-holding frame at the sending end. Adjustments of current values for "light" and "dark" conditions are then made, over the line; after which the two cylinders are simultaneously started by a signal from one end. Telephotographs have been sent not only on land lines, but also over a radio system. In radio operation, the great difficulty is to be able to secure complementary atmospheric conditions, so that steadiness of transmission and freedom from interference can be assured. From this, it is evident that the air must be free from electrical disturbances, and it further indicates that the best hours for this type of transmission by radio are those of the early morning.

While it is true that the invention is highly interesting as a scientific achievement, the important points are that it provides a practical and successful method of sending pictures by wire, and that the process is in actual daily use between three of our leading cities - New York, Chicago and San Francisco. A photograph, drawing, hand-writing exhibit, fingerprint, or other graphic record, desired for transmission to San Francisco can be filed at New York at 8:00 a. m. and, an hour later, or at 6:00 a. m., Pacific Coast time, be available for use. The time consumed in the photographic processes at either end is approximately three-quarters of an hour.

When President Coolidge was inaugurated, pictures of the ceremony were transmitted across the continent and, shortly thereafter, the service was placed on a commercial basis.

The fields in which electrically transmitted pictures may
be of greatest service are those in which it is desired to transmit information which can only be conveyed effectively, or at all, by an appeal to vision; for instance, portraits, as of criminals or missing individuals; and drawings, such as details of mechanical parts, weather maps, military maps, or other representations of transient conditions.

The public has been quick to recognize the value of telephotographs and to make use of them. The press, realizing the value of pictures, has in the past employed special trains, airplanes, and other means of speedy transportation, for quickly conveying pictures of special events of great interest. Now, with the commercial inauguration of telephotographs, newspapers have been able to break all records in the presentation of news pictures to its readers. Photographs of the Santa Barbara earthquakes were shown in the East a few hours after people received their first information about the disaster. Among other recent news events which have been similarly covered was the start of the Amundsen Expedition, the Boston dance-hall disaster, and the funeral of William Jennings Bryan.

The California Railway and Power Company of San Francisco was anxious to have a picture of a new type trolley car shown at a meeting of the board of directors in New York. In some manner, the matter had been overlooked and the picture had not been sent. However, on the morning when the meeting of the board of directors was to be held, a picture was sent by telephotograph and arrived in sufficient time to make it available for the meeting.

The medical profession is much impressed with the possibilities offered by the invention, which would enable specialists to be called in consultation and to give valuable advice without delay for, while written descriptions or word pictures are often misleading, the actual condition can be shown graphically in X-ray pictures.

Anything that can be photographed can also be telephotographed. This includes X-ray pictures, finger-prints, fashion drawings, charts and engineering drawings, shorthand notes, typewritten letters, pencil sketches by architects, cartoons, pictures of types of machinery and motors, and even signatures.

The telephotograph suggests a military use which might prove most valuable in active operation. Contoured maps may be sent with reasonable fidelity over the telephone wire. The commander in the field in open warfare, or in pursuit of an active enemy, might find himself out of the available maps, though possibly a map of the area needed would be available in a distant city. This could be forwarded by wire, as a demonstration at Fort Leavenworth recently proved.

Since time is usually a vital factor in military operations, the service offered by the telephotograph should appeal to, if not challenge, the imagination of far-seeing soldiers and engineers, whose telegraphic orders, reports and plans can now be accompanied by helpful maps or charts or drawings.