Synchronizing Television With Light Beams

Television's two great problems—speed sufficient for faithful reproduction of moving images, and proper synchronism of receiver with transmitter—are still awaiting a final and perfect solution. Proof that the challenge of these problems is not being declined is given in this article, which describes a method whereby synchronism is made automatic, being controlled by the light impulses of the received energy itself.

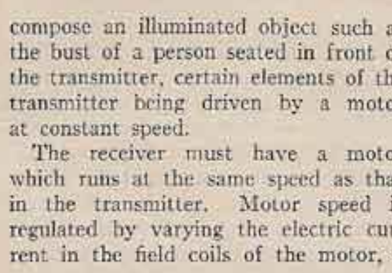
By PAUL L. CLARK

SENDING pictures by television may be likened to a military drill or maneuver having many lines of soldiers in regimental order, supervised by a single individual, the troops advancing as a single unit or as related units of the command, marching in step to rhythmic music. But what happens on the long turns, platoon formation? The line bulges a little in the center, recedes, advances, surges slightly and straightens out. It is largely a matter of alignment. Each man determines his position and speed by watching the rest of his outfit, and must be ever alert. So it is with the sending and receiving of pictures by apparatuses which are miles apart and yet which must keep in orderly arrangement the many parallel lines of shaded dots that make up the picture.

Experimenters on television term this aligning process "synchronizing," which means keeping the receiving set in step with the transmitter, so that the pictures will not bounce around the screen. You tune your radio set by *listening* to your loudspeaker; but only by *watching* the pictures on the small television screen is the experimenter given a clew to tuning his motor speed and framing the incoming pictures, the light flashes of which follow each other so fast that the eye fails to note a break in illumination. Once the picture is manually framed, no more attention to motor speed should be required, enabling the operator to control merely the brightness of the picture, letting synchronism take care of itself.

The experimental art has now arrived at the stage of sending 16 small pictures each second, each consisting of 50 lines having 50 shaded dots in each line, forming a picture which consists of 2,500 tiny areas, each of these areas being of a light or shade corresponding to one of the successive areas which compose an illuminated object such as the bust of a person seated in front of the transmitter, certain elements of the transmitter being driven by a motor at constant speed.

The receiver must have a motor which runs at the same speed as that in the transmitter. Motor speed is regulated by varying the electric current in the field coils of the motor, a

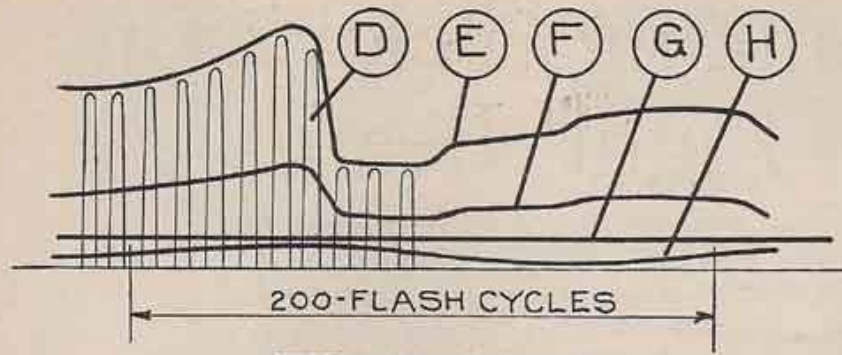


A MAGNIFIED VIEW OF THE LIGHT CHOPPER

FIGURE 1: *At A successive flashes from the neon lamp register with successive slits in the chopper, showing that the motor speed is too high. At B the flashes overlap the chopper bar, showing a speed drop from high to low. At C the flashes are intercepted by the bar, and half the light passes through the slits so as to fall on the photo-electric cell (F in Figure 3). This condition is the ideal interception of flashes to produce the least oscillation relative to synchronism.*

strongly excited field slowing down the motor. The motor of the receiver of Figure 3, in addition to the regular shunt winding, is provided also with an extra coil, G, which is wound so as to weaken the field and speed up the motor when current is passed through the coil. This is the coil which automatically regulates the motor speed, being energized by current which is set up in the local photo-electric cell, F, by virtue of light rays falling upon the cell, as described below. The motor should be manually started and brought up to run at a speed about one per cent below the speed of the transmitter motor, it being assumed for the time being that there is no current in the reverse field coil so that the received picture tends to travel slowly backwards across the screen, thereby indicating motor underspeed. The speed-correcting system herein described is designed to speed up the motor automatically at least two per cent, so that the speed with the reverse coil full strength will be about one per cent too high. The effect of the underspeed and overspeed field control is such, when applied successively at intervals a fraction of a second apart, as to hold the picture quite steady, the automatic feature of this device being merely a simple form of photo-electric light valve governed by different degrees of stoppage of successive flashes of the received picture light, these flashes being swept in the form of a swinging beam rapidly across a stationary grid or "light-chopper," made up of bars and slits, as shown in Figures 1 and 3.

The action of this valve is such as to vary the quantity of light which falls upon the photo-electric cell, the light used for this purpose being about 10 per cent of the light in each signal flash emitted by the neon lamp, these flashes being produced by signals received from the transmitter at the dizzy rate of many



TYPICAL ENERGY CURVES

FIGURE 2: *At D are indicated the neon lamp flashes, 40,000 per second, is the total flash energy applied to delineate the image on the screen. F indicates the energy reflected by the small mirror (C in Figure 3) to fall upon the chopper. G indicates the maximum illumination required on the photo-electric cell to compensate for one per cent underspeed. H is the approximate synchronizing cycle made up of 200 flashes.*

thousands during each second. The cell is connected through an amplifier so as to supply energy to the pole-tip coil of the motor, so that bright light on the cell speeds the motor up; dim light slackens the speed; intermediate light flashes, as shown at C in Figure 1, falling upon the cell produce a neutralizing effect essential for accurate synchronizing.

The transmitter motor in Figure 3 drives the scanning disk consisting of 50 concave mirrors arranged at gradually increasing angles in the form of a spiral, so that as the scanner is rotated successive vertical lines of the illuminated image are traversed, point by point, by a single turn of the scanner; and all points of the image are successively changed into corresponding electrical currents by the photo-electric cell and sent to the receiver by a suitable broadcasting set or wire line. The chopper which is placed against the illuminated image is made of a glass plate, 3 inches square, on which are photographed 50 blackened bars each about as wide as a darning needle, alternating with transparent slits of equal width; so that as the scanning beam, SB, rapidly sweeps across the image, due to the rotation of the scanner, a series of lighted picture dots alternating with uniformly dark spots which are formed by the black chopper bars, is focused by the concave mirrors on the scanner, so that the light or shade of each illuminated picture area, alternating with the black chopper areas, falls upon the cell, producing therein a series of electrical currents derived from the bright picture areas, alternating with the electrical currents of extremely low and uniform energy, the latter impulses being derived from the low intensity of the light reflected by the dull surface of the black bars. The advantage of using a chopper in the transmitter is seen to lie in its ability to break up the picture into a large number of disconnected, equispaced areas or lines which, when swept by a pointed beam, give rise to a corresponding number of instantaneous successive current impulses in the photoelectric cell and in the circuit which supplies current to the cell. The number of these impulses which are produced and transmitted in a single second of time, is technically called the "picture point frequency," which we will assume to be 40,000 per second. Changing the series of instantaneous currents into an alternating current by means of a suitable transformer, we find that in each 1-40,000th second we have a complete electrical action or wave which is made up of two parts, one being the positive picture signal which may be either strong or weak, depending on the shade of the picture dot, the time during which this half-wave is formed being 1-80,000th of a second; the other half of the wave being the negative or low intensity chopper bar signal of constant value.

Now, it is evident that if we have a receiving scanning system similiar to that of the transmitter and run them both at the same speed, and if similar choppers are used, we will find that during each successive 1-80,000th second the focused scanning beams will simultaneously register: first, upon corresponding bars; second, through corresponding slits, in both apparatuses; so that when the beam is sweeping bar number 1 in the transmitter, the receiver beam is sweeping bar number 1 of the receiver; and 1-80,000th of a second later, the two beams will simultaneously sweep across slits number 2 of both pieces of apparatus. The above condition is that prevailing during exact synchronization, showing that the picture receiving set is perfectly timed. This idealistic assumption is, however, a little more than we can hope to obtain for periods of more than a few seconds. But we can attain a close registration by limiting the deviation to less than the width of a single slit, *i. e.*, a maximum error of cross-travel of less than one per cent, by providing a reasonable margin of excess energy in the motor-speed compensating circuit of the receiver. Too much cross-travel necessitates manual rephasing.

In order to obtain zero illumination on the cell, F, and consequently no current in the polarity reverse coil, G, throughout both halves of a given picture flash cycle during which cycle are transmitted a complete picture point luminous signal followed by a complete low energy black bar signal, it is evident that the luminous signal must have struck the chopper in such a way that it is entirely stopped by one of the chopper bars as shown at the lower part of the vertical series, B, in Figure 1, due to faulty synchronization resulting from overspeed; for it can be seen that for accurate synchronization the local scanning element should instantaneously be in such an angular position as to reflect the pointed conical beam emanating from the simultaneously produced neon lamp flash, so that the point of the beam shoots squarely against the edge of a corresponding slit of the chopper, as shown at C in Figure 1, at the exact middle of the 1-80,000th second during which the flash occurs. Darkness or bright light on the cell can persist only on account of continued overspeed or underspeed which produce respectively a slightly advanced or retarded scanning element.

As we have assumed the motor to be normally, say, one per cent underspeeded, it will start to slow down from true synchronous speed until it reaches a speed which is one per cent too low, *provided there is no energy supplied to the speed-up coil*, and will backwardly deflect the signal flash beams so that some of them instantaneously pass squarely through the slits as shown at A in Figure 1. This illuminates the cell with full light and excites the speed-up coil with maximum energy, causing the motor and scanner to advance the reflected signal beams a slight degree *ahead* of registration, until light is again shut off from the cell so that the cell circuit ceases to supply excitation to the coil, G, and another drop in speed occurs. This alternate speed-up and slow-down period may be called a "synchronizing cycle." The receiver motor is of about 1-30th h.p., 960 r.p.m., with regulation

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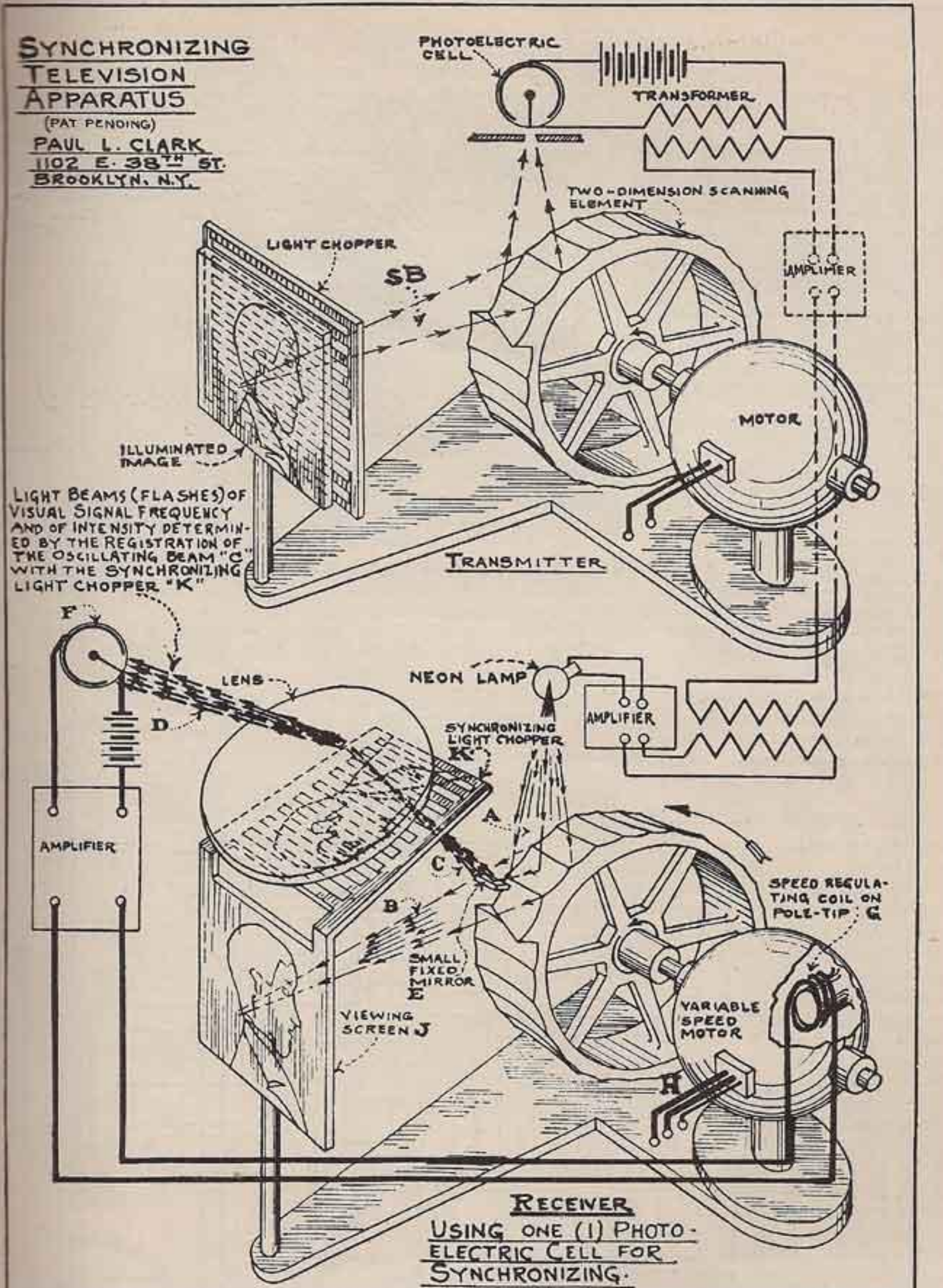

HOW AUTOMATIC SYNCHRONISM IS ACCOMPLISHED

FIGURE 3: *The use of "light choppers" of similar dimensions in the transmitter and receiver is the key to Mr. Clark's solution of the synchronization problem, shown diagrammatically above. The transmitting scanning element scans the image through a light chopper; hence it delivers to the photo-electric cell series of light lines alternating with dark lines caused by the bars of the chopper. At the receiver part of the light energy of the neon lamp is reflected by a small mirror through another light chopper to a photo-electric cell whose output controls a speed regulator on the receiver scanning device motor. It is the registration of the light and dark flashes on the second photo-electric cell that is used to bring about proper synchrony.*

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shunt-wound field coils for normal speed control.

In starting up the apparatus it is essential that the motor speed be regulated by the operator until his picture is steady, which condition implies exact timing with the incoming picture signals. Considering that the picture is steady, the successive flashes, C, reflected by the small mirror shown in the middle of the rapidly vibrating flash beam, B, in Figure 3, will register upon the chopper, K (shown also at C, in Figure 1), so that about one-half of each flash is stopped by the chopper bar and the other half falls upon the lens next to the chopper and is focused to fall upon the photo-electric cell, F. Now, suppose that the motor speeds up a little bit, causing the flashes C, Figure 1 and 3, to overlap the bars *more* than halfway, let us see what takes place: (1) The quantity of flash light which passes through the slits is lessened; (2) Dimmed lights falls upon the cell; (3) The current in the cell is decreased; (4) The current in the reversed-field coil is decreased; (5) The tendency to *reversing* the field is lessened; (6) The field itself resumes its normal full strength by virtue of its fixed shunt-winding excitation; (7) The motor slows down a little bit due to the stronger field; (8) The signal flashes are backwardly deflected by the scanning element due to the lagging action so that more light falls in the slits, passes through the lens and falls upon the cell; (9) The current in the cell and in the reversing field coil is increased, thereby weakening or de-polarizing the field; and (10) The motor again starts to speed up. This swinging, automatic, speed control cycle repeats again and again, as long as there is enough average light during each synchronizing cycle to stir up sufficient speed-up current. By providing an amplifier which has an output of about 1 watt, enough reserve energy is available for control.

Each synchronizing cycle embraces, say, an interval of 1-200th second, and consists of 200 valved flashes passing from dim illumination on the cell, to medium illumination, to bright illumination; and repeating the cycle. The frequency of the synchronizing cycle is determined by considering that 99 bar traversals occur in the time interval during which, for exact synchronism, 100 traversals should occur. Figure 2 shows such a synchronizing cycle consisting of 200 successive picture flashes progressively intercepted by virtue of underspeed and overspeed; the line G indicates the comparative value of the reverse energy required to maintain synchronization or "critical speed."