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A SIX INCH CARBON RECORDER WITH ITS RECORDING  
AMPLIFIER AND SYNCHRONOUS DRIVE MOTOR

## **Facsimile and Picture Transmission and Reception**

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DR. ALEXANDERSON AND CHARLES J. YOUNG  
STANDING BEFORE THE FACSIMILE MACHINE  
WHICH RECEIVED THE ELECTRICAL IMPULSES  
AND PRINTED THE NEWSPAPER PAGE SHOWN  
BELOW



THIS FRONT PAGE OF A SAN FRANCISCO  
NEWSPAPER WAS REPRODUCED IN  
SCHENECTADY ONLY THREE HOURS AFTER  
IT WAS PRINTED ON THE PACIFIC COAST —  
SOME 2500 MILES DISTANT

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### FACSIMILE AND PICTURE TRANSMISSION AND RECEPTION

The beginning of facsimile transmission is marking a new era in radio. It means the sending of intelligence in a form which the eye can use instead of the ear — a picture instead of a story, a printing machine instead of a loudspeaker.

For, after all, if you want to impart an idea to someone else speech is a rather limited method. You can only talk so fast and you can only tell one story at a time. Or, if you are distributing news to many people it is like asking them to read their newspaper through a hole which covers only one sentence at a time. That is not the way one reads his paper. He scans the entire sheet, notes the headlines of many stories and their relative importance, and then reads those of interest to him. From looking at a simple picture, he becomes instantly acquainted with a situation which it would take many minutes to portray in words.

It is because one of the objects of radio is to transmit facts and ideas clearly that facsimile will be of great importance. The threshold has already been crossed. Pictures have been sent from point to point both in this country and abroad. Recently, the front page of a San Francisco newspaper was reproduced in Schenectady only three hours after it was printed on the Pacific Coast — some 2500 miles distant. This feat has been made possible as a result of a long series of developments in the radio laboratories of the General Electric Company under the direction of Dr. E. F. W. Alexanderson.

Facsimile transmission, picture transmission, and television have many things in common. Light, lenses, photoelectric cells, amplifiers and radio signals all play important parts in these systems.

#### A SYSTEM USING PHOTOGRAPHY IN ITS PROCESS

In the first part of this lesson we take up the principles of the photoradiogram system. Photography has its use in photoradiogram work. Only that part sufficient to give us an idea of the meaning of "positive" and "negative," as applied to films and prints, will be taken up. The taking and finishing of a photograph requires five operations; namely, the preparation of the plate, exposure of the plate to light rays, developing of the plate, the fixing of the plate and, finally, the printing of the picture.

In the preparation of a photographic plate a solution of silver bromide is precipitated, that is, caused to separate and then held in a watery suspension of gelatine. The gelatine mixture is maintained at a warm temperature and allowed to age, thus rendering it more sensitive to light rays. This mixture, better called emulsion, is then applied to glass plates or is spread over strips of transparent celluloid. If we speak of photographic plates we refer to the glass plate, if a film is mentioned we refer to the emulsion covered celluloid strip. Plates are not usually employed by the amateur photographer; either film pack or film rolls are used.

When this prepared film is exposed to light by the opening of a shutter allowing light to enter the camera through a lens, the rays of light fall upon the prepared gelatine surface and a chemical change takes place, which to the eye produces no visible effect. But the silver bromide under proper treatment can now be more easily reduced to metallic silver and this reduction will be in proportion to the intensity of the light that falls upon the surface containing the silver bromide. To bring this reduction about a reducing agent, which is an alkaline solution of pyrogallic acid or hydro-quinone, is applied and possesses such slight activity that its effect on portions of the bromide film not exposed to illumination is practically zero. This reduction works very rapidly and deposits more metallic silver where the illumination is of the greatest intensity.

This explains why the film becomes more opaque where the object being photographed is brightest and more transparent where the object is the darkest. Because of this reversal the name "negative" is given the developed plate or film. Since white light rays are the ones to most affect the bromide during the exposure the developing is carried out under a red light which has practically no action on the silver bromide. If nothing further were done with the developed film, daylight would in time gradually reduce the remaining unchanged bromide to silver, therefore, the developed film is placed in a "fixing" bath or hypo, where the bromide is dissolved out. The negative is now placed in a quantity of clean pure water and washed to remove all the chemicals except the gelatine and silver image. This is the finished negative that is used in photoradiogram transmission.

A "positive" print or film may be obtained from any negative film by allowing a sensitized photographic paper or unexposed film to be illuminated through the negative. The denser portions, that is, more opaque portions protect the light sensitive paper or film from being acted upon by the light, while the light readily passes through the transparent parts of the negative, bringing about a chemical action in the light sensitive paper, or film. This is developed and the result is a "positive", or image just the reverse of the "negative" in light and shade.

Before discussing regular photoradiogram equipment a simple set-up will be explained in order to fix the principle in mind. Figure 1 shows a source of light, lens and photoelectric cell with associated circuit and indicating device. When light enters the cell the meter will be deflected showing that current passes through the circuit.

If an opaque substance is placed between the light and photocell, the meter will return to zero showing that no current will flow when the light is prevented from reaching the light sensitive element of the cell. Suppose in place of the solid opaque screen we perforate a

number of openings in the screen; for example, like that shown in Figure 2 and then pass this between the light source and the photocell. As light passes through the openings of group #1, a slight flicker of the meter needle will take place, then a longer sustained deflection.

Passing through group #2, a sustained deflection will first result followed by three short deflections. If an extremely sensitive buzzer were connected in the circuit instead of the meter you could read the signal "A B" in code (by sound) as these openings passed between the light and the photoelectric cell.

Suppose we prepare another screen as in Figure 3; a strip of material is placed in the opening which, beginning at A, is transparent but so

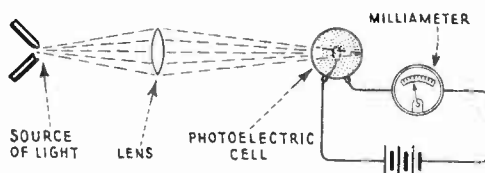


Fig. 1 - A DEFLECTION IS SEEN ON THE MILLIAMMETER WHEN LIGHT RAYS STRIKE THE PHOTOCCELL.

made that as it approaches point B it gradually passes less and less light until at B it is opaque allowing no light to pass. Assume from B to C just the reverse is true. When this screen is passed between the light and the photocell the needle will show a maximum deflection as point A passes, then as the strip moves across the light beam toward B the needle will show a decreasing deflection, until at point B it will drop to zero. As the strip is moved on, the milliammeter needle will indicate an increasing current strength and when C is reached maximum deflection will again be noted.

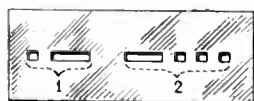


Fig. 2 - OPAQUE SUBSTANCE STAMPED TO RECORD CODE LETTERS "A" AND "B."



Fig. 3 - MORE OR LESS LIGHT REACHES THE PHOTOCCELL DEPENDING UPON THE OPTICAL DENSITY OF STRIP ABC.

Now if you will examine a negative of a snapshot by holding it between your eyes and the light you will see that it consists of transparent, translucent and opaque areas. If such a screen is placed between the photoelectric cell and a source of light the milliammeter needle will show deflections of various magnitudes depending upon the amount of light that the film allows to pass and strike the light sensitive element of the cell.

WORKING PRINCIPLE OF A PHOTORADIOGRAM TRANSMITTER.

Figure 4 takes us a step further and gives us an insight into the working principle of a photoradiogram transmitter. This sketch is only for the purpose of explaining the principle of operations. Consider the housing H which incloses the photoelectric cell P E and lenses L3 and L4 all mounted upon a carriage which travels laterally side to side. Attached to the same movable carriage is the rigid arm A-A supporting the arm C-B, which passes through the center of the glass cylinder and supports lenses L1, L2 and prism P.

Now, starting the electric motor utilized to drive the carriage upon which the housing H is mounted, the entire movable system, comprising H with its lenses L3, L4 and photoelectric cell P E, together with arm C B supporting the lenses L1, L2 and prism P, will travel to the left and right as one unit. When the lamp L in the reflector R is lighted, L1 will collect the rays and direct them to L2 where they converge to a small point and pass into the prism P which now reflects the small pencil of light at right angles directing it into the lenses L3 and L4 and finally into the photoelectric cell PE.

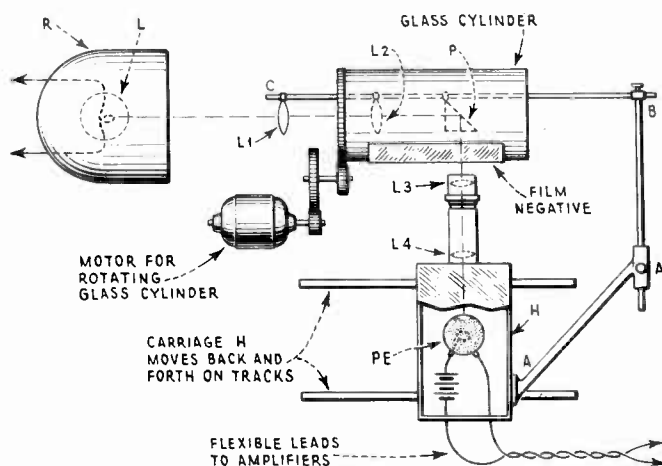
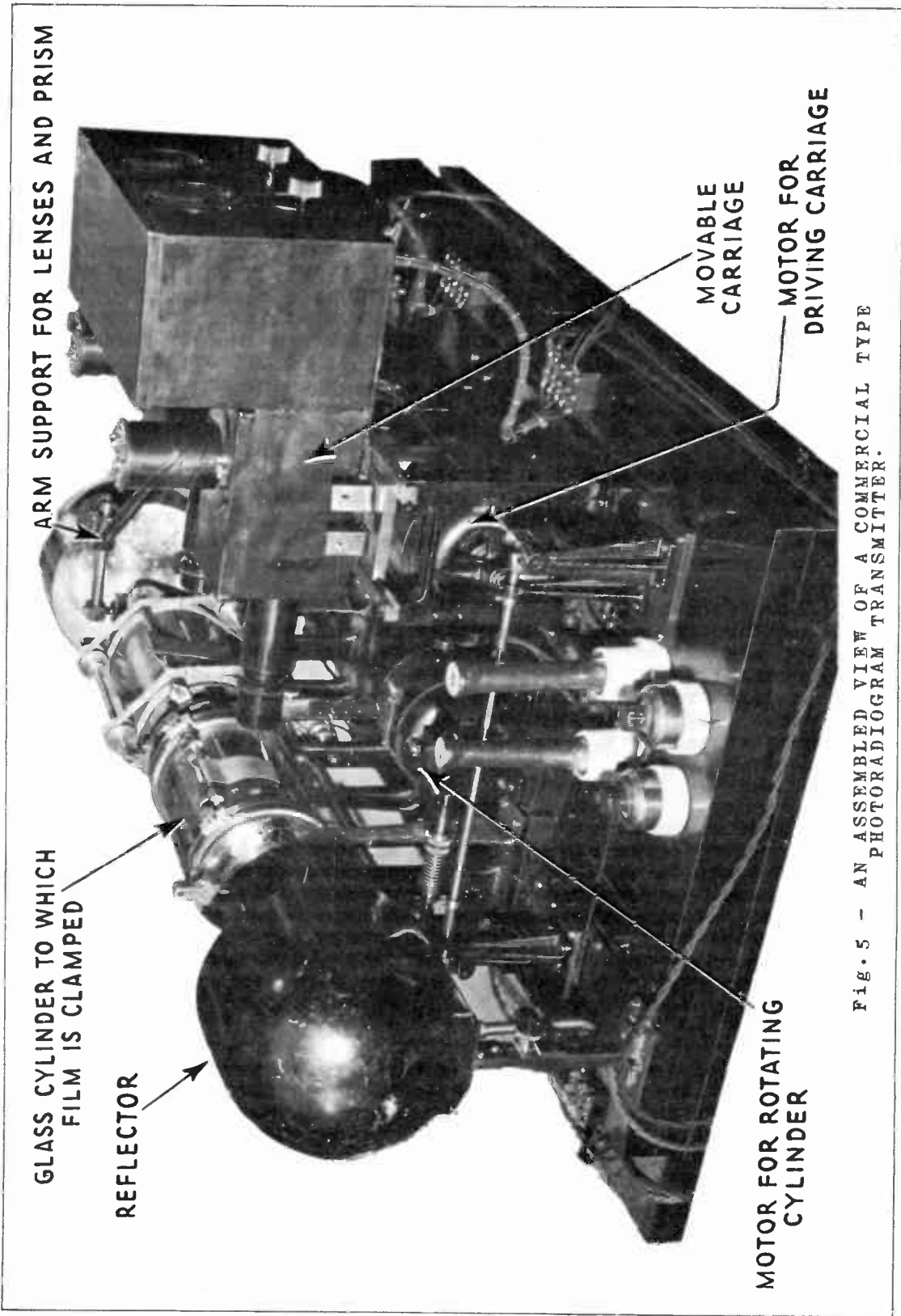


Fig. 4 - ILLUSTRATING WORKING PRINCIPLE OF A PHOTORADIOGRAM TRANSMITTER.

Let us place a negative on the glass cylinder and clamp it in such a way that it conforms with the curvature of the cylinder. As soon as this is done the pencil of light, upon leaving the prism, will no longer have a direct unobstructed path in which to reach L3, L4 and the photoelectric cell, but must first penetrate the negative. It follows then that the amount of light reaching the photoelectric cell will depend upon the transparency of the negative, and the output of the photoelectric cell will be directly proportional to the light reaching it through the clear elementary areas of the negative.

With the negative in place and the electric motor started, the small intense point of light will move back and forth across the inside of the cylinder and for each single crossing of the prism the light will



ARM SUPPORT FOR LENSES AND PRISM

GLASS CYLINDER TO WHICH  
FILM IS CLAMPED

REFLECTOR

MOVABLE  
CARRIAGE

MOTOR FOR  
DRIVING CARRIAGE

MOTOR FOR ROTATING  
CYLINDER

Fig. 5 - AN ASSEMBLED VIEW OF A COMMERCIAL TYPE  
PHOTORADIOGRAM TRANSMITTER.

have covered a very narrow line width of the negative. At the end of each stroke the glass cylinder is rotated very slightly by means of a motor geared to the end of the cylinder to present a new line width of the negative to the small spot of light as a return stroke of the system takes place. If the spot of light traverses a transparent, i.e., light portion of the negative, it has no difficulty in passing through to the photoelectric cell. On the other hand, if a dark width of the negative is in the path of the light little or no light will penetrate the negative, and correspondingly little or no current will be passed by the cell.

Since the photoelectric cell functions practically instantaneously, that is, without time lag, the moment the slightest change in the amount of light reaches the cell there will be a corresponding change in the output current of the cell. Because of this the photocell, figuratively speaking, sees the most minute variations of shading and records electrically thousands upon thousands of different current impulses as the searching spot of light sweeps back and forth across the negative, each current impulse corresponding with the light and dark elementary areas of the negative.

The currents thus produced are extremely minute in magnitude, in fact, too weak to be of any practical value in themselves. Therefore, they are fed into vacuum tube amplifiers and made many times stronger in the same way that a radio signal is increased in strength by the amplifier in any receiver.

The amplified current impulses are then ready to control a large radio transmitter through a series of relays in such a manner that the transmitted signals convey impulses of radio-frequency energy which in a way resembles the dots and dashes of code but actually they correspond to light values of the negative. These impulses are, of course, unintelligible so far as deciphering them is concerned and they cannot be read as you would read the alphabet of continental code.

#### CONTROL OF THE SIGNAL.

The actual control of these signals is accomplished as follows: When the spot of light is passing over a light part of the film very little current, if any, is radiated; this corresponds to a few dots or none at all. Then, as the light beam sweeps across a shaded strip of the negative a great many small impulses are released from the antenna which corresponds to a great many short dots. As the sweeping spot of light passes over a dark section of the negative, long and continuous heavy impulses are radiated which correspond to long heavy dashes.

A fully assembled view of the commercial type photoradiogram transmitter just described is shown in Fig. 5. When the undecipherable code impulses are released, it is necessary to operate some sort of apparatus that will translate them into light and shade—each electrical impulse in the form of a dot or dash performing a certain task in such a way that a picture is built up as each impulse is received.

The signals picked up by the antenna at the receiving station are weak impulses, exactly as are those received from a broadcasting station, and they must be detected and amplified in precisely the same manner. Before we put this signal to work we must pause for a moment



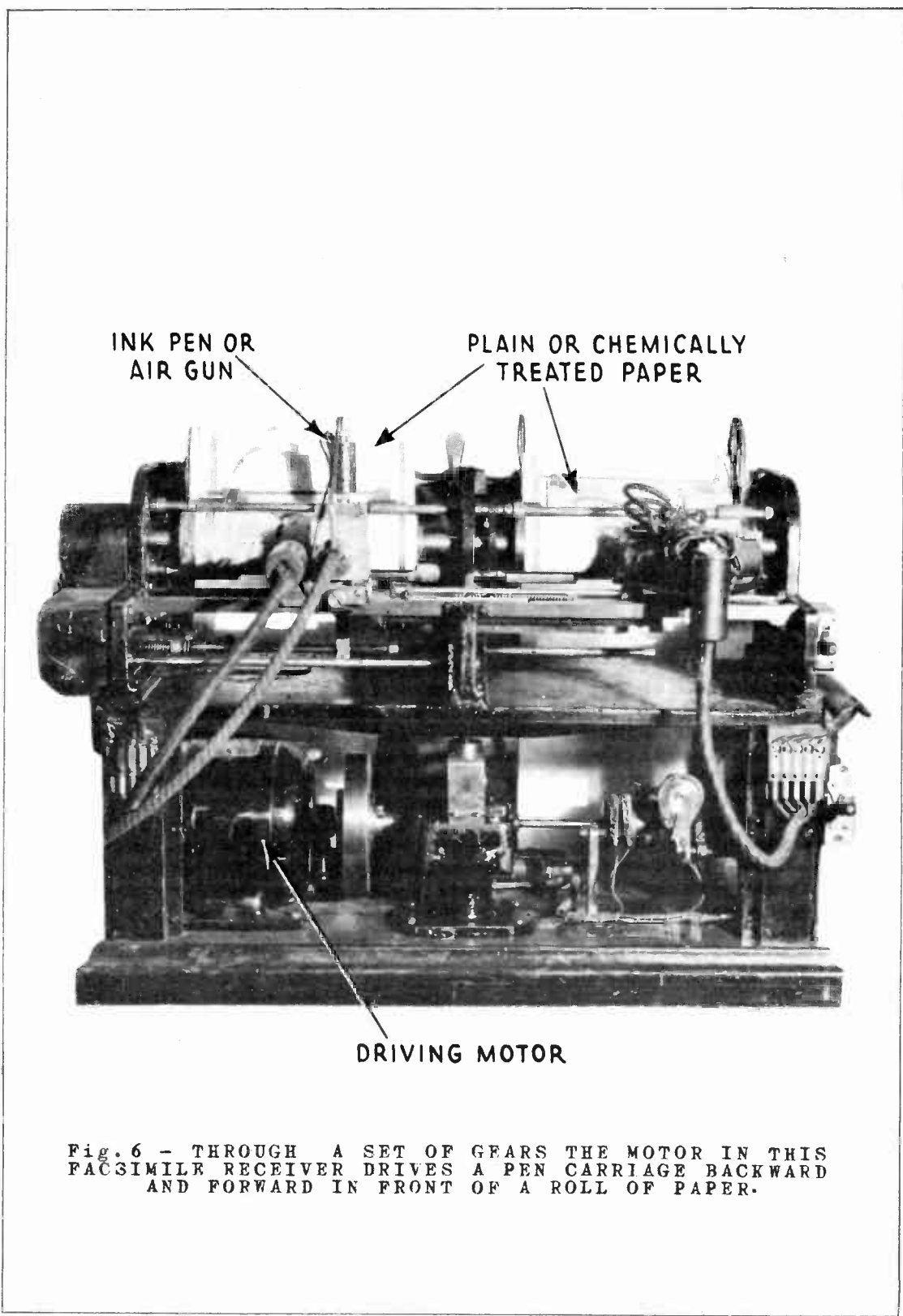


Fig. 6 - THROUGH A SET OF GEARS THE MOTOR IN THIS FACSIMILE RECEIVER DRIVES A PEN CARRIAGE BACKWARD AND FORWARD IN FRONT OF A ROLL OF PAPER.

and study the mechanical and electrical features of the receiver shown in the photograph of Fig. 6.

An electrical driving motor is installed in the base of the receiver. Through a set of gears this motor drives a pen carriage backward and forward in front of a roll of paper. A most important function of this carriage is that it moves through each stroke in absolute synchronism with the carriage of the transmitter; this is a rigid requirement because, should the receiver lag the slightest amount behind the transmitter, a blurred and unrecognizable reproduction would result, therefore, exact synchronism must be maintained by the use of special driving motors. Once the transmitter and receiver are synchronized the receiver is ready to build up the picture. The pen carriage supports a small pen controlled by a tiny electrical relay in such a way that as each signal impulse passes through the electromagnets of the relay the pen is moved to the surface of the paper and leaves a fine ink mark as long as it is in contact. If the signal impulse is steady a straight ink line will result, but if the current passing through the relay magnets is varying in strength then the pen will wobble in step with the varying current impulses resulting in a wavy ink record. Back and forth across the paper, line by line, a picture is finally reproduced.

A picture of ex-president Coolidge which was transmitted by the photogram system over a distance of 3000 miles and one of Bobby Jones transmitted from London to New York are shown on the back cover page.

#### INK PEN AND HOT AIR SYSTEMS.

In a later development the ink pen was replaced by a hot air method of reproduction. Instead of the ink pen a small air gun is mounted on the carriage which projects a fine column of air (which has been previously heated) toward a roll of chemically treated paper. The hot air acts as thousands of minute burning bullets which, upon striking the paper, instantly produce a sepia mark. (Sepia is a shade of brown.) Since the hot air is projected continuously toward the paper some means must be utilized to prevent it from striking the paper at times when no impression is desired. To accomplish this a stream of cold air from a second gun is arranged to blow aside the hot air at the proper interval. A small electrically controlled valve actuated by the incoming signal controls this cold air blast as follows: When a signal is coming in on the receiver, small electromagnets actuate a tiny valve which shuts off the supply of cold air; the hot air stream then, having no interference, strikes and burns the paper leaving the small brown impression.

Every time a ray of light from the transmitter finds its way through a clear space of the negative, and into the photocell, an impulse is transmitted in proportion to the intensity of the ray and this impulse, when intercepted by the receiving antenna, actuates the small electromagnets in the receiver thus controlling the duration of the cold air stream.

Thus in this system for every clear space in the negative traversed by the spot of light at the transmitter end a corresponding brown mark is made on the paper at the receiving end, and as the spot of light explores the negative line by line a positive print is built up by various shades of brown.

## FACSIMILE TRANSMISSION

Facsimile means to make an exact copy of the original and differs somewhat from photoradiograms in that the original does not require a special preparation before transmission as does the negative in photoradiogram work. We can divide the methods of picture transmission into two classes; first, the photoradiogram, which requires a special preparation before transmission, and second, the facsimile, which can be transmitted directly from the original without special preparation. The methods requiring the preparation of a transparent master, either in positive or negative form, are still in use, and in such transmission which has been explained the transparent original is explored by a sharply defined pencil of light which pierces each elementary area as it passes across the original, one line at a time, activating a light sensitive cell on the opposite side. The amount of light reaching the photocell depends upon the variation in optical density of the original, and consequently controls the electric current delivered by the cell.

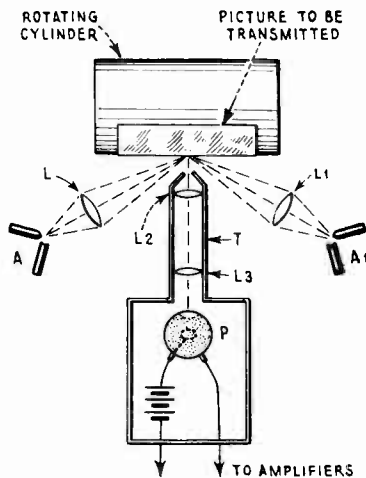


Fig. 7 - A REFLECTED SPOT OF LIGHT FROM THE PICTURE IS DIRECTED ONTO A PHOTOCELL THROUGH A LENS SYSTEM.

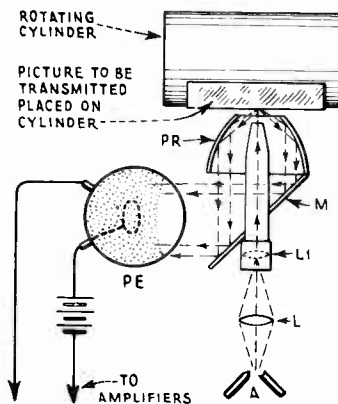


Fig. 8 - IN THIS SYSTEM THE EXPLORING PENCIL OF LIGHT IS REDUCED TO THE REQUIRED DIMENSIONS BY THE LENSES.

The trend, however, is toward greater speed in the transmission of pictures, therefore, engineers had to devise other methods to meet this demand and "facsimile" was the result. This makes possible more rapid work; a typewritten letter, checks, newspaper clippings, pictures from magazines, postcards or photographs, and so on, may be clamped to a glass cylinder, and instead of a spot of light passing through the original it is shot directly at it and the reflected light utilized to actuate a photocell.

### 1ST METHOD.

One of these methods is to illuminate the original by a strong diffused or concentrated light and then isolate or cut off a small spot of the light flooded area; the reflected light from this spot is then directed into a photocell. Figure 7 indicates how this may be accomplished. A source of light A, A1, is collected by lenses L and L1

and projected to a small area on the picture to be transmitted. Close to this illuminated area is placed a hollow tube T, which cuts off a small spot of reflected light from the brightened area which passes into the tube; this is collected by a system of lenses L2 and L3 inside the tube and directed into the photoelectric cell P. It is known that a light area will reflect considerable light while a dark surface reflects only a small amount of the light directed against it. Therefore, if a spot of light sweeps across a surface of light and shade more light will be reflected from the light area than from a dark space. The photocell, of course, is affected according to the amount of light reaching it. The cylinder moves forward a small line width at the end of each stroke of the sweeping light spot, and in this respect there is very little mechanical change in design from the photoradiogram equipment.

#### 2ND METHOD.

Another system that will provide a facsimile is to first reduce the exploring pencil of light to the required dimension by a special system of lenses and then use all the light reflected instead of capturing or cutting off a small section of the total illuminated area. Figure 8 fundamentally illustrates this system. The light from A is collected by the lens L which focuses it upon the optical system in L1 in order that the size of the spot will be independent of the size of its source and strikes the surface of the picture in an extremely small but intense spot of light.

The reflected light from the picture is then picked up by the parabolic mirror P R and reflected to a plain mirror M which in turn reflects the light into the photocell P E. The current from the photocell is amplified and actuates the receiver. Any standard short-wave receiver may be used for the reception of picture signals. Mechanically, the receiver is identical with the transmitter. A standard bromide photographic paper is used on the receiving cylinder and the recording is accomplished by means of a small helium glow discharge tube. A special mask restricts the glow to the required size. The varying intensities of glow from this tube is dependent upon the light picked up by the transmitter photocell and blackens the sensitized photographic paper accordingly. The receiver employed with the system mentioned in connection with Figure 7 may also be an electrically controlled ink pencil or a hot air gun as described under "Photoradiograms".

#### FACSIMILE RECEPTION

CARBON RECORDER. The carbon recorder for facsimile reception prints directly on a continuous strip of paper and has an advantage over earlier facsimile machines where photographic developing of the image was required before it could be read. A photograph of a six inch carbon recorder with its recording amplifier and synchronous drive motor, as developed by the General Electric Company and the RCA-Victor Company, is shown on the front cover page of this lesson. This machine provides a very practical method of securing instantaneous prints. It has abolished all photographic processing at the receiver, as just mentioned. Its use is limited to subjects having extreme contrast, such as printed or typed matter, maps, and line drawings.

The printing mechanism consists of two strips for causing pressure of carbon paper against white paper. These may conveniently be in

the form of two rolls which unwind simultaneously. One pressure strip is a straight narrow-edged bar which is pressed forward a fraction of an inch by the signal coming to an electromagnetic mechanism. This bar would naturally make its mark as a long black line across the paper but for the second pressure strip which is behind the white paper. The latter metal strip is set into a spiral groove around a metal cylinder and sticks up above the cylinder a short distance. The two strips therefore cross each other at some one point along the horizontal line which is determined by the position of the cylinder. This rotates in synchronism with some rotary part of the transmitting scanner so that, whenever the straight bar is pressed, the one point of pressure against the cylinder strip will be placed in the record of this receiving equipment at a spot identical with the spot of the original then being scanned. Of course this requires a uniform unrolling of the white paper to make each picture line fall in the proper succession on the record.

By this system a whole front page of a newspaper has been transmitted by radio across the continent and received at Schenectady.

#### NEWSPAPER BY RADIO — CALIFORNIA TO NEW YORK

In making this transmission the front page of the newspaper was cut in three strips and each strip fed in succession through the scanning machine in the transmitting station at Oakland, California. As a result radio signals were sent out on 17 meters wavelength which were interrupted in accordance with the light and shade on the picture. These were picked up at the Sacandaga receiving station near Schenectady and sent in to the laboratory over a telephone line. There they were properly amplified and used to operate the recording or printing machine.

This recording machine prints by a carbon method directly on a continuous strip of paper, and the copy feeds steadily out as fast as the original goes through the scanning machine. It has an advantage over earlier facsimile machines where photographic developing of the image was required before it could be read.

At the present time the printing paper used is 8-1/2 inches wide, but for special services a wider machine could be developed. The signals for facsimile are not necessarily sent out on short waves, as any good radio circuit will do.

The utilization of the facsimile invention will, of course, lead to many new types of service. There will be transmission of written messages, charts and photographs.

#### MODULATION PROBLEMS

It has been stated that the picture signal modulates the radio-frequency power of the transmitter. This is the early way; improved results have been secured with a system requiring the intermediate use of an audio signal of constant frequency and amplitude, locally generated by an alternator or oscillator. Very gradual changes in intensity of a picture negative are the equivalent of a very low frequency signal which is difficult to amplify at high power. But it is possible, at low power, to impress this picture signal on the steady audio tone referred to, which becomes modulated by the picture signal. An additional vacuum tube performs this pre-modulation

function. The radio power of the transmitter is then modulated by the picture-modulated tone signal. At the receiver the radio detector output provides the audio-frequency tone whose amplitude is modulated by the picture-signal. An audio amplifier, selective to the frequency of the constant tone plus its picture side bands, may be used to secure a good level of signal and selectivity against static and other interferences. The modulated tone signal is fed into another detector which makes available the picture modulation signal which is the counterpart of the photoelectric cell current at the transmitter. It is seen that such a use of a signal tone requires two steps of modulation at the transmitter and therefore two steps of demodulation or detection at the receiver.

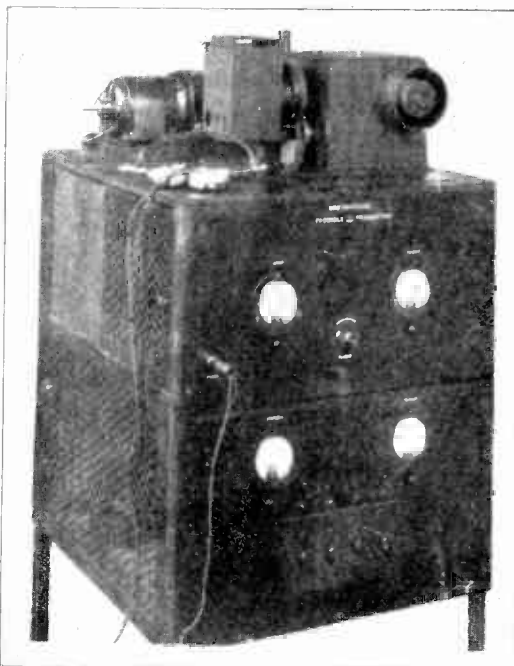
The work of pre-modulation is sometimes done without the use of the extra vacuum tube in the transmitter. The method is simple, and merely requires the use of a "chopper" in the beam of light which is used for scanning. The chopper may have several forms; probably the simplest to understand is an opaque disc which has holes punched in it at regular distances along a circle. As this disc rotates at constant speed, the chopper disc alternately passes and stops the light directed into the cell, producing therein an audio-frequency current variation of constant frequency which depends on the number of holes in the chopper disc and its revolutions per second. The amplitude of successive current waves depends as before on the efficiency with which the scanning light is transmitted through the picture negative, or reflected from the positive print, as the case may be.

Another thing to remember is that the transmitting and receiving systems must be co-ordinated so that white becomes white, and black becomes black, in the transfer from point to point. At the transmitter it is perfectly arbitrary with the designing engineers as to whether an increase in whiteness of an original causes an increase in radio power transmitted or the opposite, where a decrease in whiteness (darkening) may cause an increase in power. Usually the choice is dictated by the effects of static and other interfering electrical disturbances on the received picture. Here the print is usually made on white paper, or on paper which will turn out as white if no recording is made on it. If the white areas of the original picture cause an increase in radio power transmitted, then any static added to the signal received at a distant point will only cause increased whiteness in the corresponding areas of the record. If static occurs when a dark portion is being recorded the visible effect of the static is stray dots and lines of white, which are not very objectionable as there is always in a received picture a certain percentage of space (white) in between adjacent dark markings.

On the other hand, if an increase in darkness along a scanned line of the original causes an increase in power transmitted, the addition of static to the received signal causes dark spots in the entirely white areas. The contrast is less desirable than under the previous method.

Frequently a receiver is equipped to receive on either method, as transmitting stations may differ on this point. Even when a receiver is used only for a fixed service where the modulation method of the transmitter is known, it is desirable to be able to change the recording equipment to make either positive or negative prints. This can be done by a switch which changes the tone demodulator tube from

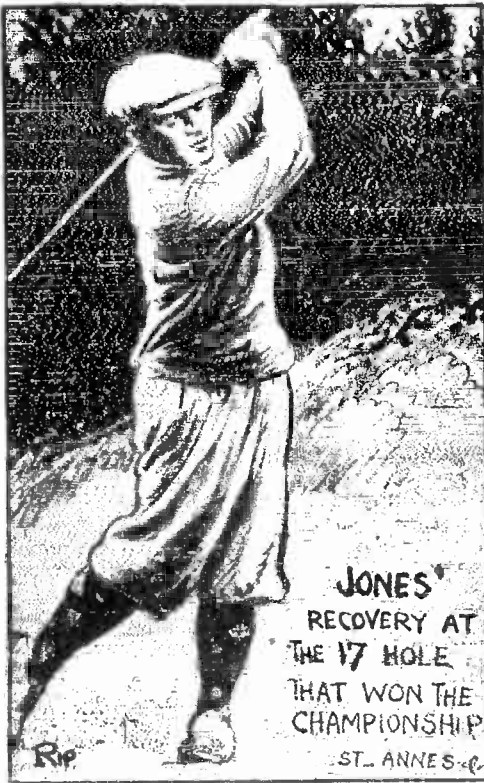
grid-leak to grid-biased detector operation, or by reversing one winding of a transformer between that demodulator and the output stage used for recording purposes. By this means an increase in whiteness on a scanning line at the transmitter may be made to record either as an increase or decrease in whiteness in the received record. This provides either a positive or a negative at will.



A COMMERCIAL FORM OF FACSIMILE SCANNER WHICH HAS THE OPTICAL ARRANGEMENT OF FIGURE 8. (COURTESY OF WESTINGHOUSE E. AND M. CO.)

#### EXAMINATION QUESTIONS

1. What is a negative?
2. How does light affect a photographic film?
3. What does a negative look like when closely examined?
4. How is the hot air in a photoradiogram receiver controlled?
5. What is the difference between photoradiograms and facsimile?
6. Why is a photoelectric cell used in picture transmission?
7. What two motions are necessary in a recorder?
8. Describe briefly the fundamental difference between two optical systems used for facsimile scanning.
9. Why must the light path of a scanning system be shielded from outside lamps or other light sources?
10. How may a recording system be changed from positive to negative recording?



THE REPRODUCTION OF A  
DRAWING TRANSMITTED  
BY RADIO FROM LONDON  
TO NEW YORK



A PICTURE OF EX-PRESIDENT  
COOLIDGE WHICH WAS  
TRANSMITTED BY THE  
PHOTORADIOGRAM SYSTEM  
OVER A DISTANCE OF  
3000 MILES



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