No. 129.

THE INSTITUTION OF
POST OFFICE ELECTRICAL ENGINEERS

PICTURE TELEGRAPHY.

BY

E. S. RITTER, D.F.H., M.I.E.E.

A PAPER

Read before the London Centre of the Institution on the 8th October, 1929, and at the following Centres on other dates:—Leeds, Birmingham, Bristol, Reading, Cambridge, Cardiff. and Manchester.

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PICTURE TELEGRAPHY.

1. INTRODUCTION.

Picture Telegraphy may be defined for the purpose of this paper as the transmission of print, drawings and sketches in black and white or facsimile and also the transmission of photographs, half-tones, etc., either over a telephone line, a radio link or long submarine telegraph cable.

The author has deliberately refrained from calling it Photo-Telegraphy or Tele-Photography as all systems do not use photographic methods and " tele-photography " is used by photographers to denote photographs taken with tele-photo lenses; nor does the author like the term *" facsimile telegraphy."

All systems, so far as the author is aware, require a sending apparatus, a receiving apparatus, means for keeping the movements of the sending and receiving apparatus in synchronism and a line or medium for connecting the sender and receiver, as well as arrangements for starting and stopping the apparatus.

Probably the earliest form of system was Bain's chemical telegraph dating from 1843. In this system the chemical action of the telegraph current produced visible signals on an impregnated paper tape. It was not until the advent of the thermionic valve and the photo-cell that the various systems could be developed to their present state of comparative perfection.

2. METHODS OF TRANSMITTING OR SENDING.

The sending apparatus has to scan the picture or print to be sent, line by line, and originate an electric current proportional to the whiteness or blackness of the picture. A distinction must be made here between those systems which send a current proportional to the whiteness of the picture, thus rendering all the intermediate tones, and those systems

* In America the term " facsimile telegraphy " has been put before the Standards Committee as suitable for defining the transmission of print or " black and white " diagrams or pictures.

which only send a current for *" white " with no current for " black," or vice versa, thus giving no half tones but only " black and white." A system working on the latter lines would transmit print and diagrams, but would not be suitable for pictures of photographs containing a range of tones.

The picture to be transmitted is usually mounted on some form of drum which is rotated and traversed in the same manner as a nut on a screw thread, so that all parts of the picture are brought consecutively under the influence of the sending device, in the form of a spiral. In some systems the drum rotates and traverses, whilst in others the drum rotates and the device traverses or the device rotates and the picture traverses.

(*a*) *The Photo-Cell.*

The Photo-Cell, developed by Elster and Geitel, consists of an evacuated or partially evacuated glass vessel with two electrodes and the necessary leading in wires. One electrode, the anode, consists of a plate of metal or a grid of wire, the other, the cathode, being a very thin film, generally of potassium, deposited on the glass. When suitably treated this deposit emits electrons when light falls on it, the number of electrons emitted being, within limits, proportional to the quantity and intensity of the light. To coloured light its sensitivity follows that of the ordinary photographic plate, but by special treatment its colour sensitivity may be changed. The glass vessel generally has a trace of hydrogen or other gas left in it.

Light from a lamp is projected on or through the picture to be sent and the reflected or transmitted light, as the case may be, acts on the photo-cell. The light is either projected as a small spot on the picture, or a small spot on the picture is focussed on to the photo-cell.

A battery is connected to the photo-cell so as to draw off the electrons in the form of an electric current. This current is extremely small, being of the order of 10^{-8} amperes for a normal white portion of the picture with good illumination. The photo-cell current is applied to the grid of an amplifying

* When setting up a circuit preparatory to transmitting a picture it is usual to transmit to the line or circuit a standard voltage, usually 0.5 or 1.0 volts, when the sending spot of light is reflected from a standard white surface. This is known as sending " white," and hereafter in the paper will be so described.

valve, or valves, in order that it may be amplified to any desired extent. The priming battery voltage must not be so high as to cause ionisation glow: up to about 150 volts will be found suitable, the precise value depending on the photo-cell used. Working 10 or more volts below ionisation point will be found satisfactory. There does not appear to be any appreciable time lag in the light/current effect in the photo-cell so long as ionisation does not occur.

(*b*) *The Selenium Cell.*

When Selenium is acted upon by light its electrical resistance changes. The voltage or current change with light is greater than with the photo-cell, but there is a time lag in the effect. The photo-cell has therefore superseded it for this type of work.

(*c*) *The Pin-Point Contact on Copper Foil.*

A picture is printed on copper foil, using the gum-bichromate process, and the gum is dissolved in places, so that a pin-point going over the surface can make contact with the copper; at other places it is insulated by the gum so that no current can flow between the pin-point and the copper foil. The current flowing through the pin-point actuates the transmitter.

(*d*) *Coding.*

The picture may be split up into elementary squares and each square may have a code letter assigned to it according to its density. *This is done by printing five copies on copper foil, but each copy is printed to a different depth, so that, when placed simultaneously in the same relative position under five pin-points, current flows in one or more paths, selecting one of five densities to be transmitted. The code may be telegraphed in the ordinary way, received and decoded; a picture is thus built up at the receiving end, each little square being given its appropriate density. The five-unit telegraph code is generally used for the purpose, the message being received on cross punched tape and sent from

* Since the paper was written the photo-cell has been adapted to this system. The varying output of the photo-cell suitably amplified operating five relays which in turn enable the paper tape to be punched. By an arrangement of coding about fifteen tones can be transmitted instead of five.

the telegraph office in that form to the newspaper or reproducing office.

3. AMPLIFIERS.

The photo-cell current is so small that it requires amplifying; this is conveniently done by means of thermionic valves.

Precautions are necessary to keep out any stray E.M.F's by careful screening of the valves and other apparatus.

Where the light from the sender lamp is not interrupted but only modulated by the picture density, then a battery coupled amplifier is used. The amplified current could then be sent over the line; as telephone lines will not carry low frequencies it is usual to cause this current to modulate an alternating current known as the " carrier " current. This carrier is conveniently produced by means of a valve oscillator, and is of a suitable frequency for transmission over the line. The modulated carrier is generally amplified before it is sent on to the line.

In other systems interrupted light is projected on to the photo-cell. In this case, the carrier frequency is the frequency of the light interruptions; and an amplifier of the resistance capacity or transformer type of coupling is used to amplify the signals. With all the amplifiers it is necessary to have a straight line amplitude-frequency characteristic from about half the carrier frequency to at least one and one half times the carrier frequency.

4. METHODS OF RECEPTION.

It is necessary at the receiving end to build up an image line by line in accordance with the current sent. Where " black " and " white " only are sent without half tones the receiving apparatus is required to make a black mark either when current is being received, or alternatively, when no current is being received. Where photographs or half tones are being transmitted black will be produced for strong currents, shading off into white for weak currents for producing a negative, or the reverse for a positive. For black and white the received current may operate a stylus which can ink a sheet of paper. For half tones it is usual to employ a photographic process in which a light spot is projected on to a photographic film of paper, the film drum rotating in synchronism and traversing with that at the sending end, the

intensity of the light being controlled electrically by the received current. Three methods of controlling the light spot will now be described.

(*a*) *The Oscillograph.*

The received current is amplified and rectified by means of thermionic valves. The resulting current is passed through an oscillograph which consists of a coil of wire on which is mounted a small mirror, the coil being placed in a strong magnetic field, the coil supports and the inertia of the coil being so proportioned that the coil can respond to rapid changes in current strength and the angle of movement of the coil and mirror proportional to the current. Light from a fixed lamp is projected on the mirror and thence through a specially shaped aperture and lens as a spot on the film. The aperture is arranged so that the intensity of the light spot varies with the tilt of the oscillograph mirror. The shape of the aperture is adjusted so that the light intensity may follow any required law of light to received current, either a straight line or preferably logarithmic curve, in order to suit the photographic requirements of the film.

(*b*) *The Vibrating Tape Light Shutter.*

The amplified current is passed through a thin metal tape of ribbon placed in a strong magnetic field, the field being at right angles to the length of the ribbon and also perpendicular to its flat side. The received alternating current will cause the ribbon to vibrate from side to side, the amplitude of the vibrations being proportional to the received current and the frequency of vibration being that of the carrier current. The ribbon is set in front of an aperture through which light is projected from a fixed lamp and as a spot on the film. Two adjustable jaws mounted one on each side of the ribbon serve to limit the light passed when the ribbon is at rest, and are so adjusted that a narrow band of light is passed on each side of the tape. When the tape is vibrating with maximum amplitude the current is adjusted so that a narrow black line is seen in the middle of the aperture, thus showing that the tape does not quite uncover half the aperture on either side.

The aperture is rectangular in shape but could be shaped to give other than a straight line law of current against light if required and the light spot width on the film is the same as the traverse of one revolution of the film.

(*c*) *The Kerr or Karolus Cell.*

The previously described devices depend on the electric current operating a mechanical light shutter; being mechanical there must be some inertia or time lag, thus limiting the carrier frequency to some degree. In the case of the Kerr cell the effect is purely electrical and no appreciable time lag has been measured; at any rate up to frequencies of 10^6 cycles per second.

If polarised light is passed between two electrodes immersed in certain liquids the plane of polarisation of the light is changed as the voltage across the electrodes is changed.

Professor Karolus has developed this effect, discovered by Kerr about 1890, to act as an electric light shutter. Light from a fixed lamp is passed through lenses and a nicol prism; it then passes through a glass vessel filled with nitro-benzol, in which are immersed two electrodes across which a potential difference may be applied. As used, this potential difference is the amplified alternating carrier current and is therefore proportional to the current received. The light then passes through an analyser prism and lens, and falls as a light spot on the film.

The nicol prisms are adjusted so that no light is passed when there is no potential difference across the electrodes. With a small increase in potential difference, very little light passes after a further increase in potential difference, the increase in light is proportional to the voltage up to a point where increased voltage does not increase the light but may decrease it. Special steps are therefore necessary if the light passing is to be made proportional to the current.

The curve of volts against light is shown in Fig. 1. In one system a direct current bias is given to the cell by a battery in series with the transformer; in another system two photo-cells are used at the sending end, a fixed one producing a voltage which brings the voltage to the bottom bend of the curve, and a second, which works from the picture, adding to it and thus working over the approximately straight portion of the curve. In another system, sending black and white only, no bias is given.

Types of cell. There are three types in use. The first, the "Simplex," consists of two electrodes about two millimetres in diameter with flat bases and the edges rounded off,

KERR CELL.

LIGHT PASSED : VOLTAGE ACROSS ELECTRODES. (DIRECT CURRENT).

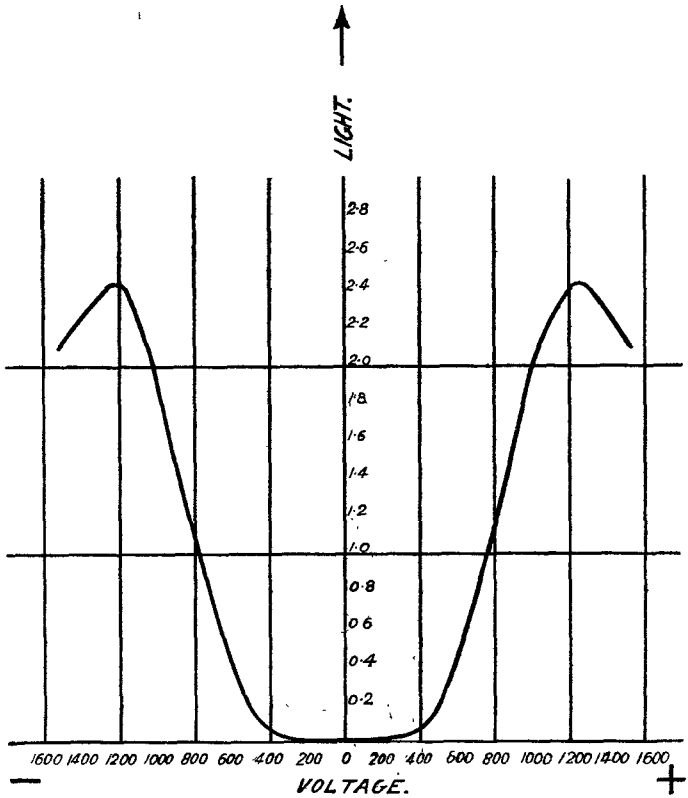


FIG. 1.

one electrode being adjustable so that the gap can be varied, the usual adjustment being a gap of one tenth of a millimetre; the second, the " Multiplex Type," shaped like the plates of an air condenser is not adjustable, but, like the first type, may be taken out for cleaning purposes; the third type is the " Multiplex " sealed in a glass vessel with the nitrobenzol. Fig. 2 illustrates the Simplex and Multiplex cells.

The voltages used for maximum light, that is " white " light, sent are :—

KERR CELL ELECTRODES.

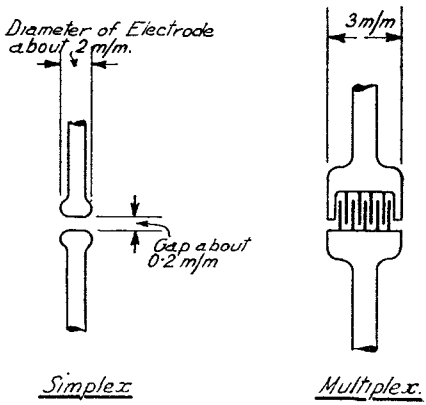


FIG. 2.

" Simplex " type—
Siemens, with 200 v. D.C., bias 600 volts A.C.
Marconi, without bias 800 ,, ,,

" Multiplex " type—
Unsealed, 170 v. D.C., bias 400 ,, ,,
Sealed, no bias 700 ,, ,,

(*d*) *The Neon Lamp or Ionised Gas Electric Discharge.*

Light from a Neon or other type of glow discharge lamp is concentrated as a spot on the film. The intensity of the illumination is controlled by the received current. Certain difficulties yet remain to be overcome, as with existing lamps the voltage required to start the glow is greater than the voltage at which the glow ceases, thus causing a certain lack of proportionality between the incoming energy and the light produced.

(*e*) *The Pin-Point Contact and Chemical Electrolysis.*

The picture current amplified (and rectified if alternating) is passed from a pin-point through paper, previously chemically treated and moist, and mounted on a rotating metal drum. The electric current decomposes the chemicals,

producing a colouration more or less proportional to the current received. Starch and potassium iodide are suitable chemicals to employ for this purpose.

(*f*) *The Hot Air and Waxed Paper Method.*

A stream of hot air controlled by the received current impinges on a waxed paper. The wax is more or less removed and allows the paper afterwards to take up more or less ink, giving a grading of tones. The " Ranger " system has used this method.

5. METHODS OF SYNCHRONISATION.

By " synchronisation " is meant the driving of the sending and receiving ends with exactly the same angular velocity. The picture to be transmitted and the film or paper at the receiving end are usually mounted on drums which rotate, or alternatively, the light spot rotates; in either case the angular velocity must be exactly the same or, at any rate, within very close limits.

(*a*) *The Independant Valve Driven Tuning Fork.*

A tuning fork driven and kept in vibration by means of a thermionic valve, and kept at a constant temperature by means of a heat insulating container with a thermostat and heater, or surrounded by a water jacket, has its tone amplified and applied to the stator of an alternator or synchronus motor.

The synchronus motor is used to hold a direct current motor at a constant speed. As an alternative, an harmonic of the tuning fork tone may be chosen by the use of a tuned circuit and applied to the alternator, giving under suitable conditions a choice of driving speeds.

In the case of transmission over a telephone circuit it is generally possible to send the " fork tone " over the line, and compare it with the " fork tone " at the receiving end, by watching a stroboscopic disc driven from the motor shaft and illuminated by a Neon lamp lit from the amplified " fork tone." The rate of vibration of the fork may be adjusted within small limits by altering the condenser reaction on the driving valve. Increasing the reaction increases the amplitude of the vibrations and slows down the fork, whilst decreasing the reaction has the reverse effect.

(*b*) *The Tuning Fork controlling a Carrier Current sent with the picture.*

A tuning fork, with a slower rate of vibration than that just described and electrically driven by means of make and break contacts, such as is used to drive some of the Baudot or Murray multiplex telegraph instruments, is employed to drive the sending apparatus by means of a phonic wheel or La Cour motor, and in addition, may be used to modulate a carrier current different from the picture carrier current, and sent along the line with the picture carrier current, but separated from it at the ends of the circuit by means of band pass filters. At the receiving end the carrier current is amplified and rectified, and used to hold a second fork in synchronism.

(*c*) *The Mechanical Governor with Correction Device.*

A mechanical governor of the friction or other type may be used to hold the speed constant either with or without correction.

6. METHODS OF PHASING.

Having arranged that the rotational speeds of the sending and receiving apparatus at the two ends are the same, or that the ends are " synchronised," it is necessary to ensure that when the clip or joint in the picture is opposite the sending spot of light the clip or joint on the film drum is opposite the receiving spot of light at the instant the electrical impulse emanating from the sending end is received. This operation is known as " phasing."

(*a*) *The Automatic Start with Relay and Clutch.*

The picture drum at the sending end may be started off from a definite position either by means of a mechanical or electromagnetic clutch. At the same instant a signal may be sent over the line starting the receiving drum from the corresponding position. Such a signal may be given by the interruption of the picture carrier current at the sending end. At the receiving end the current is amplified and rectified, and holds a relay which releases and starts the drum on the momentary cessation of the picture carrier.

(*b*) *The Rotating Neon Lamp.*

The driving mechanism including the attachments of the

sending and receiving drums, may be rotating continuously, the drums fitting the attachment in one position only. In this case, it is necessary to set the sending and receiving ends relatively in the corresponding position. This may be done by having a white line on the clip on the sending drum, the rest of the drum at this end being black. As this line passes the sending light spot picture carrier current is momentarily sent over the line and is used at the receiving end to light a rotating Neon lamp. The machine at the receiving end is adjusted, either by turning the stator of the alternator, or by pulling the set out of synchronism momentarily until the lamp lights opposite a set mark indicating the correct position. As an alternative the signal may be sent by means of a contact on the sender drum shaft. In cases where the receiver spot rotates it is also possible to " phase " by sending signals; and observing the light spot, the position of the joint in the sender drum being observed and adjustment made accordingly.

(*c*) *The Mechanical Governor with Correction Device.*

A mechanical detent can be arranged to stop the drum each revolution. The detent may be released by means of a signal sent when the picture clip passes the sending device. This system is known as the d'Arlingcourt principle.

7. SIGNALLING AND SPEAKING.

It is necessary to provide means for signalling or speaking between the terminal stations. In the case of transmissions over a long underground repeatered telephone circuits a telephone is used over the picture circuit between picture transmissions, calling being by 500 cycle tone with 20 cycle interruptions. In another case, a loud speaker is fitted at the receiving end, the sender only having to speak into the transmitter to call; this method has the advantage that if pictures are being sent one way only over a 4-wire circuit, instructions may be sent in the other direction during the transmission of a picture. An independant speaker circuit cannot in general be justified on cost, but if it exists there is no reason why it should not be used.

In one picture installation open wire aerial lines are used for telephone trunk purposes; pictures are sent over the same lines simultaneously using a carrier above audible frequency, and the picture speaker is a Morse sounder circuit worked over the same wires with direct current.

8. MEASURING INSTRUMENTS.

Ammeters and voltmeters, if not essential, are desirable for the valve filament and plate circuits and their batteries. In addition an alternating voltmeter for measuring the picture carrier output is very useful. Voltmeters of the thermionic valve type are supplied with some picture sets. The measuring equipment together with fuses and alarm relays is generally mounted on a control rack.

PICTURE SYSTEMS.

Picture systems at present in use in this country will be briefly described, the principal features of each being pointed out. Appendix 1 gives a comparison between the systems so far as it is possible to compare them. As some systems have several different carrier frequencies, scanning distances, etc., the scanning distance and carrier chosen for comparison is that nearest the average of the other systems.

9. THE SIEMENS-KAROLUS-TELEFUNKEN EXPERIMENTAL APPARATUS. (Fig. 3).

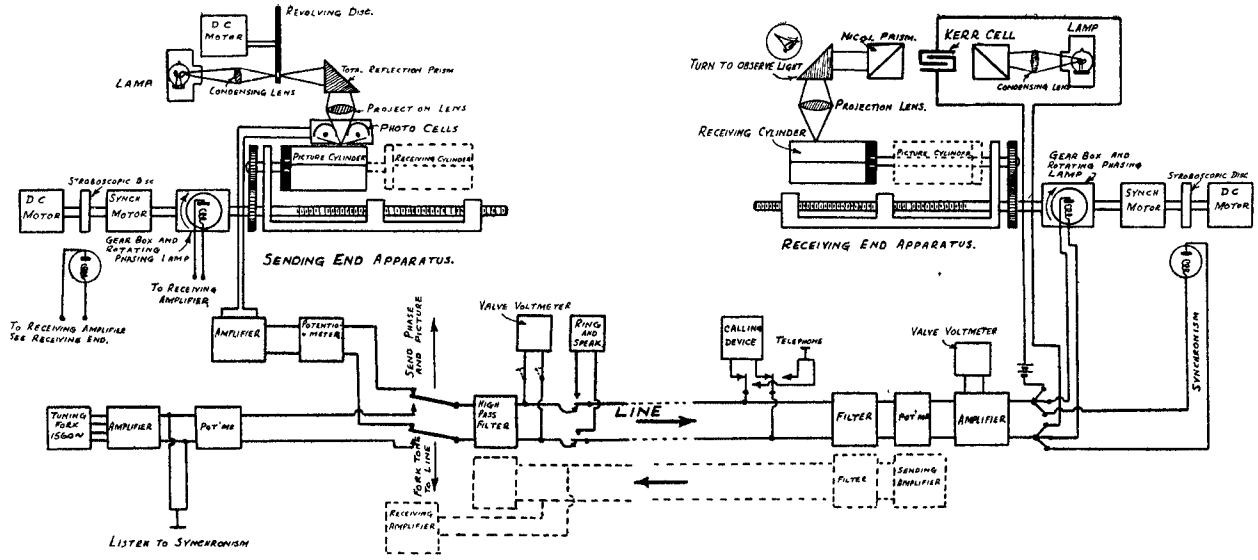
This apparatus is in use between *Berlin and Vienna and has also been used between London and Manchester for certain newspapers, pending the installation of permanent apparatus. It has also been used experimentally between London and Berlin and London and Paris and later for the transmission of newspaper pictures between these points. In addition a few experimental pictures have been made between London and Vienna *via* Berlin, a line distance of about 1,800 miles.

The sending and receiving instrument and driving mechanism are mounted on one table, the associated amplifiers on an adjacent table, and close by the control panel containing the battery switches, fuses, alarm relays and telephone ringing and speaking equipment, together with direct current ammeter and voltmeter, with shunts and series resistance for measuring the battery and motor voltage and currents.

The Sender.

Light from a 6 volt 5 amp. gas filled lamp with a concentrated filament, over run at about 7 volts; the filament being displaced from the centre to avoid reflections from the

* Since replaced by the commercial apparatus.



SCHEMATIC DIAGRAM OF SIEMENS-CAROLUS EXPERIMENTAL SYSTEM.

FIG. 3.

glass walls, is interrupted by a rotating disc with holes in its circumference and driven by an electric motor. The number of interruptions settles the carrier frequency. Three discs are provided with 30, 60 and 120 holes. The 60 disc is generally used and run at a speed giving about 1300 cycles per second, the exact frequency being adjustable with the speed of the driving motor. The light then passes through a prism to turn it at right angles, through a lens which projects an image of the diaphragm placed in front of the lamp as a spot on the picture to be transmitted about 0.2 mm. in diameter. To reach the picture the light passes through the middle of the photo-cell, which is in the form of a hollow ring, and is reflected back into the photo-cell.

The picture to be transmitted which should not exceed 20 cm. in length (the paper being 21.8 cm. to fit a drum 22 cm. in circumference, the breadth of the picture being up to 10 cm.) is clipped on to the sending drum. The sending drum when started clutches in to the rotating mechanism at one point in the revolution only. It can be made to traverse by engaging a half nut with a rotating screw thread, the half nut being coupled to the drum. The traverse is 1 cm. for 50 revolutions of the drum. The speed of the drum is 50 revolutions per minute. The receiving drum on the same shaft and coupled to the sending drum. A higher speed is available, if required, by gear changing.

The photo-cell, primed with from 100 to 150 volts and at least 10 volts below ionisation point, is coupled to the grid of a four valve resistance capacity amplifier. The anode resistances of the two middle valves are tapped, to provide means for adjusting the output from the last valve coupled to the line with a transformer. The adjustment is usually 0.3 volts for " white " on the picture. The sent voltage is measured on a valve voltmeter on the amplifier table. The energy passes to line through a high pass filter cutting off below 650 cycles per second. The amplifier is run off a 12 volt filament battery pairs of valves in series with a barretter resistance. The resistance consist of fine iron wire in a glass bulb filled with inert gas and arranged to hold the current to 1.1 amps. with reasonable variations of the filament battery voltage. The anode supply is 220 volts.

As direct current will not be amplified, fixed light reaching the photo cell will not, within certain limits, affect the results.

The Receiver.

The picture current from the line comes in through a high-pass filter and potentiometer, used for adjusting the amplification, into a two valve, transformer coupled, amplifier, the second valve being a power valve. In the output circuit of the power valve is a transformer with three windings, one for the anode current, one with a few turns for voltage measurements and listening with a high resistance receiver, the third having many turns and capable of giving up to 600 volts for application across the Kerr cell terminals.

Films 21.2 cm. by 10.4 cm. are mounted on portable drums with a clip, and placed in a light tight case in a dark room convenient to the receiving set. The drum and case are then fixed in the machine. The arrangement is such that the machine can be loaded and worked in daylight.

Light from a lamp similar to the sender lamp is sent through an aperture, lens and Nicol prism, Kerr cell, Nicol prism and a prism, which can either be turned to observe the light spot or turn the light rays through another lens as a spot on the film.

If the Kerr cell is of the " Simplex " type the received voltage is adjusted to about 600 for " white," and biassed with about 200 volts D.C. in series with the Kerr cell; if, however, the cell is of the " Multiplex " type the received voltage is adjusted to 400 A.C. with a bias of about 170 volts D.C. This gives a reasonably straight line law of light to volts on the Kerr cell.

Driving Mechanism.

The machine is driven by a D.C. motor, the speed of which is held constant by an alternator or synchronous motor. The latter is controlled by a 1560 cycle per second tuning fork placed in an iron case, the iron case being placed in a water jacket, which is surrounded by cotton wool in a wooden box. The fork is coupled to a bright emitter valve whose filament current is controlled and set by means of a variable resistance and milli-ammeter; a power valve stage follows, which in turn is followed by three power valves in parallel, the anode output of which is transformed into the alternator stator.

Synchronisation.

Having switched on the machine the motor is brought

up to speed, and held by its tuning fork. " Tone " from the fork at the far end is sent over the line and the receiving amplifier is switched on to a fixed Neon lamp instead of the Kerr cell. The stroboscopic disc on the motor shaft should be observed to see if it appears to move. If the home fork is fast, the rate of vibration of the tuning fork is slowed by increasing the condenser reaction; but if slow, decreasing the reaction speeds up the rate of vibration, alternatively the distant end fork may be adjusted.

" Phasing."

The picture drum is started, but not traversed; a white mark on the clip sends " tone " as the clip passes the sender light " tone " spot. At the receiving end the receiving amplifier is switched over to a rotating Neon lamp, and this lamp is caused to light opposite a mark by pulling the machine momentarily out of synchronism or rotating the stator of the synchronous motor.

A white spot on the picture is next set opposite the light spot and the sent and received volts adjusted. The drums are then started, and at the word " go " the traverse is engaged.

The receiver observation prism is turned on to the film, when observation shows that the picture is coming in. At the end of about eleven minutes the drum stops at the end of the traverse. It is then taken from the machine and the film developed.

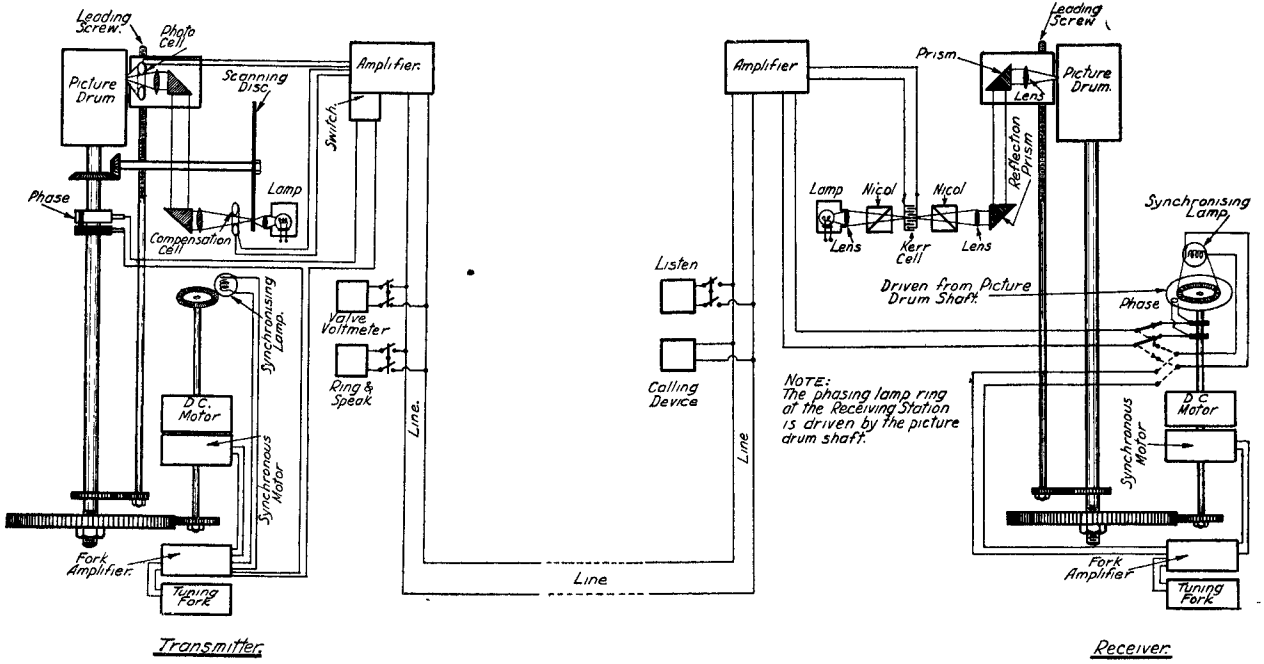
A second picture is inserted at the sending end and a second film at the receiving end, " white " is sent, and the voltage adjusted and the picture started, re-phasing and re-synchronisation being unnecessary, having been done for the first picture. With a 4-wire circuit, it is usual to send and receive a picture at the same time. Should the picture clip appear on the received film the " phase " can be adjusted. An amplifier and loud speaker at the receiving end may be used to indicate a line interruption. If a serious interruption has occurred the picture can be stopped and the operation recommenced without waiting for the 11 minutes to elapse. Ringing is by means of 500/20 cycle current, the receiving ringer always being across the line so that if required a picture may be interrupted and the line spoken on in an emergency.

10. THE SIEMENS - KAROLUS - TELEFUNKEN COMMERCIAL APPARATUS. (Fig. 4).

This apparatus is used by several British newspapers. The design is based on the experimental apparatus, but there are important differences which facilitate operating.

The sender is mounted in a metal box, the motor and drum are vertical, with the scanning disc geared from the motor shaft. The drum can be removed with its holder and is 27 cm. in circumference, taking a picture 25 cm. by 18 cm. The picture is mounted on the drum away from the machine, the drum is placed in its case and the case inserted in the machine, the drum automatically taking up its correct position on the shaft which is continuously rotating. The optical system, conveying the light from the lamp to the pictures and photo-cell, traverses up for one picture, and down for the next. As soon as a drum is removed from the machine, " white " is sent by the light from a shutter which reflects back into the photo-cell. " Phase " is sent by passing the photo-cell current through a brush and contact on the drum shaft. Three different traverses are available of 50 (normal), 40 and 30 lines per centimetre. Three rotation speeds are available of 47, 94 and 188 revolutions per minute, the normal for loaded telephone lines being 47; but with a suitable line the higher speeds could be used. In addition, at each speed a choice of two or more carrier frequencies is available, a 180 hole disc at the lowest speed giving about 1125 cycles per second and a 130 hole disc about 810 cycles per second. Other discs are also available. On the slowest speed and finest traverse a picture takes about 20 minutes. The machine can be set to traverse any pre-arranged distance and stop when the picture does not take up the whole drum. An indicator shows the position of the photo-cell, which being inside the case is invisible.

With this type of apparatus two photo-cells are used, the " picture-cell " and a second, a " compensation-cell." The " compensation-cell " is arranged to send a fixed amount of carrier frequency current irrespective of the picture tone density, whilst the " picture-cell " varies its output in accordance with the tone density of the picture. By arranging for the outputs of the two cells to add the output will be a maximum for a white portion of the picture and for black there will remain the output from the compensation cell as a minimum. When sending " white " the output being



SCHEMATIC DIAGRAM OF SIEMENS-KAROLUS- TELEFUNKEN COMMERCIAL APPARATUS.

FIG. 4.

adjusted to 0.5 volts with both cells and 0.4 volts with the picture-cell only a 20% compensation is said to be given. Varying the compensation ratio changes the photographic contrast in the received picture compared to the sent picture. Compensation ratios of from 15 to 30% are used, depending on the character of the sent picture. When black and white print or diagrams are sent no compensation is sent.

The " compensation-cell " also enables positive pictures to be received: in this case the " compensation-cell " output is adjusted to 0.5 volts and the " picture-cell " output is arranged to subtract from the " compensation-cell " output so that when " white " is being sent the output is 0.1 volts. In this manner a black portion of the picture will send 0.5 volts, whilst a white portion will only send 0.1 volts.

Adjacent to the sender is the control board consisting of a rack containing the tuning fork (which is thermostatically controlled), amplifiers, fuses, keys, meters and telephone, etc. The photo-cell batteries are in an adjacent room in a screened metal box, and are of the secondary cell type.

The receiver is very similar to the sender, with the exception that a phasing disc is placed below the synchronising disc. The Kerr cell is sealed in a glass vessel and it has no D.C. bias, the fixed carrier current from the second or " compensation " photo-cell at the sending end fulfilling the function of the bias by bringing the carrier current voltage to a point where the light-voltage curve begins to be reasonably straight. The receiving voltage is adjusted to 700 A.C. for " white " light sent.

Synchronisation is by a Neon lamp lit from the " fork tone," lighting a disc, on the motor shaft, with radial lines on it. When these appear to stand still the machine is held by the fork. Distant end " fork tone " can be switched to this lamp for adjusting the receiving end fork by switching in or out capacity reaction on the fork amplifier.

The films are mounted on drums in the dark room, and inserted in the machine in daylight. The drum rotates and if the light spot is traversed the reverse way to the sender then the picture prints like an ordinary photograph, film to film; but if the light spot is traversed the same way the picture is reversed and has to be printed the wrong way through the film. When receiving a positive on paper the traverse is the same direction at both ends. The valves work

off a 12 volt filament battery, and the plates and motors off 220 volts.

The diameters of the drums are 88 millimeters, taking a picture 25 centimeters by 18 centimeters.

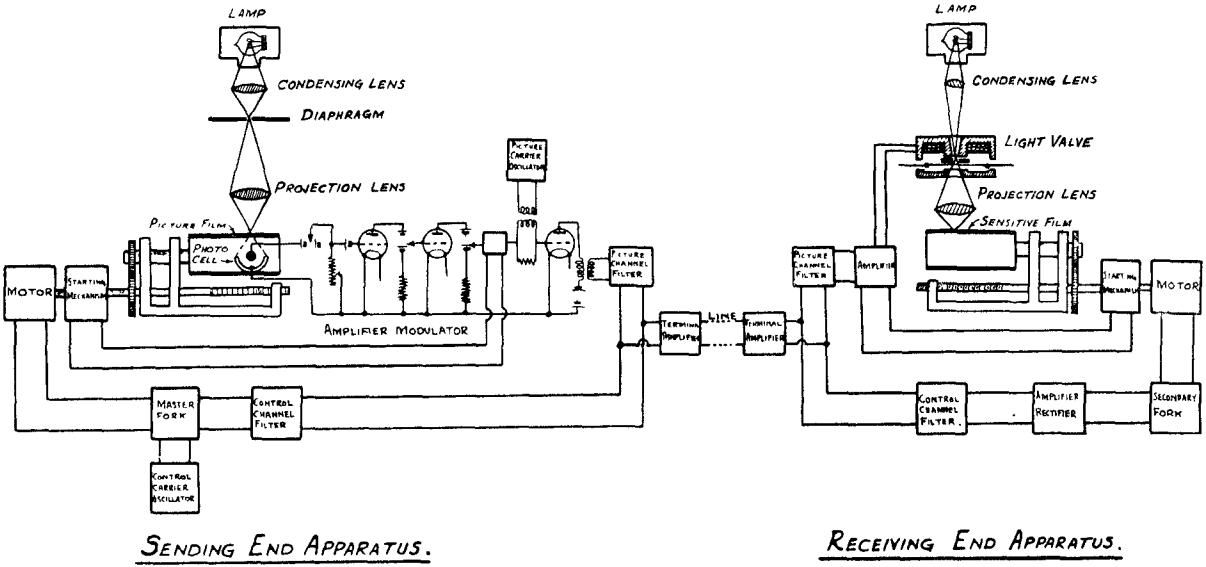
11. THE BELL SYSTEM.

This system (Fig. 5), which has been developed by the American Telephone and Telegraph Co., is in use in this country by a newspaper.

The Sender. A positive film is prepared from the picture to be sent, then mounted in the carrier either wet or dry and placed in the sending machine. Light from a 12 volt 4 amp. lamp, whose current is adjusted with an ammeter and resistance to about 3.7 amps. is projected as a spot through the film into the photo-cell, which projects inside the film carrier. The film carrier rotates and traverses. The photo-cell current is amplified with a battery coupled amplifier, and modulates a carrier current from an oscillator of about 1300 cycles per second. It is further amplified and sent to line at the power of 1 milli-watt for " white light " sent. Adjustments are provided for contrast, *i.e.*, for ratio of " white " to " black," and also for amplitude of amplification to line. " Black " is adjusted to be 14 db below white, a ratio of voltage of about 5 to 1.

The Receiver. A film is mounted on a carrier, a slow film being used. As the film is exposed the machine has to be worked in a red light. A lamp similar to that used at the sending end transmits its light through an aperture in front of which is placed a ribbon of thin metal. The amplified picture carrier current traverses the ribbon which vibrates, its amplitude of vibration corresponding to the strength of the picture carrier current. The ribbon is adjusted so that when " white " is sent it just leaves a line covered in the middle of the aperture and when " black " is sent white lines are just visible on each side. This is arranged for a power difference of 14 db, or a current ratio of about 5 to 1.

Driving Mechanism and Synchronism. A 60 cycle per second tuning fork, driven from a 110 volt supply by contacts worked by the fork, drives a phonic wheel motor. This motor is similar to that used to drive certain telegraph apparatus, only it has a large fly wheel and is geared to the picture shaft by a skew gear. The motor is not self-starting, but has



SCHEMATIC DIAGRAM OF BELL SYSTEM.

FIG. 5.

to be started by hand by means of an instrument similar to a drill brace.

The tuning fork at the sending end is also used to modulate a 495 cycle per second oscillator tone which is sent over the line along with the picture carrier current, but about 30 db lower in power, and is separated at the two ends by band pass filters from the picture carrier current. At the receiving end the modulated fork tone, which is amplified and rectified, keeps the receiving end fork in synchronism.

"*Phasing,*" as such, is not required. The sender film holder always stops with the support opposite the light spot. A hole in the holder allows light through, thus sending "picture tone" to line. A key, which operates the starting clutch at the sending end interrupts this tone which, in turn, at the receiving end, operates a relay starting the drum at the receiving end. As the film drum starts from a definite position the two drums are in phase.

Adjustments of 1 milli-watt are sent for white; black 14 db below; but when no half tones are required black is 20 db below white. When no film is in the holder at the sending end, a window equal in density to clear film is placed in the light path. The adjustments are made by the sender lamp current or by the voltage on the photo-cell, which is normally about 80 but may be raised to about 100 volts.

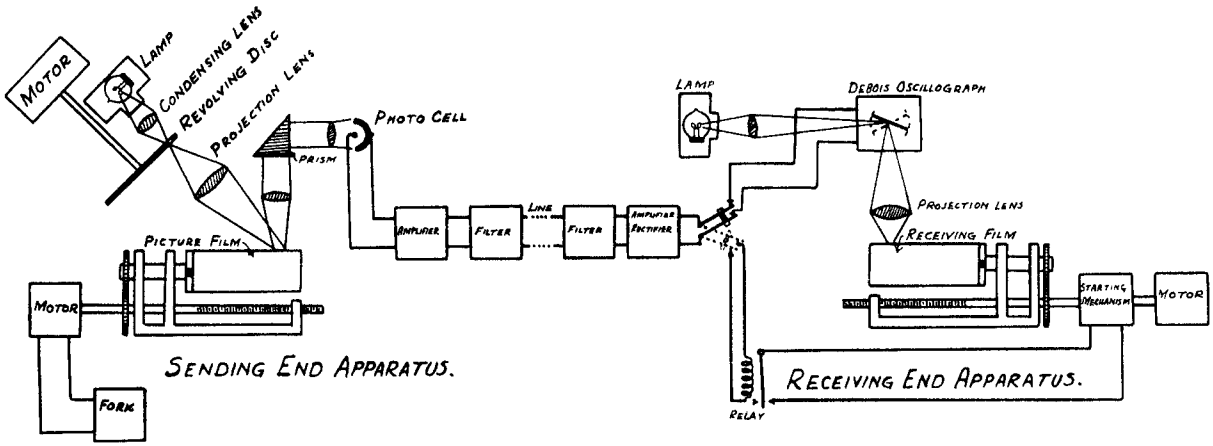
The size of the picture is 7″ by 5″, and the drum which has a circumference of 6″ rotates at 90 r.p.m., and traverses at 100 lines per inch.

12. *THE BELIN SYSTEM.

This system, of French origin, is used in this country by one or two newspapers. (Fig. 6).

The Sender. Light from a 16 volt, 60 watt lamp is interrupted by a rotating disc with holes in its circumference and projected by a lens as a large spot on the picture to be sent. An image of a spot on the picture, about 0.5 mm. in diameter, is focussed on the photo-cell through a small aperture. The resulting photo-cell current is amplified (a four electrode valve being used for the purpose in the first stage, and push-pull in the last. Four volt valves are used).

* Since the paper was written a new type of apparatus has been introduced with several improvements.



SCHEMATIC DIAGRAM OF BELIN SYSTEM.

FIG. 6.

The picture is fastened by clips to a drum, which is identical in sender and receiver. The drum rotates and is slid along the shaft by the traverse mechanism. The drum circumference is 16.5 cm., and takes a picture 15 cm. by 10 cm. The speed is 78 revs. per minute, but this can be changed if desired. The traverse is 55 lines per cm. The carrier frequency is from 800 to about 1300 cycles per second, and is adjustable with the speed of the scanning disc motor.

The Receiver. Fast speed paper (which gives the best results), or film, is mounted on the drum in the dark room, and the drum enclosed in a light-tight case for mounting on the machine which runs in full daylight. Light from a lamp similar to the sender lamp is focussed on to the mirror of an oscillograph, and is then projected, through a specially shaped aperture, as a spot on to the receiving drum. The incoming picture tone is amplified and rectified and operates the oscillograph. Pictures may be received either as negatives or positives. The ratio " light to current received " can be altered by the use of different shaped apertures.

Synchronisation. A 32 cycle per second tuning fork contact drives a phonic wheel motor. No phasing is requied. A starting signal is sent by having a white band on one end of the sending drum, except at the clip, which is black. At the receiving end the tone is amplified and rectified. The interruption of the tone as the clip passes the sending light spot causing a relay to release and start the film drum.

13. THE FULTOGRAPH.

This is a relatively simple and cheap instrument. The sender drum, on which is mounted the picture to be sent, is driven by a gramaphone motor with a special governor to keep the speed constant. The picture is prepared on copper foil by a process which keeps the parts to be received white insulated, and the black parts conductive. A stylus traverses the picture as it rotates current flowing and producing picture carrier current on the conductive portions and no current on the insulated parts. The amplified and rectified current in the receiver flows through a stylus on to chemically prepared paper and produces a mark, more or less proportional to the current, by electrolysis of the chemicals in the paper.

Synchronisation. A mechanical governor holds the speed of the receiver to within 1% of that of the sender at the

instant the clip of the sender is passing the stylus. A detent holds up the receiving drum for an instant and is released by the picture carrier. The drum is about 10 cm. long and 5 cm. in diameter, taking a picture $4\frac{1}{2}'' \times 3\frac{1}{2}''$. The speed is 50 r.p.m., and the traverse about 25 lines per cm. Picture time is about $4\frac{1}{2}$ minutes.

14. *THE MARCONI FACSIMILE SYSTEM (Fig. 7).

This system has been developed principally for the purpose of getting high speed facsimile working, *i.e.*, black and white without half tones on radio services, such as the Beam System, the proposed use being to send writing or print. Strictly speaking it is not a picture system, though pictures could be sent.

The Sender is driven by a D.C. motor, which is held in synchronism by an alternator on the same shaft. In line with the alternator and motor is either the transmitting drum in the sender, or the receiving drum in the receiver, directly coupled by means of a special flexible coupling with no backlash. The optical system goes down the centre of the hollow shaft and the light spot rotates, only the picture to be sent traversing. Light from a sender lamp in line with the shaft has its light interrupted by a disc with holes in it, the frequency being adjustable, but of the order of 5,000 to 10,000 cycles per second for transmission over aerial lines prior to radio transmission. A diaphragm is interposed between the disc and the motor shaft, the image of the diaphragm being projected by a lens and rotating prism as a spot on the print, to be sent through a slot on the outer fixed drum. The reflected light is taken by another prism and sent through the shaft to the photo-cell and the first amplifier, which are in a screened metal box in line with the shaft.

Synchronisation and Phasing. A valve-driven tuning fork, in a heat-insulated case and the temperature controlled by a thermostat, gives out a 300 cycle per second tone which, when amplified and applied to the alternator, gives a speed of 90 revolutions per minute. The output stage of the oscillator takes 500 milli-amps at 500 volts, so that a good control exists. By using either the second or fourth har-

* Since the paper was written the apparatus has undergone several modifications and improvements.

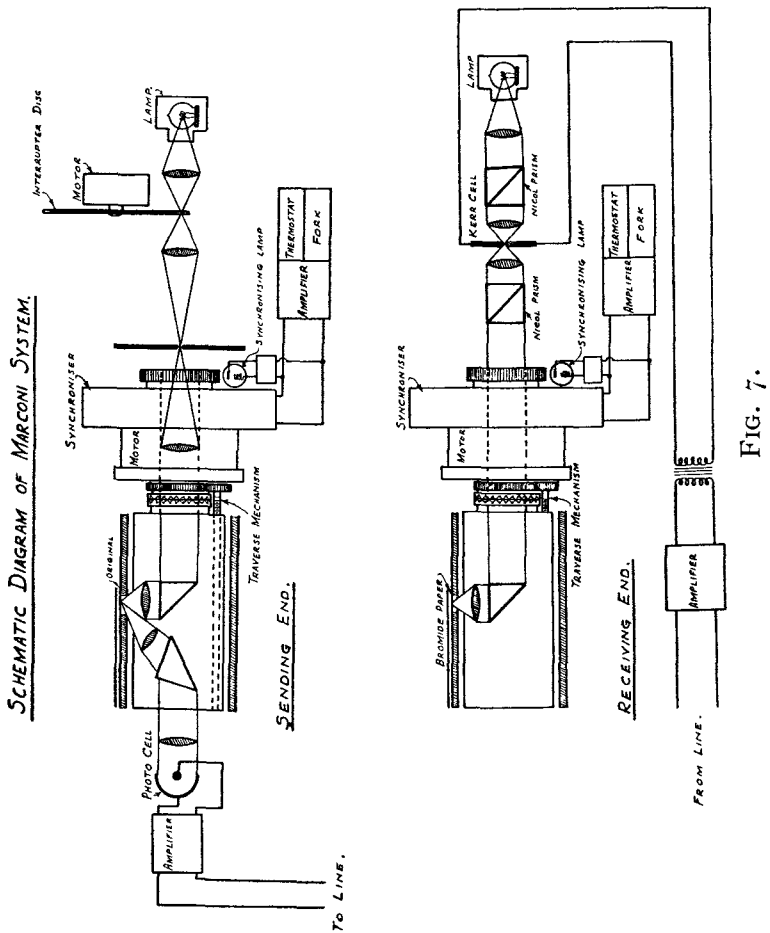


FIG. 7.

monics, speeds of 180 or 360 r.p.s. are obtained. It should be mentioned that one of the features of this machine is the lack of gearing with its liabiity to backlash and unsteady running. A toothed wheel is mounted on the motor shaft and lit from a Neon lamp supplied with fork tone; when the teeth appear to be stationary the motor is in synchronism with its own fork. No attempt is made to adjust the fork vibrations, such adjustment having been made prior to the apparatus leaving the factory. The temperature is kept close to the calibrated value, it is therefore unnecessary to

send " fork " tone to the distant end, a process which might prove difficult under radio transmission conditions. The stator of the alternator and motor can be rotated to adjust " phase."

A leading screw geared to the motor shaft, as in a screw-cutting lathe, with change wheels, provides means for altering the traverse, traverses of 60, 80, 100, 120, and 140 lines per inch are provided. A leather flap, connected to a nut can be engaged with the leading screw, slides the document to be transmitted along the outer fixed drum and past the sending slot, the document being placed under the flap.

The Receiver is almost identical in construction with the sender. Light from a lamp is passed through a lens, Nicol prism, " Simplex " Kerr cell, Nicol prism and through the hollow shaft to a prism, which passes the rotating light spot on to a piece of bromide paper through the slot in the outer drum. The bromide paper is held down by a sheet of transparent celluloid connected to the traversing nut and slides the bromide paper along. The machine has to be worked in an orange light, as the bromide paper is exposed to the light of the room.

The lamp filament image is focussed on to the Kerr cell, and the Kerr cell gap as a point on the paper; means are also provided for turning one Nicol prism to get extinction of the light. No bias is used on the Kerr cell, which works with about 800 A.C. volts.

Only half the sending and receiving end drum circumference is utilised; the second half being taken, if required, with a second machine. Phasing is carried out by sending from a striped paper, the receiving spot which appears to stand still being observed. The alternator stator is turned until the black and white stripes appear in the top half of the circumference at the receiving end.

The drum circumference is 21″; of this 10″ is used, 1″ wasted and 10″ taken by a second machine. The size of document is 10″ round, by 8″ or less long, observation of the light spot at the receiving end indicates at once the finish of a transmission when the picture is less than the standard length of 8 inches.

The time for two 10″ by 8″ messages at the slowest speed of 90 r.p.m. and 100 lines to the inch is 8.9 minutes or at the

maximum speed of 360 r.p.m. 2.22 minutes. With a coarse traverse of 60 lines at maximum speed the time is 1.33 minutes. For other traverses and speeds the times are proportional.

One advantage of the high carrier frequency on the aerial lines employed for this system is that most of the low frequency disturbances are eliminated by the high-pass filter at the receiving end.

15. *THE BART-LANE SYSTEM.

This process is used by an English illustrated daily newspaper to receive pictures by cable from America. *The original is printed on five sheets of copper foil to five different depths of tone; the parts to be transmitted being conductive, and those not to be transmitted being insulated. The five prints are mounted in line on a shaft which rotates; five copper needles make contact one with each print at the same point in each picture, where five tones are to be transmitted, all five make contact; but where only four, three, two, one or no tones are to be transmitted contact is made accordingly. Each needle controls a magnet, or relay, which operates a selector bar punching out tape of the five-unit telegraph code. This tape is sent to the telegraph office, and is transmitted in the ordinary way. At the receiving end the message is received on a similar punched tape which is delivered by the telegraph company to the newspaper office. The tape is placed in the receiving end of the machine, the holes controlling the light received on a rotating film which reproduces the original picture. The machine is designed to take a picture 4″ round the circumference and up to $3\frac{1}{2}$″ long or a maximum of 14 sq. inches. Each unit of the picture is one seventy-fifth by one fiftieth of an inch, or 3750 units per square inch.

The Western Union Company's cables which are used, can transmit 1620 letters per minute, using four channels on the high speed cable. A picture of full size containing 52,500 units can therefore be sent in about 33 minutes; with the older cables a longer time is required.

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* Since the paper was written the photo-cell has been adapted for transmitting on this system.

16. THE TELEPHONE LINE AND "PHASE" CORRECTION.

In order to receive good pictures over a telephone line certain characteristics are essential. The principal requirements being:—

(1) The attenuation of all frequencies used on each side of the frequency of the carrier current should be the same: say from half the carrier frequency to one and one half times.

(2) The propagation velocity, or more strictly the propagation time, of the frequencies in this band should be the same, or not differ by such a time interval that the picture is affected appreciably. One rule would be to take the time as the interval for the drum to move a distance equal to the traverse distance of one revolution. The effect of different propagation velocities is that a time is required to build up the signal to its full value from the time it commences arriving. In a coil loaded line the higher frequencies travel slower than the lower ones, until at the cut off frequency they never get there. Let "x" be the wave-length constant per loading section, or in other words the phase change per loading section at the particular frequency being considered. "ω" equal to 2π times the frequency "f." "N" the number of loading sections, and "Nx" equal to "a" the total phase change of the line, "L_0" the inductance of a loading coil in Henries, and "C_0" the capacity of a loading section in Farads.

"ω_c" equal to 2π times the cut off frequency.

Then:—

$$\omega_c = \frac{2}{\sqrt{L_0 C_0}}$$

"t" the time of transmission from the sending end to the receiving end $= \frac{xN}{\omega} = \frac{a}{\omega} = \frac{2N}{\omega} \sin^{-1} \frac{\omega}{\omega_c}$ (seconds)

Now it is known from elementary trigonometry that when the angle is small the sine is equal to the angle in radians, so that when "ω" is nearly zero $\sin^{-1} \frac{\omega}{\omega_c}$ is the same as $\frac{\omega}{\omega_c}$ or that "T_0" the time of zero frequency is $\frac{2N}{\omega_c}$ (seconds). Further it is seen that $\frac{\omega}{\omega_c} = \sin \frac{1}{2}a$.

Now the time of propagation plus the time required by the signal to build up to approixmately half its full value is given by :—

$$\text{“ T ”} = \frac{\alpha_c}{\alpha\omega} = \frac{2N}{\omega_c} \text{ sec. } \tfrac{1}{2}\alpha \text{ (seconds).}$$

If the time of zero frequency is subtracted from this, the time taken for the signal to build up to half value from the arrival time of zero frequency is $T - T_0 = \frac{2N}{\omega_c}$ (Sec. $\frac{1}{2}\alpha - 1$).

Taking a concrete example of a line 100 miles long loaded at 1.125 mile intervals with 175 *m*H coils. It has a cut off of 17,750 radians per second or 2820 cycles per second and is known in the Post Office as a Medium Heavy Side Circuit or L155, a common type of line :—

T_{650} = the time for 650 cycles per secn. is 10.3 milli-secs.
T_{1300} = ,, ,, ,, 1300 ,, ,, ,, 11.3 ,,
T_{1950} = ,, ,, ,, 1950 ,, ,, ,, 13.9 ,,

If a high-pass filter is inserted in the line the signal may be said to build up from 650 cycles to the carrier 1300 cycles, giving a building up time of 11.3 − 10.3 = 1 ms. Strictly speaking, a further time should be added to take account of the attenuation or amplitude distortion; an approximate figure may be determined by taking the frequencies f_1 and f_2 in cycles per second where the attenuation at each end of the band of frequencies received begins to exceed by about 5 db the best transmission efficiency in the band; then the time to be added is $1/(f_1 - f_2)$ seconds. If the picture traverses at 50 lines per cm. then the scanning velocity should not exceed 20 cm. per second. (In the case of the Siemens commercial apparatus on the slow speed the scanning velocity is 22 cm. per sec.). For 200 miles the speed should not exceed 10 cm. per sec., and so on. The alternative is to use a lighter loading on the line for the longer distances; such a line has more attenuation, requires more amplification, and it may not exist on a route over which a picture circuit is required. Another alternative is to insert at some point, or points, in the line “ *Time Correction* ” or “ *Phase Correction* ” networks made up of capacities and inductances. Such networks have been developed in Germany and America, and by means of them it is possible to correct the propagation time over a reasonable range of frequency.

(3) The line should be reasonably free from noise and cross-talk. The power level should not be allowed to fall very far below 1 milli-watt, say, not more than 15 db.

(4) The attenuation of the line should not vary from time to time or during the transmission of a picture. A low resistance telephone placed across the line produces an appreciable loss.

(5) The amplifiers or repeaters should not add spurious frequencies. The repeaters should not be overloaded, the output level should not exceed 10 milli-watts.

(6) The line should be free from echo and transient effects. " Monitoring on " or leaving the monitoring plug in a 4-wire repeater couples the " Go " and " Return " circuits, and as pictures may be sent both ways simultaneously cross-talk between " Go " and " Return " circuits results. Echo suppressors must be cut out for the same reason. The circuits must be extended 4-wire at the ends. In the case of a 4-wire circuit using one-way transmission either the circuit must be extended 4-wire at one end or balance networks inserted to prevent circulating currents.

17. THE PHOTOGRAPHIC PROBLEM.

A photograph with its smallest spot one two hundredth of an inch in diameter is said to be critically sharp, anything coarser than this falls off proportionally in perfecton.

It is easy to reproduce black and white, such as print, or writing, which have no half tones. The correct rendering of all tones in a photograph, however, is quite another problem. The ratio of light and exposure to density in the negative and from the negative to positive, is not constant.

In the case of electrical transmission starting with a positive the reception may be as a negative or as a positive, and similarly starting with a negative the result at the receiving end can be made negative or positive. In the electrical transmission proportionality of current and light may be lost to some extent, as well as definition. Further, in making blocks for newspaper reproduction the tones are deliberately distorted.

It is not possible within the limits of this paper to give a more detailed survey of the question. A good photographer, by properly choosing the exposure and quality of the printing papers, is able to correct some of these faults.

18. PICTURE TRANSMISSION SERVICES.

A public service using the " Bell " system is available in America between New York, Boston, Atlanta, Cleveland, Chicago, St. Louis, San Francisco and Los Angeles.

Since this paper was written a public service has been opened by the British Post Office in conjunction with Foreign Administrations using the Siemens-Karolus system between London and Berlin, Frankfort-on-Main, Munich, Vienna, Copenhagen and Stockholm and in addition a private service to Paris. Newspapers and the Post Office also can work to private stations on the Continent at Paris, Berlin, Hamburg, Milan, etc.

A public service has also been opened between Melbourne and Sydney in Australia.

A private newspaper service also exists in Japan.

In conclusion, I wish to express my indebtedness to the Engineer-in-Chief of the Post Office and Col. H. E. Shreeve, of the American Telephone and Telegraph Co., Messrs. Siemens and Halske, Ltd., Capt. Bartholomew and " The Daily Mirror," " The Daily Mail," " The Daily Express," " The Daily News," " The Daily Sketch," " The Scotsman," " The Glasgow Herald," for the loan of specimen prints and for information supplied.

APPENDIX I.

COMPARISON OF SYSTEMS.

The following table compares the various systems. Some of the information may not be exact, but it is the best available.

System.	*Sending System.*	*Receiving.*	*Synchronisation.*
(1) SIEMENS EXPERIMENTAL ...	—	—	—
(2) SIEMENS COMMERCIAL ...	Interrupted light, light spot focussed on picture as spot 0.2 mm. dia. reflected into photo-cell. Interrupted light to fixed photo-cell for altering contrast in picture. Scanning disc geared to picture drum. Picture drum rotates, photo-cell traverses. Fixed photo-cell carrier added to picture carrier or picture carrier may be subtracted when receiving positive from positive sent.	Amplified A.C. to Kerr Cell, Sealed Multiplex type. No D.C. bias. Bias provided by fixed carrier. Drum rotates light spot traverses. Machine in daylight.	Valve driven tuning fork, thermostat control, drives alternator which controls D.C. motor. Phasing necessary.
(3) BELL	Fixed light through special aperture. Transmitted through prepared transparent film. Battery coupled amplifier. Picture current modulates oscillator produced carrier.	Amplified A.C. operating vibrating ribbon light valve, slow film used for receiving. Drum rotates and traverses. Machine in dark room with a red light.	Contact driven tuning fork drives phonic motor. Also modulates driving carrier sent to line along with picture carrier. Separation by Band filters. Autimatic start.
(4) BELIN	Interrupted light, large spot on picture, reflected light, small spot taken and focussed in photo-cell. Scanning disc independent drive. Picture drum rotates and traverses.	A.C. carrier amplified and rectified operates oscillograph light projected through specially shaped aperture. Drum rotates and traverses. Machine in daylight. Can receive positive or negative by reversing aperture.	Contact driven tuning fork operates phonic wheel motor. Automatic start.

System.	Sending System.	Receiving.	Synchronisation.
(5) FULTOGRAPH	Pin point on copper foil with prepared picture modulates carrier.	Pin point produces image by electrolysis carrier amplified and rectified. Drum rotates pin point traverses.	Gramophone motor drive, mechanical governor, mechanical detent released electrically each revolution.
(6) MARCONI FACSIMILE ...	Interrupted light, spot focussed on picture, spot reflected and focussed on photo-cell. Independent drive of scanning disc. Light spot rotates, picture traverses.	Amplified carrier to Simplex Kerr Cell. No. D.C. bias (black and white only) or Neon lamp. Reception on bromide paper. Spot rotates and paper traverses. Machine in orange light as paper exposed.	Valve driven tuning fork, thermal control, drives alternator holds D.C. motor in synchronism. Phasing required.
*(7) NIPPON ELECTRIC CO. ...	Interrupted light, can use either transmitted or reflected light. Picture drum rotates and traverses.	Oscillograph movement vibrating with carrier frequency, special apertures for receiving positive or negative from either positive or negative sent. Machine works in daylight.	Phonic wheel control of D.C. motor either 100 cycles per sec. transmitted over line with picture, or beat frequency between 350 and 450 cycles per sec. used. Automatic start.
(8) BART-LANE	Five prints prepared on copper foil with different exposures, pin points make contact and operate 5 selectors which punch up 5-unit code telegraph tape for transmission. Pictures rotate and traverse. Now uses the photo-cell to operate the 5 relays which operate the punch selectors.	Five-unit code cross punched tape received from telegraph office put in machine. Light controlled by tape. Film on drum rotates and traverses. Machine works in daylight.	Machine motor driven. No synchronism. Tape started at correct position. End of line indicated by punching holes 1, 3, and 5 in succession.

* The Nippon Electric Co. System has not been referred to in this paper,

APPENDIX II.

COMPARISON OF SYSTEMS.

System.	Carrier frequency ( ) indicates adjustable.	Scanning Speed CM./ Sec.	Scan min. per cycle.	Traverse.		Drum.		Picture.			Time min.	cm.² per min.	Tuning fork frequency cycles per sec.	Single space typewriting at 9 15 letters per square centimetre letters per minute transmitted by phototelegraph apparatus.
				mm. per rev.	Revs per cm.	Revs. per min.	Drum mm.	Round cm	Along cm.	Area cm.²				
(1) Siemens Experimental	(1,300)	16.5	0.127	0.2	50	50		20	10	200	11	18 2		
(2) Siemens Commercial	1,125	21.6	0.192	0.2	50	47	88	25	18	450	20	22.5	1020	206
	—	—	—	0.25	40*	—	—		—	—	16	28.2	1020	258
	—	—	—	0.33	30	—	—	—	—	—	12	37.5	1020	343
(3) Bell	1,300	22.8	0.175	0.254	39.4	90	—	12.7	17.8	226	8	28 3	60	259
(4) Belin	(1,000)	19.8	0.198	0.185	54	72	—	15	10	150	8	18.8	32	172
(5) Belin (as altered by the *Scotsman*.)	(900)	25.9	0.288	0.185	54	72	—	20.1	15.1	302	12	25.2	32	230
(6) Fultograph	(500)	12.9	0.258	0.4	25	50	—	11.5	8.9	102	4.25	24	—	219
(7) Marconi (Various combinations of speed and traverse available.)	(5,000) to (10,000)	—	—	0.318	31.5	20								
				0.254	39.4*	30								
				0.212	47.3	40								
				0.182	55	60	89	26 7	25.4	678	—	—	500	—
						80								
						120								
						150								
(8) Nippon	1,500	15.7	.105	0.167	60								100	
				0.250	40*	60	50	14.7	11	162	13	13 8	or 350	126
				0.125	80								and 450	
(9) Bart Lane	—	—	339	0.509	19.7	—	—	10 2	8.9	90.5	32	2.8		25.6
(10) Proposed International Standard Will work to	1,300	20.7	—	0.1875	53.33	60	66	18	13	234	12	19.5	—	When transmitted over Western cable at 1,620 letters per min. —
		27 6	—	0.25	40	60	88	25	18	450	12	37.5	1020	—

* Alternative traverses.

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