July 28, 1942. C. F. KERNKAMP 2,291,476

COMMUNICATION SYSTEM

Filed Oct. 8, 1941 2 Sheets-Sheet 1

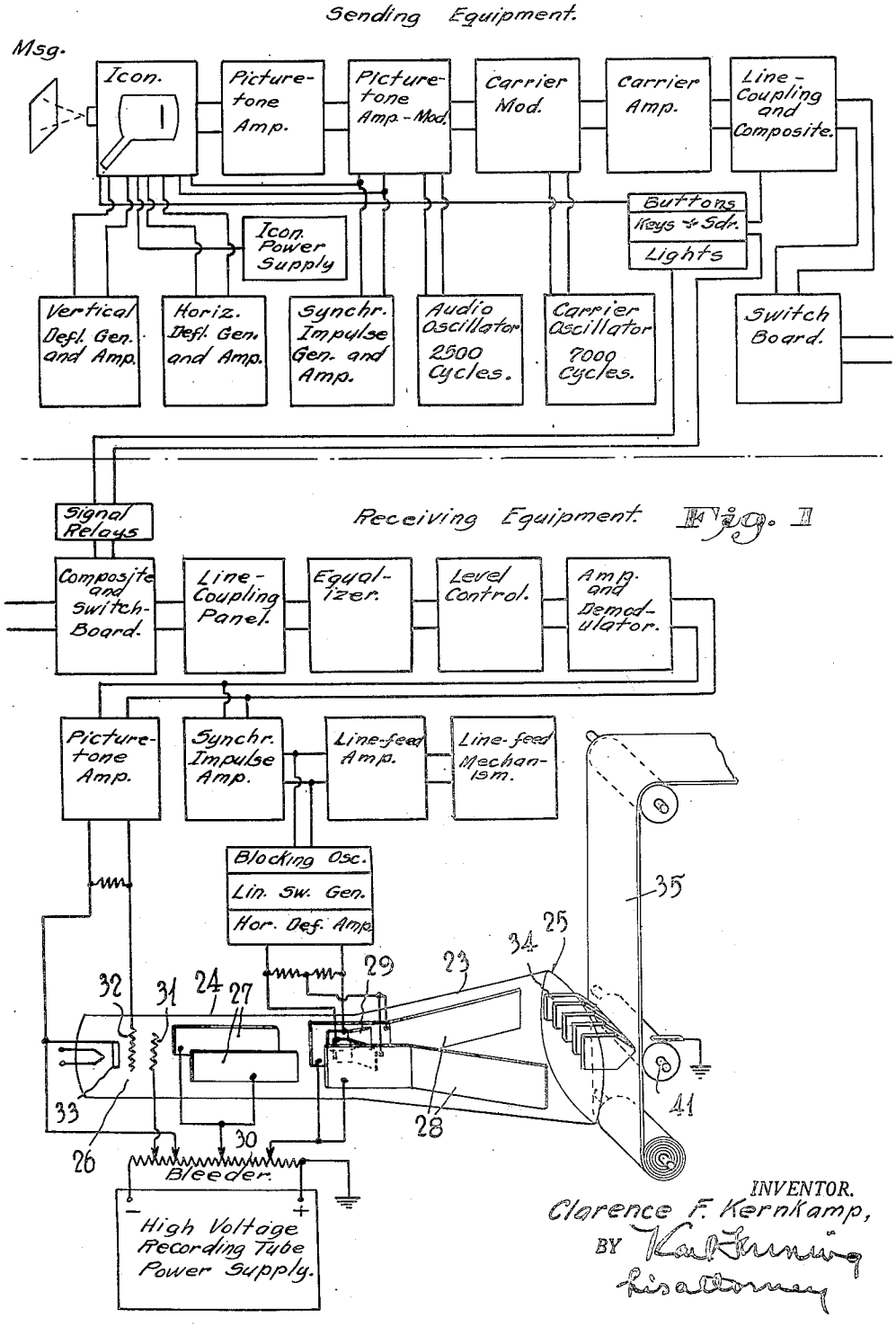


Fig. 1

INVENTOR.
Clarence F. Kernkamp,
BY Karl Fenning
his attorney

July 28, 1942. C. F. KERNKAMP 2,291,476

COMMUNICATION SYSTEM

Filed Oct. 8, 1941 2 Sheets-Sheet 2

Fig. 2

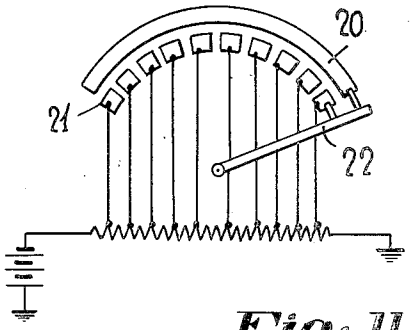


Fig. 3

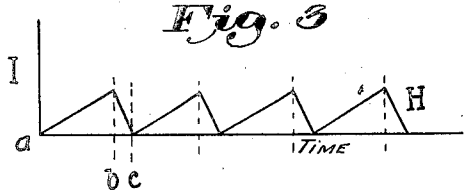


Fig. 4

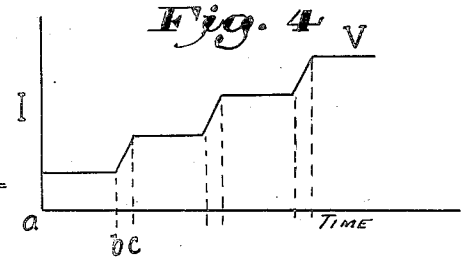


Fig. 11

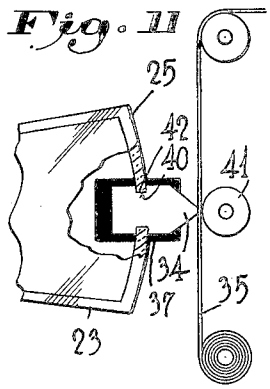


Fig. 8

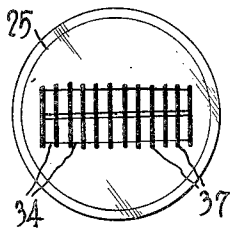


Fig. 5

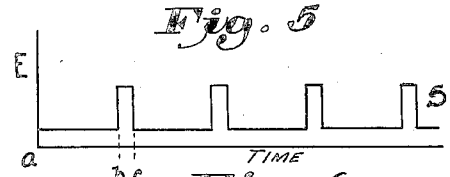


Fig. 6

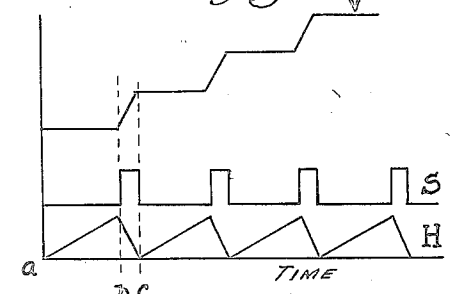


Fig. 9

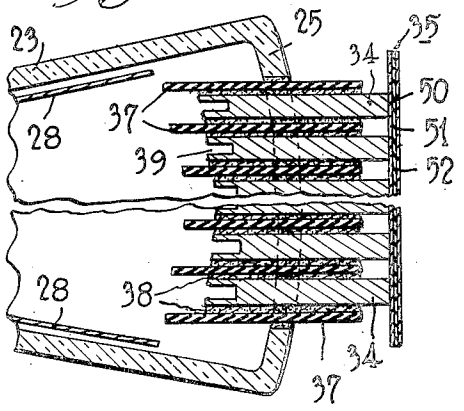
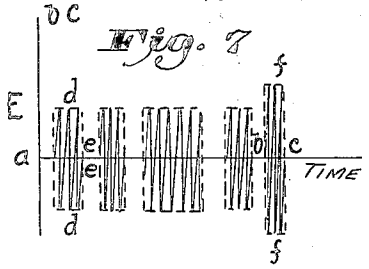


Fig. 7



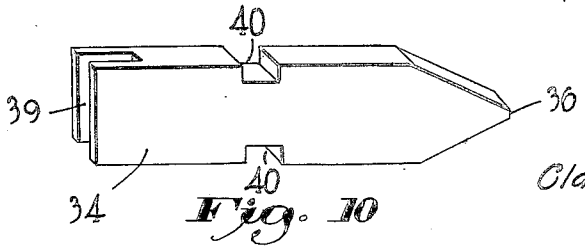


Fig. 10

INVENTOR.
Clarence F. Kernkamp,
BY Carl Fleming
his attorney

Patented July 28, 1942 2,291,476

UNITED STATES PATENT OFFICE

2,291,476

COMMUNICATION SYSTEM

Clarence F. Kernkamp, Riverdale, Md.

Application October 8, 1941, Serial No. 414,214

9 Claims. (Cl. 178—6.6)

This invention relates to facsimile systems and, more particularly, relates to high speed facsimile recording by electronic scanning and electron current recording which may be directly on paper sensitized to the passage of an electron current.

In the conversion of pictures or messages to electrical facsimile signals mechanical scanning operations have been employed whereby a narrow beam of light is traced over the picture or message elements and corresponding variations in the light beam intensity reflected or directed into a photoelectric cell converting them into variations of current strength. In some systems the picture or message may be mounted upon a drum and scanned in a closely wound, long spiral as the drum revolves; in other systems the picture sheet may be successively advanced past an oscillating scanning means which moves transversely with respect to the sheet whereby successive transverse scanning operations are perfected. Corresponding scanning operations are produced at the receiving station in synchronism with the transmitter scanner for composing the reproduction. In the case of the revolving drum type with photographic recording, a recording light beam of varying intensity may reproduce the original upon a photographic negative revolving in synchronism with the transmitting drum. Another method is to replace the light beam by a single wire finger moving across sensitized paper which is mounted upon a drum and revolved in synchronism with the transmitting drum, thus using the single finger, or stylus, to record directly upon the sensitized paper due to the passage of the electric current through it.

The speed of operation of prior systems is limited by the mechanical scanning operations and the requirements for maintaining the transmitter and the receiver scanning mechanism in perfect phase synchronization. A further limitation is the attenuation of the picture signals by the line wires connecting two distant stations. The inertia of the moving mechanical components and the mechanical synchronizing operations have limited the speeds of these systems.

The present invention contemplates eliminating substantially all of the mechanical scanning and synchronizing elements and in addition eliminating the photographic processes of recording. Direct recording is effected upon paper sensitized to the passage of an electric current, by a plurality of fixed wiping styli receiving their electronic current impulses from an electron beam in a cathode ray tube. Because of recent advances in the art of equalizing long lines, higher frequencies may now be applied without excessive attenuation. These may be of the order of 7000 cycles as the carrier frequency which may be modulated by the picture tone signals which will be about 2500 cycles maximum. A reduction in the number of lines per inch of recording may further increase the rate of recording. Accordingly, the present invention permits much higher transmission speed and an increase in recording speed since the recording is not photographic, but direct.

In carrying out the present invention a cathode ray iconoscope tube may be used to generate a picture tone signal. Light reflected from the object to be transmitted may be focussed upon a mosaic of photoelectric elements within the iconoscope. The mosaic area acquires potentials corresponding to the intensity of the light reflected from the object. Progressive scanning is used, thereby generating the picture tone signals in an external circuit. At completion of each periodic horizontal excursion across the mosaic the electron beam is caused to return rapidly to the starting margin by means of a voltage applied to the horizontal deflecting coils and to drop down a small distance by means of a voltage applied to the vertical deflecting coils of the iconoscope beam. This may be done automatically. No picture-tone signals are transmitted during the return period. A synchronizing impulse simultaneously generated during the return period may be employed for advancing a corresponding recording paper at a remote or receiving station. The recording paper may be thus automatically advanced by an amount equal to the width of the scanning line of the iconoscope at the end of each horizontal line of scanning. Each successive line of the recording paper may be exposed to an electronic current through the wiping styli of a cathode ray recording tube energized from the transmitting station.

In a preferred form of apparatus for carrying out the invention there is provided a cathode ray recording tube which has a comb-like member arranged transversely across the lens of the tube and extending through the lens so that on the interior of the tube it is subjected to the sweep of the recording electron beam generated within the cathode ray tube. The comb-like member may be made up of teeth or styli which project outside the wall of the tube and are in surface contact with a film or band of recording material which is advanced line by line by suitable mechanism and which may be backed by

a reel or roll of conducting material. The recording material preferably is provided with an electro-sensitive chemically prepared surface so that an impression is recorded whenever the paper is in surface contact with the end of a tooth which is electrically excited. Thus as the recording electron beam strikes a particular stylus inside the tube an imprint is applied to the recording material where it contacts that particular stylus outside of the tube. By reason of the electronic selection of the coacting styli images which have been progressively scanned at the transmission end of the system are progressively reproduced at the junction of the tips of the styli and the recording material.

In Figure 1 is shown diagrammatically the apparatus at one end of the line. The transmitting apparatus is shown above the dotted line and therebelow the apparatus for receiving. Identical apparatus is at the other end of the line. This provides 4-wire, two-way transmission. Fig. 2 is a diagrammatic showing of a stair step voltage device for the vertical deflecting generator and amplifier. Figs. 3 and 4 are current curves. Fig. 5 is a voltage curve. Fig. 6 shows time-phase of curves in Figs. 3, 4 and 5. Fig. 7 shows a typical 2500 cycle signal modulated by picture-tone signals. Fig. 8 is a front view of a recording tube showing its teeth. Fig. 9 is a fragmentary horizontal section through the faceplate and teeth of the recording tube and record film. Fig. 10 is an enlarged perspective view of a tooth and Fig. 11 is a fragmentary side elevation of the tube broken away in part to show the faceplate and teeth.

In Fig. 1 the sending equipment for transmitting to a remote terminal is shown above the dot and dash line and the equipment for receiving or recording from the remote terminal is shown below the dot and dash line.

The sending equipment shown comprises an iconoscope tube with its associated power supply, sweep circuits, picture tone amplifier, picture tone amplifier modifier, 2500 cycle audio oscillator, 7000 cycle carrier oscillator, carrier modulator, carrier amplifier, synchronizing impulse generator and amplifier, line coupling panel composite, signalling system for the operators, a Morse communication system and switchboard for the testing and regulating attendants.

The iconoscope may be of the conventional type upon the mosaic of which is formed the different electrical potentials corresponding to the variations in light intensity reflected from the message to be transmitted. The object to be transmitted is placed in front of the focusing lens of the iconoscope and strongly illuminated.

The iconoscope tube is an image pick-up device of the storage type. In this type, the photoelectric current from an element of the picture charges an individual condenser for a period of time equal to the scanning time of one complete picture. This condenser is discharged once during the scanning time of a complete picture, the time of discharge being only the time of scanning of one picture element.

The iconoscope consists of a photosensitive mosaic and an electron gun, assembled in a glass bulb which is highly evacuated. The electron gun is of the same general type as those used in television cathode ray tubes and is known to those skilled in the art.

The picture-signals of the iconoscope are amplified by the picture-tone amplifier and modulate the amplitude of a 2500 cycle audio frequency sine wave oscillator. The audio oscillator frequency and picture-signals are fed into the picture-tone amplifier-modulator the output of which modulates a 7000 cycle carrier frequency at the carrier modulator for transmission to the line.

The iconoscope uses electromagnetic deflection of the scanning electron beam. This requires a saw-tooth linear wave of current through the horizontal deflecting coil. Since a saw-tooth wave of current through a pure inductance produces a rectangular impulse of voltage across it, and vice-versa, the horizontal sweep generator is so designed as to produce a rectangular impulse of voltage periodically at a predetermined rate. This is obtained from an inductor-type generator consisting of a drive-coil, a particularly shaped rotor, and a pick-up coil, so positioned with respect to each other that the magnetic flux will be caused to vary in the pick-up coil according to the shape of the rotor, as the rotor revolves. The rotor alters the magnetic reluctance of the path of the flux. This generates the desired wave-shape of voltage in the pick-up coil which is amplified by a vacuum tube amplifier and applied to the horizontal deflecting coils of the deflecting yoke.

Fig. 3 shows the linear saw-tooth characteristic curve of current applied to the horizontal deflecting coils, and illustrates how this current through the coils varies with time. This current through the horizontal deflecting coils causes the electron beam to sweep periodically across the mosaic. The linearly rising portion of the curve corresponds to the constant rate at which the beam is transversely moved across the mosaic. The return portion of the curve corresponds to the rapid return of the beam to the opposite end of the mosaic after the completion of its periodic traverse. The time interval represented by intercepts *a*—*b* of Fig. 3 curve, corresponds to the time in which the beam is uniformly swept horizontally across the mosaic. The shorter time intercept *b*—*c* represents the rapid return interval of the beam for its periodic excursion.

The horizontal deflecting coils are contained in a so-called yoke which also contains the vertical deflecting coils. These coils are so arranged in the yoke that they cause the existence of two magnetic fields at right angles to each other. One field is used for horizontal deflection and the other field is used for vertical deflection. An electromagnetic field due to the action of the horizontal deflecting coils deflects the electron beam at right angles to the field lines of force, and at right angles to the axis of the tube. The deflecting yoke is placed external to the tube, usually slipped over the long round neck of the bulb.

The vertical deflecting voltage applied to the vertical deflecting coils of the above mentioned yoke may be obtained from a "stair-step" voltage device such as illustrated in Fig. 2. This consists of a voltage dropping circuit the potentials at various points of which are connected to segments so arranged as to form a segmented ring. A solid contact strip 20 is located adjacent to, but insulated from the segmented ring 21. A wiping brush 22 is caused to rotate across these rings thus electrically connecting the segmented ring to the solid ring. As the wiping contacts rotate clockwise a progressively higher voltage is transferred to the solid ring as contact is made from the first to the last segment in the ring. The first segment is connected to the

negative potential of the voltage dropping circuit and the last segment is connected to ground. The other segments are connected to intermediate potentials which vary uniformly between connections. The wiping contacts are mounted on the end of a rotating arm and insulated therefrom. The arm is geared to the same shaft which drives the inductor generator for horizontal deflection. The gear ratio and length of the rotating arm and length of each individual segment are all so arranged and selected that the next higher step of voltage will be applied to the solid ring during the interval *b*—*c*, Fig. 3. The solid ring is connected to a vacuum tube amplifier (not shown in detail) the output of which has for its load the vertical deflecting coil. This effectively applies a stair-step of current through the vertical deflecting coil. Fig. 4 shows the characteristic stair-step curve of current through the vertical deflecting coil. This current causes the electron beam to be dropped down by a predetermined amount at the mosaic during the interval *b*—*c* Fig. 3 when the horizontal deflecting coils are returning the beam to the starting end of the mosaic. The portion of the curve represented by the intercepts *a*—*b* Fig. 4 is of a constant value and corresponds to the constant vertical position of the electron beam as it is periodically swept across the mosaic. The portion of the curve represented by intercepts *b*—*c* corresponds to that interval during which the wiping contact **22** is being transferred from one segment **21** to an adjacent segment **21**. The voltages are preferably so selected at the voltage dropping circuit connections that the current which will flow through the vertical deflecting coils will cause the electron beam to drop down one fiftieth of an inch at the completion of each horizontal excursion across the mosaic. Thus the mosaic is scanned progressively. The intercepts *a*—*b* in Fig. 4, 5, 6 and 7 represent equal time intervals during which progressive scanning is accomplished. Intercepts *b*—*c* Fig. 4, 5, 6 and 7 represent equal time intervals for the return of the scanning electron beam and the generation of the synchronizing impulse to be described. The current values as shown in these graphs are not drawn to scale.

In order to reproduce the message as transmitted over wires by the electrical impulses generated by the iconoscope, it is necessary that the recording tube electron beam be controlled in intensity according to the intensity of the transmitted picture-tone signal and also be maintained in horizontal synchronism with the iconoscope scanning beam.

Horizontal synchronism is accomplished by means of a synchronizing impulse generated and amplified at the sending equipment during the interval *b*—*c* Fig. 5. This synchronizing impulse extinguishes the iconoscope scanning beam and at the same time is applied to the picture-tone amplifier-modulator for transmission to the recording equipment at the receiving end. Fig. 5 shows the characteristic curve of the synchronizing impulse of voltage. Fig. 6 shows the time-phase relationship of the horizontal sweep current H; the vertical deflecting current V; and the synchronizing impulse voltage S.

The phase relationship of the synchronizing impulse is obtained by a second inductor-type generator mounted on the same shaft as the horizontal sweep generator. By arranging the two rotors with the proper position with respect to each other, it will be seen that the synchronizing impulse *b*—*c* Fig. 5 is generated in the synchronizing impulse pick-up coil during the return interval *b*—*c* Fig. 3, and during the same interval *b*—*c* Fig. 4 when the vertical deflecting current is being increased. The synchronizing impulse amplitude is so controlled by its amplifier and applied to the picture-tone amplifier-modulator in such a manner that the modulated output signal is greater than any picture-tone signal level. This increase in amplitude actuates selective equipment at the receiving end which causes the recording electron beam in the recording tube to move horizontally in synchronism with the transmitting electron beam in the iconoscope, as will be explained.

The amplified picture-tone signals at the output of the picture-tone amplifier are conducted to an amplifier and modulator stage (Fig. 1) by leads. An audio frequency oscillator generating 2500 cycles per second is impressed upon the picture-tone amplifier modulator. The type of modulator which I prefer to use is commonly termed grid-circuit modulation.

Inasmuch as "negative transmission" is used, it will be understood by one skilled in the art that white tones in the image being transmitted will be represented by low amplitudes in the picture signal. The relative amplitude is indicated in Fig. 7. Successively deeper grays are represented by higher amplitudes, until at the level shown in the diagram (*d*—*d* Fig. 7) the amplitude represents a total absence of light reflected from the message being transmitted. This signal value is that which would be transmitted from the black print on the message. The minimum or zero values (*e*—*e* Fig. 7) correspond to the background of the printed message.

Since this method of transmission is designed primarily for the transmission of printed or typed messages of uniform density the signal output of the picture-tone amplifier-modulator would have the envelope as shown in Fig. 7, which is a graphical representation of a typical signal. In effect, the 2500 cycle audio frequency is suppressed or permitted to flow with a predetermined amplitude as the background or picture-tone, respectively, is being transmitted.

The time interval *a*—*b* Fig. 7 represents one scanned line of the message the reflected light from which is focused upon the inconoscope mosaic. The time interval *b*—*c* represents that time during which the synchronizing impulse of greater amplitude, or infra-black is transmitted. The ordinate E is the relative voltage intensity of the picture-tone signal and the synchronizing impulse signal. Fig. 7 is a schematic illustration and is accordingly not drawn to scale. In operation it may be that 75 to 80 percent of the maximum amplitude of the signal will be devoted to the picture-tone modulation while the remaining 20 or 25 percent of the signal amplitude is devoted to synchronization.

The envelope of the 2500 cycle audio frequency represents the picture-tone signal modulations superimposed upon the audio frequency. The envelope is symmetrical with respect to the horizontal axis as will be evident to those skilled in the art. (Fig. 7.) The signal level represented by *d*—*d* corresponds to the black picture element; the zero level *e*—*e* corresponds to a white picture element; the maximum level *f*—*f* corresponds to the synchronizing impulse signal.

It is to be understood that the image to be transmitted is stationary during the scanning operation. It is placed in front of the iconoscope

and an intense light is directed upon it. The light is under the control of an operator. Light reflected from the image is focused through a suitable lens combination upon the iconoscope mosaic upon which the electron beam performs the necessary progressive scanning, as previously explained.

The received message, however, is preferably recorded upon a sensitized film or strip responsive to the passage of an electric current through it. This strip is advanced past the recording tube in steps corresponding to the steps of vertical displacement of the transmitting scanning electron beam.

The synchronizing impulse signal, produced by the synchronizing impulse generator at the transmitting equipment during the interval when no picture signals are being generated or transmitted, is used at the remote receiving station to operate selective equipment for automatically advancing the receiving recording paper past the recording tube in a manner to be described. This function of the synchronizing impulse is in addition to synchronizing the horizontal motion of the transmitting and recording electron beams as described above. Further, the synchronizing signal suppresses the recording tube electron beam during the synchronizing period.

The receiving equipment (Fig. 1) comprises a composite, direct current operators signal relays, line coupling panel, equalizer, level control, amplifier and demodulator, picture-tone amplifier, synchronizing impulse amplifier, blocking oscillator, linear-sweep generator, horizontal deflecting amplifier, line feed amplifier, line-feed mechanism, and recording tube, with associated power supplies.

The sending equipment, (Fig. 1) illustrates a wire transmission system for the message signals and synchronizing impulse. The output of the picture-tone amplifier-modulator stage may be transmitted to a remote receiving stage along wire lines or by radio transmission. The signals in this method of wire transmission are impressed upon a carrier frequency modulator stage. A 7000 cycle carrier frequency oscillator produces a carrier wave which is modulated by the 2500 cycle picture-tone frequencies in the picture-tone amplifier modulator. The type of modulation which is preferably used is that in which a bridge arrangement of unidirectional impedances, for example copper-oxide rectifiers, are connected in the form of a square, with one impedance in each side of the square, connected so as to be conductive in a predetermined direction. The 7000 cycle oscillator frequency is applied to two points diagonally opposite each other, and the modulating 2500 cycle frequency is applied across the remaining two points or corners of the square.

The carrier amplifier (Fig. 1) amplifies the signals from the picture-tone amplifier-modulator and the carrier modulator for application to the line coupling and composite which, through transformer action, transfers the signals to the switchboard and thence to the line.

The line coupling panel and composite provide a means of introducing the direct current operating signals from the signalling circuits to the line along with the modulated carrier frequency, in such a manner as to prevent interference between the two.

The receiving composite, (Fig. 1) functions similarly to the transmitting composite in that it is designed to separate the direct current operating signals from the modulated carrier frequency. It is a network of resistances, inductances, and capacitances, so arranged that the direct currents are diverted through relays to a signallying circuit without interfering with the modulated carrier frequency signals which are passed to the line coupling panel and thence to the rest of the receiving circuit, to be described.

The line coupling panel transfers, through transformer action, the modulated carrier frequencies passed by the composite to the equaliser.

The purposes of the equaliser are to slow down the velocity of propagation of the higher frequencies, more than the lower frequencies, in the band-width transmitted; to attenuate the higher frequencies more than the lower frequencies in the band width. This network of impedances compensates for amplitude and phase distortion of the modulated carrier frequencies introduced by the impedance characteristic of the lines used as the connecting medium between the sending and remote receiving equipment.

The level control provides a means of controlling the amplitude of the modulated carrier frequency, before application to the receiving amplifier-demodulator, and the rest of the local equipment. It is necessary to control the level of these signals to insure against interference in adjacent local circuits.

The amplifier-demodulator amplifies the carrier-frequency modulated signals impressed upon it and rectifies them. In passing the rectified modulator carrier through a low pass filter which is part of the amplifier-demodulator the desired picture-tone signals and synchronizing signals are obtained, as is usual. This output signal wave-form corresponds, for example, to the envelope of the upper side-band of the graphical representation in Fig. 7. This signal wave form is applied to the picture-tone amplifier, and the synchronizing impulse generator, which are selective circuits in parallel.

Since a dark element in the transmitted message results in a large amplitude of signal, the output of the picture-tone amplifier will correspondingly increase; while a white element in the transmitted message will reproduce a correspondingly decreased signal. These variations in signal strength are applied to the control grid of the recording tube (Fig. 1). Accordingly, the recording electron beam will be permitted to flow whenever a black element of picture is transmitted, and the beam will be suppressed whenever a white element is transmitted.

The synchronizing impulse amplifier contains a selective circuit of amplification suitably biased so as to respond only to a predetermined amplitude of input signals, namely to the amplitude of the synchronizing signals. Since the synchronizing signals *f*—*f* (Fig. 7) are greater in amplitude than any of the picture-tone signals *d*—*d* (Fig. 7) the synchronizing impulse amplifier will respond only to the synchronizing impulses as will be understood by those skilled in the art. Accordingly, the output of the synchronizing impulse amplifier (Fig. 1) will be periodically amplified impulses corresponding to the transmitted synchronizing impulses during the synchronizing period *b*—*c* (Fig. 5). The output of the synchronizing impulse amplifier is applied to the blocking oscillator (Fig. 1), which "triggers" the linear sweep generator, in the usual manner.

Signals from the synchronizing impulse ampli-

fier may not be sufficiently free from distortion under actual working conditions to be used as an accurate means of triggering the linear sweep generator for horizontal deflection. Accordingly, as is usual, there may be inserted a blocking oscillator which will produce impulses, controlled by the synchronizing amplifier, of constant amplitude and the correct duration to make the linear sweep generator circuit produce the required wave shape of sweep voltage (Fig. 3). The blocking oscillator should produce positive pulses at a rate slightly lower than the correct frequency for the linear-sweep generator, and should be so designed that its frequency will be increased to the correct value automatically when fed with the synchronizing impulse.

The horizontal deflecting plates 29 of the recording tube are actuated by the linear sweep oscillator, through the horizontal deflecting amplifier (Fig. 1) which is a stage of push-pull amplification. Thus the linear sweep generator is impulse excited by the synchronizing signals so that it will have the exact frequency of the transmitter horizontal scanning frequency. The electron beam of the recording tube will accordingly be oscillated horizontally across the face plate of the recording tube by the deflecting plates.

The "balanced field" method of deflection is used. The output of the push-pull horizontal deflecting amplifier (Fig. 1) is connected through a transformer to the deflecting plates 29. Each deflecting plate is connected to the second anode 28 of the recording tube through a high resistance—one or more megohms—and for deflection purposes one plate is lowered in potential by exactly the same amount as the other is raised. The high resistance is in parallel with the transformer secondary, and the deflecting plates, and is center tapped with the connection to the second anode.

The horizontal motion of the recording electron beam will correspond to that of the transmitting electron beam. The phase adjustment of the recording beam is automatically provided by proper design of the impulse excited linear sweep generator in relation to the predetermined occurrence of the periodic synchronizing impulse at the end of each scanning line.

The output of the synchronizing impulse amplifier is connected also to the line-feed amplifier which amplifies the impulse which is applied to the automatic line-feed mechanism for advancing the recording paper past the recording tube (Fig. 1).

The line-feed mechanisms may, for example, be well-known electromagnetic periodic advancing means which is actuated by the electrical impulses produced at the end of each scanning excursion of the electron beam, namely, the synchronizing impulse. The paper is accordingly advanced the proper amount during this interval so that the adjacent line may be scanned during the next cycle of operation.

The essential elements of the recording tube are a glass bulb 23 with a narrow neck 24, a specially designed face plate 25 at the end of the glass bulb, an electron gun 26, means for shaping and focusing the electron beam, and means for deflecting said beam across the internal part of the face plate in a horizontal motion, and means for controlling beam intensity.

Fig. 1 shows a schematic drawing of the recording tube. The electron gun 26 generates a beam of electrons of rectangular cross-section, for this purpose, approximately 0.5 inch high and 0.125 inch wide. The beam is accelerated and focused by anodes 27 and 28 so that it impinges upon the face plate with a cross-sectional area approximately 0.5 by 0.015 inch.

The horizontal deflecting plates 29 are connected to the horizontal sweep amplifier as above described for moving the electron beam horizontally across the face plate in a predetermined, periodic manner.

The accelerating-focusing anodes 27 and 28 are connected to suitable taps on a high-voltage power supply bleeder circuit 30. This provides bi-potential immersion lens accelerating and focusing action.

The beam intensity is controlled by a screen grid 31 and control grid 32. The screen grid 31 has applied to it a constant predetermined potential of negative polarity with respect to the cathode 33 such that it exerts a definite amount of suppression upon the electron beam.

The control grid 32 is connected to the picture-tone amplifier and responds according to the picture-tone signals, overcoming the action of the screen grid during the interval when a black picture element is being transmitted. During this interval the control grid 32 increases in potential in a positive direction permitting electron flow, as will be apparent to one skilled in the art. The transmission of a white element of the message, however, causes the control grid 32 to decrease in positive potential, thus aiding the screen grid 31 to suppress the electron beam.

The cathode 33 is a thermionic emitting surface heated by a separate heater circuit, the potential of which is not shown.

The face-plate or lens 25 of the recording tube has set in it a series of teeth 34, insulated from each other, across the front of the tube forming a recording stylus comb. They provide a means of conducting the beam current to the outside of the tube, where it is caused to flow through the sensitized recording paper 35, thus recording the transmitted impulses from the transmitted message.

A preferred form of recording stylus comb consists of german silver teeth 34, preferably 50 teeth to an inch, each tooth 0.015'' thick, and 0.5'' high and of a length which varies with its distance from the center of the comb. Those teeth toward the ends of the comb should be progressively longer than the teeth in the middle of the comb. The center tooth is 0.5'' long, and the other teeth vary in length up to about 1.0''. The comb is 7'' in length across the front of the tube and 0.5'' high. Each tooth is approximately arrow-shaped with the external tip 36 blunted to form a square 0.015'' on each side. The external tips of the teeth in the comb as shown in Fig. 9 form a straight edge along the length of the comb. The teeth extend into the tube further on the ends of the comb than in the middle in such a manner as to form a curved inner surface the radius of curvature of which is approximately the distance from the inner base of the comb to the nearest end of first anode plates 27 (Fig. 1) of the electron gun. A perspective of one enlarged tooth is shown in the acompanying drawings, Fig. 10, and the arrangement of the teeth in the comb is shown in Fig. 9. These figures illustrate the preferred shape and arrangement of the teeth between which are insulation strips 37 and sealing compound 38, used to form the comb and to render an air-tight joint where they pass through the faceplate 25.

At its end within the cathode ray tube each tooth may be slotted at 39 to present a U-shaped pocket or a receptacle upon which and in which the electron beam from the cathode impinges. The slotted receptacle, or "pocket" is further formed and isolated from adjoining tooth "pockets" by a slight extension of the insulation 37 into the tube on each side of each tooth 34.

The insulation 37 between teeth may be mica, 0.005" thick cut and shaped the same as or somewhat wider than the two teeth between which it is to be placed, except at the internal end of the tooth, where it is somewhat longer, so as to extend beyond the end of the tooth. The extension beyond the end of the tooth may be 0.25" to form the pockets mentioned.

Each tooth or stylus 34 and the insulation strip 37 is slotted on the top and bottom edge at 40. This provides a means of mortising into a slot 42 formed across the glass front of the cathode-ray tube. The slots in each tooth, and mica insulation between teeth, are located in such a position and so shaped that they may be inserted in the slot of the glass front, one after another, one tooth then one piece of insulation, then one tooth, etc., thus forming the comb.

A sealing compound 38, impervious to heat below 500 degrees Fahrenheit should be applied between each tooth, insulation, and top and bottom slots and also in the slot formed in the glass front of the cathode-ray tube, so as to render an air-tight joint between the above mentioned components.

The completed faceplate 25 is joined by an air-tight joint to the front of a cathode-ray tube, replacing the usual glass front which is coated on the inner surface with a fluorescent material. The air-tightness of all joints should be equal to that necessary to obtain and maintain the high degree of vacuum required in cathode-ray tubes.

Recording paper 35 is caused to pass between the tips 36 of the stylus comb and a metal roller 41 which is grounded. The paper used is commercially available and is an electrical conductor of low impedance and is preferably made in three thin layers each of a conducting material. The middle layer 51 is of a carbon-fibrous compound, comprising about 90 percent carbon and 10 percent fibrous substance to hold it together. The bottom layer 52 which is against the metal roller 41 is of aluminum applied in the form of a thin paint. The top layer 50 which is pressed against the tips of the teeth of the stylus comb and forms a wiping contact thereon, is made of silver in the colloidal state, dissolved in a lacquer which is then spread on top of the carbon-fibrous layer 51. The whole is then pressed tightly together and dried. The top layer 50 dissolves, disintegrates, or becomes a gas on passage of an electric current and in so doing exposes the black middle layer, 51, forming intelligible characters in a predetermined sequence of integration. The completed characters are built up by recording successive lines one-fiftieth inch wide across this paper.

It is to be understood that the wiping contact which the paper makes with the tips of the teeth, under a steady pressure thereon, is for the purpose of placing the paper in close electrical contact with the tips of the teeth so as to reduce the contact resistance to a uniformly low value. The wiping of the paper upon the teeth does not result in so-called pressure recording as would be the case if a piece of carbon paper were inserted between the teeth tips and the paper. The passage of an electronic current from the tip of the teeth through the paper does the recording, as described above.

The line-feed mechanism, described previously, advances the recording paper one-fiftieth of an inch at the end of each line of recording. The paper is in a continuous roll, being moved, or stepped, past the projecting tips of the teeth in the stylus comb in any suitable manner so as to form wiping contact thereon.

Direct current signalling circuits may be used, so designed as to apply a predetermined positive or negative potential to the lines at each sending end. These potentials are removed at the receiving composite and diverted to polar relays which move their armatures to one side or other side according to the polarity of the signal impressed. Thus each line is capable of conveying two signals to the receiving equipment. With two lines, four signals may be conveyed to the receiving equipment. One signal may be used to notify the operator at the sending end that the transmitted message had been completely received at the remote station. Another signal from the sending end may be used for Morse communication between attendants at each end. The third and fourth signals may be used for transmission of regular telegraph signals, or for additional operating signals if desired.

The invention may be embodied in other apparatus and is not confined to the specific size, shape, form, material or assemblage which has been shown as illustrative of one embodiment thereof.

I claim as my invention:

1. In a communication system, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube, means for directing rays of electrons within the tube successively and selectively on the contactors, and means for holding a chemically prepared conducting recording paper against the ends of the contactors outside the tube so that selected contactors will affect the paper.

2. In a communication system, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube each having a U-shaped inner end, means for directing rays of electrons within the tube successively and selectively on the contactors, and means for holding a chemically prepared film against the ends of the contactors outside the tube so that selected contactors will affect the film.

3. In a communication system, a scanning device, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube, means for directing rays of electrons within the tube successively and selectively on the contactors in accordance with the reactions of the scanning device, and means for holding a chemically prepared film against the ends of the contactors outside the tube so that selected contactors will affect the film.

4. In a communication system, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube, means for shaping and directing rays of electrons within the tube successively and selectively on the contactors, and means for holding a chemically prepared film against the ends of the contactors outside the tube so that selected contactors will affect the film.

5. In a communication system, a cathode ray tube, a plurality of insulated contactors passing through the faceplate of the tube the inner ends of the contactors being arranged in an arc about the final aperture of the electron gun as a center, means for directing rays of electrons within the tube successively and selectively on the contactors, and means for holding a chemically prepared film against the ends of the contactors outside the tube so that selected contactors will affect the film.

6. In a communication system, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube, means for directing rays of electrons within the tube successively and selectively on the contactors, a film of carbon fibrous substance treated with aluminum on one side and with silver in colloidal state on the other side and means for holding the film with its silver side against the ends of the contactors outside the tube so that the electronic current in selected contactors will affect the film.

7. In a communication system, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube, means for directing rays of electrons within the tube successively and selectively on the contactors, means for holding a chemically prepared film against the ends of the contactors outside the tube so that selected contactors will affect the film, and means for advancing the film step by step.

8. In a communication system, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube, and means for directing rays of electrons within the tube successively and selectively on the contactors.

9. In a communication system, a cathode ray tube, a plurality of insulated contactors arranged in a row and passing through the faceplate of the tube, means for moving the ray of electron discharge along the row of contactors, and means for modifying the electron ray so that it has a shorter dimension in substantially the direction of movement and a longer dimension at approximately right angles thereto.

CLARENCE F. KERNKAMP.