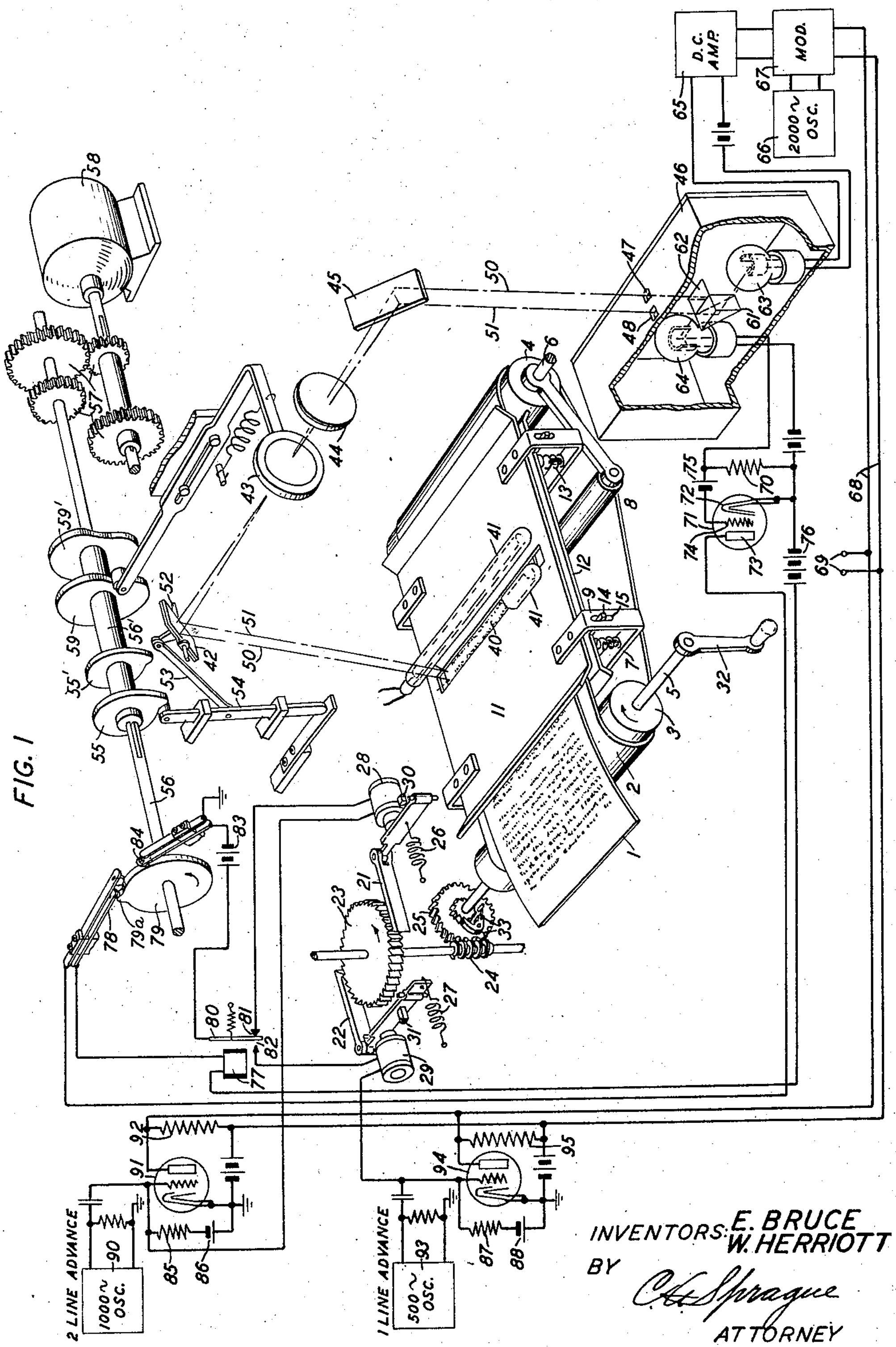
June 23, 1942. E. BRUCE ET AL 2,287,413

FACSIMILE SYSTEM

Filed Oct. 31, 1940 4 Sheets-Sheet 1

FIG. 1



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FACSIMILE SYSTEM

Filed Oct. 31, 1940 4 Sheets-Sheet 2

FIG. 2

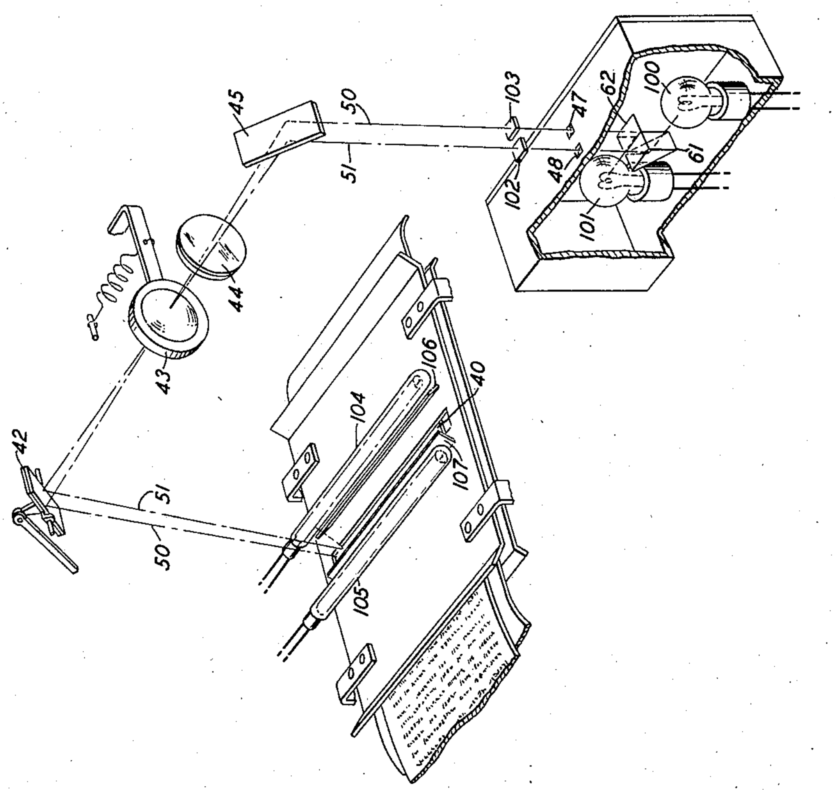

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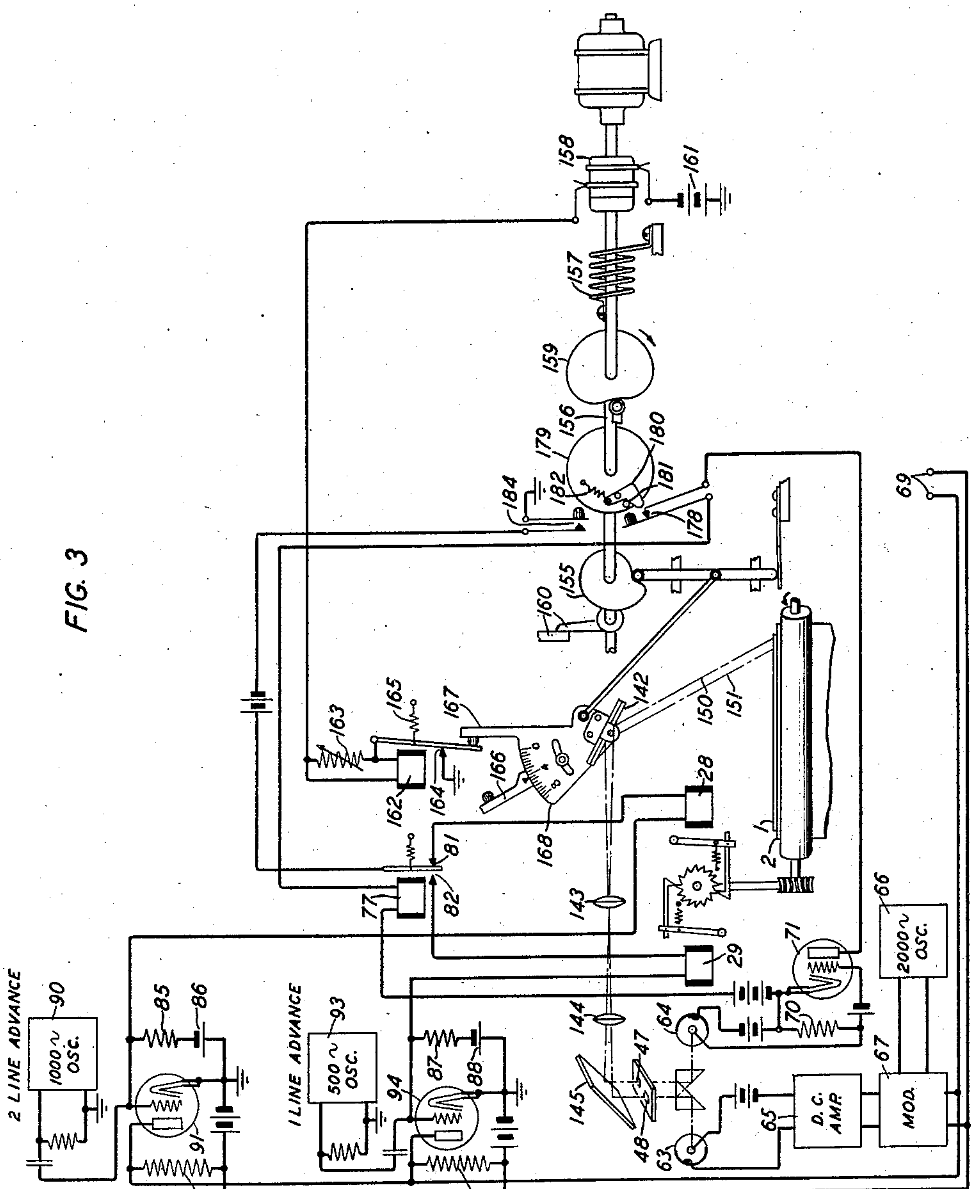
FIG. 3



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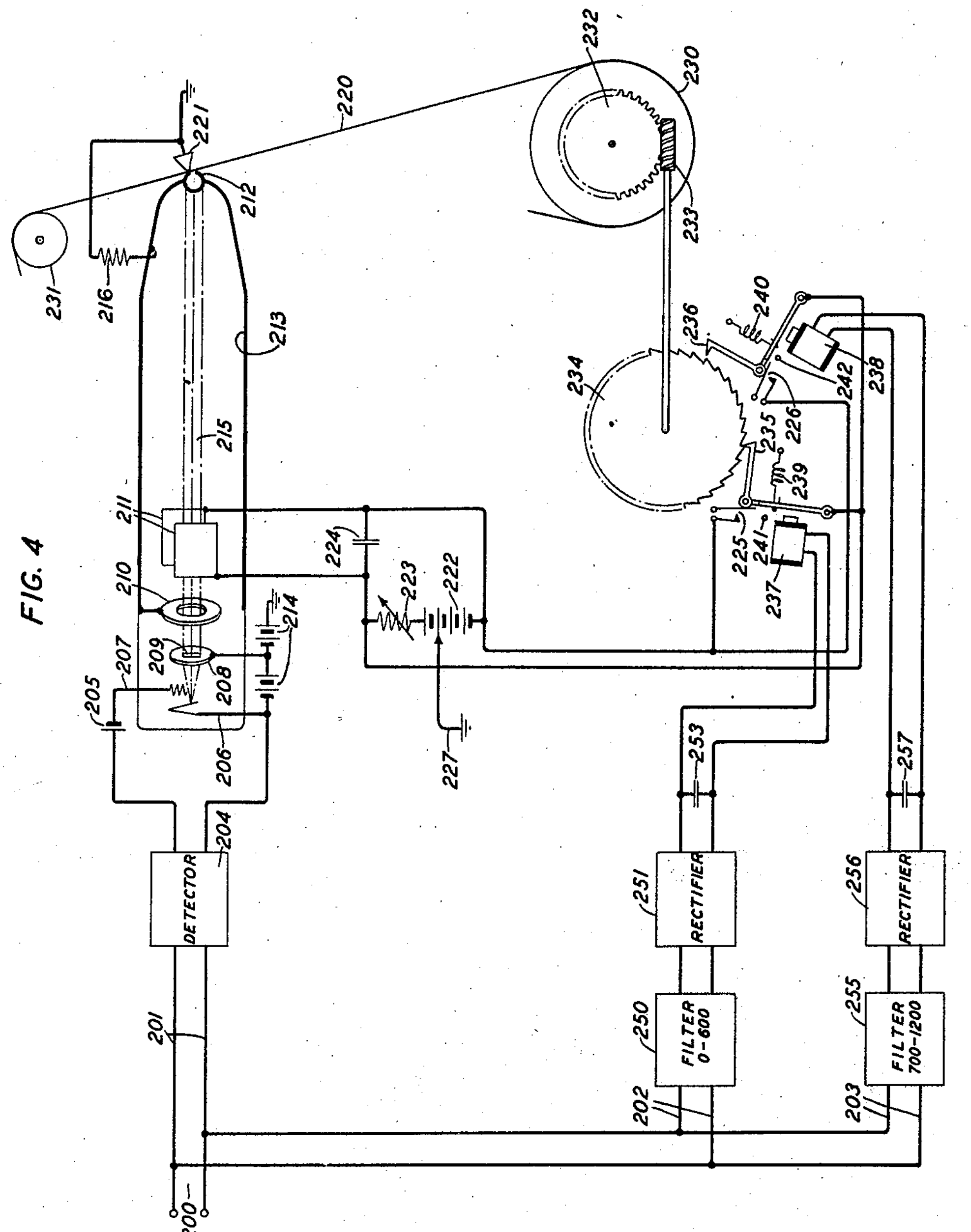
FACSIMILE SYSTEM

Filed Oct. 31, 1940 4 Sheets-Sheet 4

FIG. 4



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Patented June 23, 1942

2,287,413

UNITED STATES PATENT OFFICE

2,287,413

FACSIMILE SYSTEM

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Application October 31, 1940, Serial No. 363,598

19 Claims. (Cl. 178—6.6)

This invention relates to signaling systems and particularly to a system for deriving image signals from fields of view, especially graphic material such as written or printed matter, documents and the like, transmitting the same to a receiver and there utilizing them for reconstitution.

A principal object of the invention is to increase the speed of transmission and so reduce the time required.

A related object is to omit, as far as possible, the time-consuming transmission of signals derived from the blank portions of the field of view which contain no information as to its substantive content but only as to its form.

In pursuance of these and other objects of the invention, two independent scanning spots are caused to traverse successive elemental areas of the field of view to be transmitted, which for the sake of illustration may be taken as consisting of dark typewritten matter on a white paper backgorund, to give rise simultaneously to two separate and independent scanning signals. A scanning aperture associated with one of these scanning spots is separate from and independent of another scanning aperture associated with the other scanning spot. Likewise, the associated translating devices, for example, photoelectric cells, are separate and independent. The independent scanning spots are preferably spaced apart on the copy to be scanned, for example in a direction perpendicular to the line scanning direction and by the width of a single scanning line. They may be caused to travel together over the width of the copy in the course of the scanning operation. As they do so, independent and different light signals are impressed on the corresponding photoelectric cells, each of which may therefore be said to "see" its proper elemental area of the copy. Thus two separate and independent electric signals are derived. Signals thus derived from one of the scanning spots, which may be termed the main scanning spot, constitute the usual image signals which may be transmitted to a receiver for reconstitution in the usual way. The aperture associated with this spot may be termed the main scanning aperture. Other signals are derived from the other scanning spot, which is the first to traverse any particular portion of the copy and may therefore be termed the "advance" spot by virtue of its disposition; or, by virtue of its function, the "auxiliary" or "premonitory" spot, while the aperture associated therewith may be similarly designated. In accordance with the invention, signals derived from this advance or premonitory aperture may be utilized to cause the apparatus as a whole to skip a blank portion of the copy, that is, a portion which is devoid of dark elemental areas throughout a stipulated length. For example, if the spots are separated by the width of a scanning line the portion skipped is a full scanning line.

To effect this skipping operation the premonitory signals are supplied to a selector whose output energy governs the operation in the alternative of two different and independent copy-advancing devices at the transmitter and corresponding means for advancing an impression-receiving element at the receiver. The circuit arrangement and biases are such that when the auxiliary aperture, in the course of scanning a stipulated part of the copy, for example, a full scanning line, has seen one or more dark elemental picture areas, the selector causes the first copy-advancing means at the transmitter to operate to advance the copy by the width of a single line. When, on the other hand, the auxiliary aperture has seen no dark areas at all in the course of scanning a full line, the selector governs the operation of the second copy-advancing means to advance the copy by the width of two lines instead of one. In each case corresponding single-line or double-line advance of the impression-receiving element at the receiver is effected under control of the transmitter apparatus.

In accordance with one embodiment of the invention, a band of the original copy, at least as broad as two full scanning lines, is strongly illuminated. Light from two separate elemental areas of this illuminated band, spaced apart by the width of a scanning line, is gathered through an optical system and projected into two separate photoelectric cells, being focused on two apertures placed in front of the cells. The two areas from which the light is thus gathered are swept side by side together over the copy in the course of the scanning operation. Thus, though other areas of the band may be illuminated with equal intensity, the particular areas that are momentarily in conjugate relation with the apertures serve as the scanning spots.

In accordance with a modification of the optical arrangements, two small spots of light may be projected from two apertures, iluminated by a lamp or lamps behind them, onto the plane of the copy to illuminate two separate elemental areas of the copy, spaced apart preferably by the width of one scanning line. Light reflected from the two illuminated copy areas is incident upon the copy and by suitable means may be segregated in two separate photoelectric cells placed close to it. In order to confine the response of each photoelectric cell to the light from its particular spot, the spots are preferably illuminated by light of different color characteristics, as by placing a filter of one color in the light path from one aperture and a filter of a different color in the path from the other aperture. At the same time the photoelectric cells are preferably given corresponding different color sensitivities, either by the use of different photoelectric materials or by the use of filters in front of the cells.

The invention will be fully understood from the following detailed description of an illustrative embodiment thereof taken in connection with the appended drawings in which:

Fig. 1 is a diagram, partly in perspective, showing apparatus in accordance with the invention;

Fig. 2 is a diagram in perspective of a modification of a part of the apparatus of Fig. 1;

Fig. 3 is a diagram of a modification of other parts of the apparatus of Fig. 1; and

Fig. 4 shows receiver apparatus in accordance with the invention.

The embodiment of the ensuing detailed description and drawing constitutes a modification of the apparatus described and shown in copending application Serial No. 336,538, filed May 22, 1940, now Patent 2,262,584 issued Nov. 11, 1941. This, however, is for purposes of illustration only, since the invention is equally applicable to systems of other types, for example, systems in which scanning is accomplished by the continuous rotation of a cylinder around which the copy is wrapped, or in which scanning is accomplished by a tape having perforations uniformly spaced along its length as shown, for example, in H. J. Nichols Patent 2,176,680, October 17, 1939.

Referring now to Fig. 1, a sheet of copy 1 may be advanced by a supporting conveyor, for example, an endless belt 2 which passes around a driving roller 3 and a driven roller 4 which are arranged to turn on shafts 5 and 6 in journals, not shown, mounted on a framework or base 7 of the apparatus. Correct tension and flatness of the upper or working part of the belt may be secured by an idler roller 8 which may conveniently be swung on brackets pivoted at the journal points of one of the rollers, for example, the driven roller 4. Brackets 9 mounted on the framework or base 7 support two guide plates, an upper one 11 fixed to the brackets with its lower face in the plane of the upper surface of the upper part of the belt and bearing lightly against it, and a lower one 12 which is yieldably mounted on springs 13 to bear against the underside of the same part of the belt, and press it lightly and snugly against the upper guide plate 11, being restrained from moving with the belt by pins 14 extending through slots 15 in the brackets 9. The lower surface of the fixed guide plate 11 is preferably finished by polishing or otherwise to a fine, smooth, flat surface.

It should be understood that terms such as "upper" and "lower" which may be employed in this specification with reference to the figures and as indicating parts of the apparatus are employed merely to avoid circumlocution, since the apparatus or any part thereof may of course be mounted in any desired orientation.

The belt 2 preferably comprises a fabric base to prevent excessive stretching and is preferably provided with a resilient yielding upper surface of substantial thickness, for example, of rubber.

The belt 2 is arranged to be intermittently advanced between the guides 11, 12 in short steps by engagement of either of the relay-operated pawls 21, 22 with the teeth of a ratchet wheel 23 which drives the driving roller 3 through a worm 24 and gear 25. The pawls 21, 22 are held in disengaged position by springs 26, 27 and are arranged to engage the teeth of the ratchet and advance the latter when their respective relays 28, 29 are energized. The extent of the movement of each pawl is adjusted by correct placement of an associated stop 30, 31. These stops are preferably so placed that actuation of one of the pawls 22 advances the ratchet wheel 23 by the length of one tooth and actuation of the other pawl 21 advances the ratchet wheel 23 by the length of two teeth. The associated gear ratio is so selected that advance by the distance of one tooth corresponds to advance of the copy 1 by the width of a single scanning line while double tooth advance corresponds to advance of the copy by a double line width.

A crank 32 may be mounted on the drive roller shaft 5 for rapid manual advancement of the belt, to permit which, a freewheeling device, for example, a ratchet and pawl 33, is interposed between the worm gear 25 and the roller shaft 5.

The upper guide plate 11 is pierced by a slot 40 extending transversely of the belt 2 slightly less than the full width of the guide plate 11 and over a distance at least as great as the widest copy to be scanned. In the drawing, the width of the slot has been greatly exaggerated in order to allow space to show separation of light beams in accordance with the invention. The width of this slot need not in fact be greater than the width of a few full scanning lines, for example, a few hundredths of an inch.

Long filament lamps 41 are mounted close to this slot and preferably on each side of it in position to illuminate as brightly as possible a band of the copy 1 where it is exposed in the slot 40. One lamp will serve, but stronger illumination is secured with two placed as shown. These lamps may be provided with a reflector or a condensing lens system, for example, a cylindrical lens, in order that the illumination of the exposed band of copy may be as intense as possible. Furthermore, the upper edges of the slot may be widely beveled to admit light from these long filament lamps through wide angles and to permit light reflected from the copy to emerge unimpeded; and the lower edges of the slot are preferably slightly rounded to prevent their catching the copy and scratching or tearing it. The leading end of the guide plate 11 may be provided with a sloping riser to facilitate admission of the copy between it and the belt.

The guide plate 11 may, of course, be of transparent material, for example plate glass, or it may be provided with a glass insert instead of a slot. However, on account of the fact that glass becomes scratched, the open slot above described is preferred.

Mounted in cooperative disposition with that portion of the copy which is exposed through the slot is an optical system comprising a rocking mirror 42, a reciprocating lens 43, a fixed lens 44, a fixed mirror 45, and a shield 46 containing two small apertures 47, 48. Each of these apertures defines or limits the size and shape of an image of a single elemental area of the copy. With an optical system whose magnification is unity, and scanning lines spaced 100 to the inch, each of these apertures may be 0.01 inch square. If the magnification of the optical system is other than unity, the size of the apertures may be altered accordingly.

The mirrors and lenses are disposed to bring two elemental areas of the copy 1, spaced apart by the width of a single scanning line, into conjugate focal relation with the apertures 47, 48. This condition is indicated on the drawing by the dotted lines 50, 51, each of which represents the path of a single ray of the light beam joining an elemental copy area to its aperture. The fixed mirror 45 is a convenience and permits greater compactness of the apparatus, but it is in no sense essential.

The rocking mirror 42 is preferably mounted vertically above the mid-point of the scanning slot 40 in a frame which may be pivoted to rock on journals 52 about an axis lying in the mirror face and fixed with respect to the apparatus framework. As shown the mirror 42 is arranged to be rocked by reciprocation of links 53, 54 by rotation of a cam 55 which is slidably mounted on a shaft 56 arranged to be driven through change gears 57 by a motor 58. Rocking of this mirror causes different elemental areas of the copy to be imaged on the apertures 47, 48 in succession. In so doing, however, the total path length from the copy 1 to the apertures 47, 48 is altered so that focal points which are optically conjugate to the apertures no longer lie in the copy plane. To maintain the elemental copy areas always in conjugate focal relation with the apertures, provision is made to reciprocate the lens 43 in just the proper amount to compensate for errors in focus caused by the motion of the rocking mirror 42. This provision, which is fully described in the aforementioned Patent 2,262,584 and forms a part of the subject-matter thereof, is accomplished by the use of another cam 59 which, being mounted on the same shaft 56 as the mirror cam, rotates synchronously therewith.

In the course of the advance of the belt 2 each elemental area of the copy first meets the scanning line in which the light beam 50 which is directed toward the aperture 47 originates. This aperture may therefore be termed the "advance" aperture, and the apparatus associated therewith will be fully described subsequently. Each elemental area of the copy next reaches the line in which the other light ray 51, directed upon the aperture 48, originates. As shown, the light of the ray 51 is projected through the aperture 48 and is thereafter reflected by a prism 61 onto a photoelectric cell 63. Current output from this cell 63, which is proportional to the intensity of the main scanning beam 51 and therefore to the light values of successive elemental areas scanned is supplied to a direct current amplifier 65 to provide image signals. These image signals may then be transmitted directly to the receiver but it is preferred to transmit instead a high frequency carrier modulated in accordance with the picture signals. Therefore there is provided a 2000-cycle oscillator 66 whose output energy is supplied, together with that from the direct current amplifier 65 to a modulator 67 and thence to the line 68 and output terminals 69.

The light of the beam 50 which passes the aperture 47 is reflected by a prism 62 and projected onto a photoelectric cell 64 whose output current flows through a resistor 70. The resulting voltage drop across this resistor is impressed on the input circuit of a suitable trigger device, for example, a gas discharge tube 71 which, in addition to the usual cathode 72 and anode 73, contains a starting anode or grid 74. This gas discharge tube is biased, for example by adjustment of the voltage of a bias battery 75, to remain below its cut-off point as long as full photocell current, corresponding to bright portions of the copy 1, flows through the resistor 70. At the same time its bias is such that when the premonitory light beam 50 is momentarily reduced in strength, as for example, when a dark elemental area of the copy is imaged on the premonitory aperture 47, ignition of the tube 71 takes place and anode current from a battery 76 or other suitable source flows in the cathode-anode circuit of the tube. By virtue of the characteristics of this discharge tube, the anode current continues to flow thereafter until stopped by other means; in other words, the starting anode or grid 74 of the tube loses control so that subsequent increase in the strength of the premonitory beam 50, due for example to imaging light elemental copy areas on the premonitory aperture, has no effect.

The anode 73 of the gas discharge tube 71 is connected in series with a relay coil 77 and a switch 78 which is normally closed but is arranged to be opened momentarily once in the course of each revolution of a cam 79 which is fixedly mounted on the drive shaft 56. The armature 80 of the relay 77 is held by a spring in position to close a contact 81 in the absence of relay current and the spring tension is so adjusted that when current flows through the relay coil 77 the armature 80 is urged against the spring tension and the contact 81 is opened and another contact 82 is closed instead. The relay armature 80 itself is connected through a battery 83 or other current source, through a switch 84 to ground. The switch 84, which is normally open, is arranged to be momentarily closed once in the course of each revolution of the drive shaft 56 by the cam 79. The contact 81 is connected in series with relay coil 28, resistor 85 and battery 86 to ground and the contact 82 is similarly connected in series with relay coil 29, resistor 87 and battery 88 to ground, so that closure of the switch 84 energizes one or other of the relays 28 or 29, to advance the copy by a double line width or a single line width respectively, depending on whether or not the relay 77 is energized by anode current of the discharge tube 71.

The switches 84 and 78 are so placed with respect to each other, and the knob 79a of the cam 79 is so placed with respect to the operative faces of the cams 55 and 59 that the switches 84 and 78 are operated in succession and during the flyback time of the mirror 42. For example, the switch 84 may be closed immediately after the completion of a line scan and the switch 78 opened just prior to the commencement of the next line scan.

To provide suitable signals for advancing the recorder apparatus at the receiver station by a single line width or a double line width as required in step with the advance of the copy at the transmitter, there may be provided two separate signal sources of readily distinguishable signals, one or other of which momentarily supplies energy to the transmission channel leading to the receiver station at the conclusion of each line scan. Thus, for example, a generator 90 of oscillations of a frequency different from the image signal carrier frequency, for example, 1000 cycles per second, is connected to the input circuit of an amplifier tube 91, whose output current, when the amplifier is rendered operative, flows through a resistor 92 giving rise to a corresponding signal on the line 68 across which it is connected, and a second oscillator 93 which generates oscillations of a still different frequency, for example 500 cycles per second, is similarly connected to the input circuit of an amplifier tube 94 whose output current, when the tube is energized, flows through a resistor 95 giving rise to a corresponding signal on the line 68 across which it is connected. The amplifiers 91, 94, normally biased below cut-off by the voltages of batteries 86, 88, are rendered operative in the alternative by removing their steady biases and placing on them instead a more positive bias of the battery 83 through one or other of the relays 28, 29, each time the cam-operated switch 84 is closed.

The operation of the apparatus as described above is as follows: Assuming that the premonitory aperture 47 has seen no black elemental areas during a full line scan, then, as above, explained, the auxiliary discharge tube 71 will not be ignited, the selector relay 77 will not be energized and its armature 80 will remain in the position shown under tension of its spring so that the selector contact 81 remains closed and the contact 82 remains open. Under these conditions, at the conclusion of the full line scan the cam 79 momentarily closes the battery switch 84. This serves to apply the voltage of the battery 83 to the double line advance relay 28 and at the same time to remove the negative bias of the amplifier 91. The relay 28 is energized and advances the transmitter copy 1 by the width of the two lines and at the same time, the amplifier 91 being rendered conductive, a 1000-cycle signal from the oscillator 90 is placed on the line 68 for transmission to a receiver where it may operate appropriate mechanism for advancing the impression-receiving medium by a double line width. On the other hand, the single line advance relay 29 remains unenergized and the 500-cycle oscillator 93 remains blocked by its amplifier 94 on account of the fact that the selector contact 82 is open.

Assume in the second place that during the course of scanning the line in question the premonitory aperture 47 has seen one or more dark areas. As above explained, the auxiliary discharge tube 71 is thereby ignited. Under these conditions the selector relay 77 is energized and its armature 80 is pulled magnetically against the tension of its retaining spring to open the contact 81 and close the contact 82. The amplifier 94 and the single line advance relay 29 are conditioned for excitation when in the course of its rotation the cam 79 reaches the position in which it closes the switch 84. When this occurs, which as above stated takes place at the conclusion of the line scan, battery voltage of the battery 83 is supplied to the single line advance relay 29 and 500-cycles oscillations from the generator 93 are permitted to pass through the amplifier 94 which has now been rendered conductive by removal of its negative bias. These oscillations may then pass over the line 68 to the receiver where they may operate appropriate mechanism for advancing the impression receiving medium by the width of a single line. At the same time, the 1000-cycles oscillator 90 remains blocked by its negatively biased amplifier 91 and the double line advance relay 28 remains unenergized.

As the shaft 56 continues its rotation it momentarily opens the switch 78, thus deenergizing the relay 77, breaking the anode circuit of the discharge tube 71 and allowing the starting electrode 74 of the latter to regain control.

The discharge tube 71 serves in this connection as an impression-storage device, since it stores an impression of dark copy areas which appear anywhere within the advance scanning line for use at the conclusion of the main line scan. This stored impression is then erased by opening of the switch 78. Impression-storage devices of other types may occur to those skilled in the art as being suitable for use in this connection.

At the receiver the 1000-cycle double-line advance signals, the 500-cycle single line advance signals and the image signals may be separated from each other and directed into the devices they are intended to operate by suitable filters in well-known manner. If for any reason such separation is found undesirable, the various signals of the invention may, of course, be transmitted over separate channels, by carrier modulation or otherwise.

It will be apparent that the system of the invention permits a substantial increase in the over-all speed of transmission of image signals, particularly in the case of printed, typewritten or written copy in which the dark areas run substantially in one direction to form lines of characters (to be distinguished from scanning lines) with empty spaces of substantial extent between. Indeed, ordinary typewritten copy, single-spaced, contains entirely blank lines of substantially the same width as the character lines, and double-spaced typed copy contains blanks of still greater width. The apparatus of the invention serves to reduce the transmission time of blank areas to one-half of what it would otherwise be and therefore, with copy of this sort, effects a considerable reduction in the total transmission time for the copy as a whole.

In the system above described, an area of copy extending the full width of the copy to be scanned and at least as wide as two scanning lines was strongly illuminated, for example by long filament lamps 41 placed on either side of the scanning slot 40. It will be apparent that the greater part of this light is lost, since only two elemental picture areas of the band are utilized at one time. If desired, light can be economized by varying the optical arrangement as shown in Fig. 2. Referring to Fig. 2, two separate light sources 100, 101 are provided whose light is directed by prisms 61, 62 onto two separate scanning apertures 47, 48. The light of the two sources is preferably of different color characteristics, and this is indicated by the provision of a color filter 102 of one color, for example, a red filter, in the light path of the source 100 and a filter 103 of different characteristic, for example, a blue filter, in the light path of the source 101. The filters may be placed at any convenient point in the light paths and each of them should absorb light transmitted by the other.

If preferred, the two apertures 47, 48 may be illuminated by a single lamp or other light source by proper disposition of this source and associated optical elements.

The two beams of different colored light are then reflected by the stationary mirror 45 onto the rocking mirror 42 which serves to sweep the images of the illuminated apertures across the copy. These images, which serve as scanning spots, are preferably spaced apart by the width of the scanning line in the manner above described in connection with Fig. 1. A stationary lens 44 and a reciprocable lens 43 are provided in the manner above described to focus the apertures 47, 48 on the copy and maintain this conjugate focal relationship throughout the sweep of the scanning spots. This arrangement strongly illuminates two selected elemental areas of the copy, leaving the remainder in comparative darkness. It is therefore particularly appropriate for sensitive copy which might be injured by the prolonged application of light and heat to all parts thereof as in the arrangement of Fig. 1.

Light is then diffusely reflected in various directions from each of the elemental copy areas thus illuminated in accordance with well-known physical laws, and two separate photoelectric cells 104, 105 or other appropriate light-responsive devices are placed in the vicinity of the scanning slot 40 and disposed to receive as much of the reflected light as possible, independent of the position of the scanning beams along the scanning lines. These photocells may, for example, be of the long cathode type described in Patent 2,262,584 and the light received by each cell may be augmented by any appropriate arrangement of lenses or reflectors as likewise disclosed in Patent 2,262,584. In order to insure that the main photoelectric cell 104 shall respond only to light from the main scanning beam 51 and that the advance photocell 105 shall likewise respond only to light from the advance scanning beam 50, a further color separation may be employed. Thus, for example, the main scanning cell 104 may be provided with a red-sensitive cathode, for example a caesium compound, and the auxiliary scanning cell 105 may be provided with a blue-sensitive potassium cathode. If preferred, a red color filter 106 may be disposed in the path of the light from the copy 1 to the main scanning photocell 104 and a blue color filter 107 correspondingly disposed in the path of the light from the copy to the advance scanning photocell 105. This arrangement serves to insure separation of the signals from the principal scanning spot and the advance scanning spot and confines them to their respective photoelectric cells and associated circuits.

The associated electrical and mechanical apparatus may be identical with that shown in Fig. 1 and fully described above.

Referring again to Fig. 1, cams 55 and 59 are arranged for scanning copy of the full width of slot 40 as above described and for maintaining the effective scanning areas in focus throughout the scanning operation by coordinated movement of the mirror 42 and the lens 43. Provision is made, however, for scanning copy of reduced width and to this end the cams, instead of being fixedly mounted on the shaft 56, are fixedly mounted on a sleeve 56′ which is arranged to rotate with the shaft 56 but is free to be moved along the latter in an axial direction. Another pair of cams 55′ and 59′ are mounted on the same sleeve 56′ as shown. When the copy to be scanned is of reduced width, for example, half the full width of the scanning slot 40, the sleeve 56′ may be slid axially along the shaft 56, taking cams 55 and 59 out of engagement with their respective followers and bringing cams 55′ and 59′ into engagement therewith. The cam 55′ is preferably cut to return the mirror 42 to its initial position after swinging the beams 50 and 51 over one half the length of the slot 40 and the cam 59′ is correspondingly cut to preserve sharp focus of the images of the apertures 47 and 48 on the copy 1 throughout the resulting reduced beam motion. Since, under these conditions, the speeds of the individual moving parts will have been greatly reduced, the speed of the apparatus as a whole may be increased, as by shifting the gears 57, thereby effecting an increase in the speed of transmission of the picture. These arrangements are in the main the same as those fully described in the aforementioned Patent 2,262,584.

No attempt has been made in the drawings to exhibit the precise form of the cam faces. Rather, the description of the operation and effect of these cams, for a fuller description of which reference is again made to Patent 2,262,584, should be taken as determining their form.

Fig. 3 indicates schematically a modification adapted to scanning copy of any arbitrary width equal to or less than the capacity of the apparatus which is limited only by the length of the scanning slot 40. For this arrangement the shaft 156 instead of being rotated continuously, as in Fig. 1, is rotated through a preassigned angle against the tension of a shaft-returning spring 157 and then, upon the release of magnetic clutch 158, snapped back to its starting point where its motion is arrested by stops 160. The clutch 158 is energized from a source 161 and the electric circuit is completed through a relay 162 and contacts 164. The current through the relay 162 may be adjusted to hold the contacts 164 closed against the tension of a spring 165 when a current is flowing as by initial adjustment of the variable resistor 163 connected across it. The scanning mirror 142 is provided with two arms 166, 167 adjustable with respect to each other, the angle between them being measurable by a scale 168 which may be graduated in units of copy width. The arm 167 is disposed to close the contact 164 when the mirror 142 is in position to direct the scanning beams 150, 151 to the beginning of a line of the copy and so permits the clutch 158 to be energized and scanning to commence. The other arm 166 is disposed to open the contacts 164 when the mirror 142 has been swung through an angle preset on the scale 168, corresponding to a sweep of the scanning beam over a full line of copy of the reduced width. When these contacts 164 are thus opened, the circuit of the magnetic clutch 158 is broken, thus permitting the spring 157 to return the cam shaft 156 and therefore the mirror 142 and lens 143 which may be identical with those shown in Fig. 1 to their starting points, and at the same time the relay 162 is de-energized. The spring 165 holds the contacts 164 open until the return sweep of the scanning beam is complete. Thereupon the arm 167 closes these contacts once more to allow the clutch 158 and the relay 162 to be energized and so to commence the scanning of the following line. In this arrangement, the cams 155, 159 do not rotate continuously in one direction but rather rotate through a certain angle determined by the setting on the scale 168 and then snap back to their starting points. It is desirable that the line-advancing signal occur after the scanning of any one line is completed and before the scanning of the following line commences; that is to say, during the flyback period only. To this end, a cam 179, fixed to the shaft 156, is provided with a hinged lug 180 which is urged against a stop 181 by the tension of a light spring 182. This lug 180, pressing against the stop 181, serves to close the first switch 184 and open the second switch 178 successively during the counter-clockwise flyback motion, and the tension of the spring 182 is so adjusted that in the course of the clockwise scanning motion, neither of these switches 184, 178 is affected.

The electrical circuits associated with these switches, including generators, amplifiers, trigger devices, copy-advancing relays, selector relays and all other apparatus may be identical with those above described in connection with Fig. 1 or may be modified therefrom in various particulars as desired.

Fig. 4 shows one form of receiver apparatus embodying the invention which may, by way of example, be employed for translating the signals delivered by the transmitter apparatus above described into a replica of the original copy. Referring to this figure, signals are received at input terminals 200 and are then directed into three separate paths the first of which 201 supplies the reproducer apparatus proper, the second 202 supplies single line advance apparatus, and the third 203 supplies double line advance apparatus.

In the first path the input terminals 200 are connected to a detector 204 whose output terminals are connected to the input terminals of a reproducer device; for example they may be connected by way of a biasing battery 205 to the cathode 206 and control grid 207 of a cathode ray reproducer tube of the type described and claimed in copending applications Serial Nos. 328,816 filed April 10, 1940 and 328,819, filed April 10, 1940, now Patents 2,273,433 issued Feb. 17, 1942, and 2,273,793, issued Feb. 17, 1942, respectively. Briefly, this device comprises an evacuated vessel containing an electron emissive cathode 206, a focusing anode 208 containing a beam-defining aperture 209, an accelerating anode 210, a pair of beam deflecting elements 211, and a conductive comb 212 comprising a plurality of discrete conductors arranged in a single row and extending parallel to each other through the end wall of the vessel. The distance from the center line of each conductor of the comb to the center line of an adjacent conductor should preferably be not greater than the width of a single elemental area of the copy or field to be reproduced; for example, the distance may be of the order of 0.01 inch. The beam receiving end of the tube may be enlarged in one dimension and flattened out into the form of a blunt wedge in another dimension and its inner walls are preferably provided with a conductive coating or lining 213 which is connected to the accelerating anode 210 in order to provide an electron collecting surface near the beam receiving comb 212 and to eliminate charges on the glass. For the purposes of this application the device is also provided with an electrode or grid 207 for modulating the cathode beam in accordance with the signal strength. Any desired means, however, may be employed to secure beam modulation.

Suitable sources of potential, for example batteries 214, are connected between the electrodes to supply operating voltages thereto. Battery voltages and electrode arrangements and spacings are selected to focus an electron beam originating at the cathode sharply on the comb 212, preferably on a single one of the comb conductors.

The discrete conductors which protrude through the end wall of the vessel and constitute the comb 212 may be mounted obliquely to the direction of the oncoming cathode beam as shown in the above-mentioned application Serial No. 328,816 so that despite the minute cross-section of each particular conductor, the cathode beam will strike it at a greater or less distance from the point at which the conductor passes through the tube wall even though the focusing of the cathode beam in a direction perpendicular to the scanning direction be more or less imperfect. The comb depicted in the drawings follows the improved construction of Patent 2,273,793 which serves the same purpose as well as others.

In order to secure a high current output it is preferable that electrons of the beam strike as large an area of each individual comb conductor as possible. To this end the electron beam may be given the cross-section of a narrow rectangle and focused in a narrow rectangular spot on the comb conductor or conductors by the use of the suitably shaped aperture 209 in the focusing anode 208. The same result may also be secured by other means, for example, the means described and claimed in Winans application Serial No. 307,255 filed December 2, 1939, now Patent 2,268,195, issued Dec. 30, 1941.

It is of advantage to spread some high resistance fluorescent material such as zinc silicate onto the glass surfaces between and adjacent to the comb conductors inside the tube to enable focusing to be adjusted visually.

The path of an electron beam originating at the cathode 206, passing through the anodes 208 and 210 and between the deflecting plates 211 and impinging on the comb 212 is indicated by dotted lines 215.

A sheet or tape 220 of appropriately sensitized material such as paper is placed immediately adjacent to or in contact with the outer ends of the comb conductors 212 and is backed by a knife-edge anode 221. The latter is connected through ground to the positive terminal of the battery 214 whose negative terminal is connected to the cathode 206. Thus the electron current of the cathode beam, unless it be reduced in strength by action of the modulating grid 207, passes through the particular comb conductor onto which it is instantaneously directed, through that part of the paper 220 adjacent the outer end of the comb conductor and to the anode 221, leaving on the paper a local alteration in its light characteristics by discoloration or otherwise.

The sensitive paper tape 220 and the manner in which it is affected by the current emerging from the comb wires may be of any suitable type. For example, the paper may be electrolytically sensitive, being moistened to render it active and conductive, or it may be a carbon-loaded paper with a thermally sensitive surface in direct contact with the comb wires, the carbon-loaded paper itself being in contact with the knife edge in which case the mark is made by the heat generated when the current passes through the sensitive surface by conduction. Still other types or forms of sensitive paper and methods of forming impressions on them will occur to those skilled in the art as appropriate for use in connection with the invention.

Current passing from the comb conductors 212 to the anode 221 through the paper 220 produces a voltage drop across the paper due to its electrical resistance and holds the comb conductors below the anode voltage by the amount of this voltage drop. For best operation, the conductive lining 213 should be maintained at a potential not far from that of the comb. For a particular set of conditions this may be secured by the use of a battery connected between the anode 217 and the conductive lining, but it has been found preferable to employ, instead, the voltage drop across a resistor 216 which is connected from the anode to the conductive lining and the accelerating electrode 210 due to a part of the emitted electron current which impinges on the latter. This connection is believed to serve the additional purpose of compensating for variations in the resistance of the sensitive paper. A tentatively offered explanation of this effect is as follows. When, for example, paper of higher resistance than normal is employed, the comb conductors 212 tend to fall in potential. Secondary electrons knocked out of the comb by the impact of the primary electrons of the beam 215 migrate to the conductve lining 213 and in effect reduce the useful current passing through the paper. At the same time this secondary current, by flowing through the resistor 216, increases the voltage drop across the latter in a sense to restore the potential difference between the comb 212 and the lining 213 to its original value.

It has been found that with a beam tube of the type described in Patent 2,273,793 and adjusted to deliver a beam current of the order of 500 microamperes, good results are secured when the resistor 216 is selected to provide a voltage drop of the order of 20 volts with ordinary commercial sensitive papers.

If sufficiently high voltage is available, direct conduction is unnecessary since an arc can be caused to pass through ordinary dry white paper in contact with carbon or dyed wax paper. The heat of the arc may then cause a deposit of carbon or dye on the white paper.

Whatever the means employed for forming an impression on the tape, it is of course not limited to the formation of a single record. With a sufficiently high voltage between comb wires and knife-edge anode, a plurality of copies may be made simultaneously.

Any suitable means may be employed for deflecting the cathode beam along the comb in the course of the scanning operation. Such means may take the form of a saw-tooth voltage generator whose output terminals are connected to the deflecting elements. A highly simplified saw-tooth voltage generator is shown in the figure below the reproduced tube. A battery 222 or other source of relatively high steady potential is connected through a high resistor 223 to a condenser 224. The two condenser terminals are connected to the deflecting elements or plates 211 of the tube respectively. Short-circuiting switches 225, 226 are connected across the condenser and arranged to be periodically closed as hereinafter described. In operation the condenser 224 is charged by the battery 222 through the resistor 223 and the resulting condenser voltage is impressed between the deflecting plates 211. As the condenser voltage increases the cathode beam 215 is deflected along the row of comb conductors 212. After a stipulated time has elapsed, the condenser 224 is short-circuited by closure of one of the switches 225, 226 and the cathode beam flies back to its starting point. In order that this starting point may be at one end of the comb instead of at its center, the battery 222 may be provided with an adjustable ground 227. If desired, a constant current resistor, for example, a pentode tube, may be employed as the charging resistor, but when a sufficiently high battery voltage is readily available excellent results can be secured without resorting to this expedient.

The sensitized paper tape 220 is arranged to be intermittently advanced by rotation of a driving roller 230 while being held in correct position by an idler roller 231. The driving roller 230 is arranged to be driven through worm gears 232, 233 and ratchet wheel 234, operable by two pawls 235, 236 and which in turn are actuated by two relays 237, 238 in a manner similar to that shown in Fig. 1 and described above. It may likewise be provided with a free-wheeling device and a crank for rapid manual device, just as in Fig. 1. As in the case of the transmitter, one of the pawls 235 is arranged to advance the ratchet wheel 234 by the width of one tooth against the tension of its spring 239 and therefore the sensitized paper tape 220 by the width of a single scanning line when its relay 238 is energized. Likewise, energization of the double line advance relay 238 advances the other pawl 236 against the tension of its spring 240 by a distance of two ratchet wheel teeth and the sensitized paper 220 by the width of two scanning lines. In each case the motion of the pawl may be adjusted and limited by proper positioning of stops 241, 242.

A contact switch 225 is coupled to the pawl 235 and arranged to be closed when the relay 237 which actuates that pawl is energized. Likewise another switch contact 226 is coupled to the pawl 236 and arranged to be closed when the relay 238 is energized. These switches are connected in parallel across the condenser 224 so that the latter is short-circuited each time that either one of the two pawls 235, 236 is operated. The second path from the input terminals 200 leads through a filter 250 and a rectifier 251 to the single line advance relay 237 and the third path likewise leads through a filter 255 and a rectifier 256 to the double line advance relay 238. The filters 250 and 255 may appropriately be selected to pass single line advance signals and double line advance signals, respectively. For example, the pass-band of the single line advance filter 250 may extend from 0 to 600 cycles to include the 500-cycle signals of the generator 93 and exclude the 1000-cycle signals of the generator 90, while the pass-band of the double line advance filter 255 may extend from 700 to 1200 cycles to include the signals of the generator 90 but exclude those of the generator 93 and also those of the image signal carrier generator 66. The rectifiers are included to prevent the chatter which usually accompanies operation of relays on alternating current alone. A condenser 253, 257 is preferably connected across each of the relays 237, 238 to assist in smoothing out the current. The capacitances of these condensers are preferably chosen at the values which will tune the respective relays to the frequencies of the residual alternating components of the currents delivered to the relays by the rectifiers. If this expedient is employed the filters 250, 255 may be dispensed with.

The voltage of the scanning battery 222 and the relative magnitudes of the resistor 223 and condenser 224 determine the rate of voltage rise for the condenser 224 and therefore the speed of deflection of the beam 215 along the comb 212. The resistor 223 is preferably of the variable type so that this speed may be regulated. It may be set at such a value that the beam 215 travels the full length of the comb 212 in the time occupied by the scanning of one line at the transmitter independent of the length of the copy line and of the transmitter scanning rate. Since the flyback of the beam 215 takes place practically instantaneously, the adjustment is preferably such that the beam 215 continues to be deflected beyond the end of the comb 212 during the return sweep of the scanning mirror 42 at the transmitter. Throughout the operative portion of the sweep of the electron beam along the comb, the strength of this beam is modulated by the signals impressed on the grid 207, with the result that more or less current passes through the successive comb conductors, through the sensitized paper to the knife edge anode 221 to leave impressions of more or less darkness on the paper 220 and so reconstitute a replica of the original copy 8.

At the conclusion of each scanning line, either the 500-cycle single line advance signal or the 1000-cycle double line advance signal arrives at the input terminals 200 of the apparatus. In the one case the sensitized paper 220 is advanced by the relay 237 by the width of a single scanning line and in the other case the paper is advanced by the relay 238 by the width of two scanning lines. In either case, one or other of the switches 225, 226 is closed to short-circuit the condenser 224 and return the electron beam 215 to its starting point in preparation for the scanning of the ensuing line.

It will be apparent that the system above described results in continuous synchronization between transmitter and receiver, and that advantageous simplification of the apparatus results from the use of the single line advance signals and double line advance signals of the invention to produce flyback of the electron beam at the receiver at the proper instant and line-for-line synchronization between the transmitter apparatus and receiver apparatus. This result is, of course, not dependent on the use of the particular saw-tooth voltage generator shown. For example if the well-known relaxation oscillator be employed, it may be arranged to be tripped electrically on the arrival of either of the single-line advance or double line advance signals.

Other receiver apparatus appropriate for use in connection with the invention will occur to those skilled in the art. For example, a receiver apparatus of the well-known rotating drum type may be employed, in which single line advance is ordinarily effected by a continuous motion of the printer along a line parallel with the axis of the drum. In this case double line advance signals would be used to operate any suitable mechanism for skipping a single line.

In the embodiments above described the advance aperture is spaced from the main aperture by the width of a single line and the apparatus is so arranged that the two scanning spots travel side by side the full length of two adjacent scanning lines, with the result that when the advance aperture sees only white areas throughout the length of its full line, that line is skipped in the course of the next copy advance. It will be apparent that a different spacing of the scanning spots or apertures is entirely feasible and an associated different choice of the ensuing copy advance is likewise entirely feasible. For example, the apparatus may easily be modified to skip two lines instead of one and to do so when no dark picture areas appear anywhere within the compass of two successive lines. This may be simply accomplished merely by doubling the width, in a direction perpendicular to the scanning direction, of the advance aperture. If this should result in too great a reduction in sensitivity, it may likewise be accomplished without an increase in the size of the advance aperture by the use of a modification in the trigger circuit. For example, the trigger device may be modified to recall any dark elements seen in the course of two successive scanning lines merely by providing that the switch which deenergizes it shall be momentarily closed only once for every other revolution of the main scanning shaft by the provision of a cam which rotates at one-half the speed of its shaft.

The apparatus may likewise be modified to effect a skipping of a portion of a scanning line instead of a full scanning line and to effect this skipping when no dark areas appear anywhere in the particular portion in question. Furthermore, it may easily be adapted by modifications of a minor nature to transmission of "negative" copy, that is, copy consisting of light marks on a dark background.

Modifications to suit the exigencies of scanning systems other than the one above described will occur to those skilled in the art. For example, in apparatus in which scanning is accomplished by continuous rotation of a cylinder about which the copy is wrapped, normal single line advance is accomplished continuously, as for example by the advance of a screw thread. In this case, signals from a premonitory aperture may be supplied to an advancing mechanism to effect intermittent axial advance of the cylinder as a whole with respect to the scanning aperture, when in the course of a full revolution of the cylinder, the advance aperture has seen no dark areas.

Various modifications of the optical apparatus above described will likewise occur to those skilled in the art. In particular, if desired, more than two scanning apertures may be employed, either in accordance with the embodiment of Fig. 1 or with that of Fig. 2. In the latter case a three-way color separation, for example by pairs of red, yellow and blue filters, may be employed to confine the light of each beam entirely in the path to its associated photoelectric cell.

The apparatus described above is of a type particularly suited to transmission of image signals from opaque copy, for example printed on typewritten matter, and the reconstitution thereof. As stated at the outset, however, this is by way of example only and in no sense restrictive, since modifications may occur to those skilled in the art which adapt the apparatus to use with fields of other types, for example a transparency, either positive or negative, or indeed, a bare optical image of an object field.

In the case of each of the modifications here alluded to, corresponding modifications of the receiver apparatus may occur to those skilled in the art.

What is claimed is:

1. In an image signal transmission system, means for scanning an elemental line of a field to be transmitted and deriving image signals therefrom, means for scanning another like ele-

mental line of said field in advance of said first-named line and deriving auxiliary signals therefrom, and means for advancing said field relatively to both of said scanning means under control of said auxiliary signals.

2. In an image signal transmission system, means for scanning successive elemental areas of a line of field to be transmitted and deriving image signals therefrom, means for scanning other like elemental areas of said field in advance of said first-named elemental areas and deriving auxiliary signals therefrom, and means controlled by said auxiliary signals for causing said first-named scanning means to skip blank areas scanned by said second-named scanning means.

3. In an image signal transmission system, a scanning aperture, means including said aperture for successively scanning elemental areas of a line of a field to be transmitted, means for advancing said field by a single line width, means for advancing said field by a double line width, and means for selectively actuating said field-advancing means in dependence on the light characteristics of elemental field areas seen by said aperture.

4. In an image signal transmission system, means for producing image signals related to information-containing areas of a field to be transmitted, means for producing auxiliary signals in response to blank areas of said field, and means for causing said image signal producing means to skip blank areas of said field under control of said auxiliary signals.

5. In an image signal transmission system, means for illuminating a plurality of elemental areas of a field to be transmitted, said elemental areas being spaced apart by at least the width of a scanning line, means for sweeping said illuminated areas over said field to scan said field, a plurality of separate photoelectric devices, means for projecting light from each one of said areas onto an associated one of said photoelectric devices, means for deriving image signals from one of said devices, means for deriving auxiliary signals from another of said devices, and means for advancing said field alternatively by one line width or by more than one line width under control of said auxiliary signals.

6. In an image signal transmission system, a principal source of light, a principal aperture and a principal light responsive element, means including said source, said aperture and said element for scanning elemental areas of a field to derive image signals, an auxiliary light source, an auxiliary aperture and an auxiliary light responsive element, means including said source, said aperture and said element for scanning other elemental areas of said field to derive auxiliary signals, and selective light control means for excluding light originating in said principal source from said auxiliary light responsive element and light originating in said principal source from said auxiliary light responsive element.

7. In an image signal transmission system, a scanning aperture, means including said aperture for scanning elemental areas of a field to be transmitted in succession to derive signals, a trigger device associated with said scanning means arranged to maintain a first state prior to energiztion of said device by an impulse and to trip to a second state upon energization by an impulse, said trigger device being arranged to deliver energy in accordanced with its state, means for applying said signals to said trigger device to provide an energizing impulse when said aperture sees an elemental field area in any position in said field and differing in light characteristic from its background, and means for producing relative movement of said field and said scanning means under control of said energy.

8. In an image signal transmission system, a scanning aperture, means including said aperture for successively scanning elemental areas of a line of a field to be transmitted to derive signals, a trigger device associated with said scanning means arranged to maintain a first state prior to energization of said device by an impulse and to trip to a second state upon energization by an impulse and maintain said second state thenceforward until disabled, said trigger device being arranged to deliver energy in relation to its state, means for applying said signals to said trigger device to provide an energizing impulse when said aperture sees an elemental field area in any position in said field and differing in light characteristic from its background, means for producing relative movement of said field and said scanning means under control of said energy, and means for disabling said trigger device at the conclusion of each line scan.

9. In an image signal transmission system, a scanning aperture, means including said aperture for scanning elemental areas of a line of a field to be transmitted in succession to derive a signal having one characteristic when said aperture has seen one or more dark elemental areas in a scanning line and another characteristic when said aperture has seen no dark areas in said line, a generator of oscillations of a first frequency, a generator of oscillations of a second frequency, means responsive to oscillations of said first frequency for advancing said field by a single line width, means responsive to oscillations of said second frequency for advancing said field by a double line width, and means for actuating said generators selectively in accordance with said characteristics of said signal.

10. In an image signal transmission system, a plurality of sources of light of different color characteristics, scanning means including means for projecting beams of light of said sources onto different elemental areas of a field to be transmitted, said elemental areas being spaced apart, means for sweeping said means together over said field to scan said field, a plurality of light responsive devices, each disposed to receive light reflected from one of said elemental areas and sensitive to light of the color illuminating said area and insensitive to light of the color illuminating others of said areas, means for deriving image signals from one of said devices, means for deriving auxiliary signals from the other of said devices, and means for varying the advance of said scanning means relatively to said field under control of said auxiliary signals.

11. In a system for deriving and transmitting image signals from a field scanned, a principal aperture, an auxiliary aperture, means for scanning an elemental line of said field by said principal aperture and deriving image signals therefrom, means for scanning another elemental field line in advance of said first-named line by said auxiliary aperture and deriving auxiliary signals therefrom, and means for advancing said field relatively to both of said scanning means under control of said auxiliary signals and by distances related to the tone values of areas seen by said auxiliary aperture.

12. In a system for deriving and transmitting image signals from a field scanned, a principal aperture, an auxiliary aperture, means for scanning elemental areas of a field line in succession by said principal aperture, means for scanning other elemental areas in advance of said first-named areas in a like succession by said auxiliary aperture, means for translating tone values of areas seen by said principal aperture into image signals, and means for deriving single-line-advance signals from non-uniform areas seen by said auxiliary aperture and plural-line-advance signals from uniform areas seen by said auxiliary aperture.

13. In a picture transmission system, means for scanning an elemental line of a field to be transmitted and deriving image signals therefrom, means for scanning another elemental field line in advance of said first-named line and deriving auxiliary signals therefrom, means for storing said auxiliary signals until the termination of a line scan, and means for advancing said field at the termination of said line scan under control of said stored signals.

14. In a picture transmission system, means for scanning successive elemental areas of a field to be transmitted and deriving image signals therefrom, means for scanning other like elemental areas of said field in advance of said first-named areas and deriving auxiliary signals therefrom, means for storing said auxiliary signals until the termination of a stipulated period, means for advancing said field at the termination of said period under control of said stored signals, and means for reconditioning said storage means to repeat said signal storage.

15. In the art of picture transmission, the method which comprises scanning successive elemental areas of a line of a field to be transmitted and deriving image signals therefrom, simultaneously scanning successive elemental areas of another line of said field in advance of said first-named line and deriving auxiliary signals therefrom, storing said auxiliary signals derived in the course of scanning a line until the termination of said line scan, and advancing said field under control of said stored signals.

16. In an image signal transmission system, means for scanning information-containing areas of a field to produce image signals related to said areas, means for scanning other like areas in advance of said first-named areas to produce auxiliary signals related to blank areas positioned at random in said field, means for transmitting said image signals and said auxiliary signals to a receiver station, and at said receiver station, an impression-receiving medium, means for reconstituting information-containing areas on said medium under control of said image signals, and means for skipping certain areas of said medium corresponding to blank areas of said field under control of said auxiliary signals.

17. In combination with image signal transmitter apparatus including scanning means and delivering image signals related to elemental areas scanned and auxiliary signals related to like areas in advance of said first-named areas, receiver apparatus which comprises an impression-receiving medium, a scanning element arranged to scan said medium in one direction and form impressions thereon, means for modulating the action of said scanning element to vary said impressions under control of received image signals, means for synchronizing the movement of said scanning element with the movement of the transmitter scanning means under control of said auxiliary signals, and means for advancing said medium relatively to said scanning element by various distances in a direction perpendicular to said scanning direction under control of correspondingly various components of said auxiliary signals.

18. Means for scanning a field containing parallel rows of markings with interspersed blank strips between said rows to set up image current, said means comprising means for scanning along parallel elemental paths extending in the direction of said rows, advance scanning means for testing in advance of said first scanning means along a path extending in the same direction and for setting up a distinctive signal when said tested path is along a blank strip, and means responsive to said signal for determining the selection of the next elemental path taken by said first scanning means.

19. In an image signal transmission system, means for scanning an object field in parallel transverse elemental lines to produce image signals related to information-containing areas of said field, means for producing auxiliary signals in response to blank areas of said field, and means under control of said auxiliary signals for causing said image-signal-producing means to skip some at least of any blank elemental lines present in the field which is scanned.

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