Aug. 4, 1942. A. G. JENSEN 2,291,723

APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

Filed Feb. 29, 1940 8 Sheets-Sheet 1

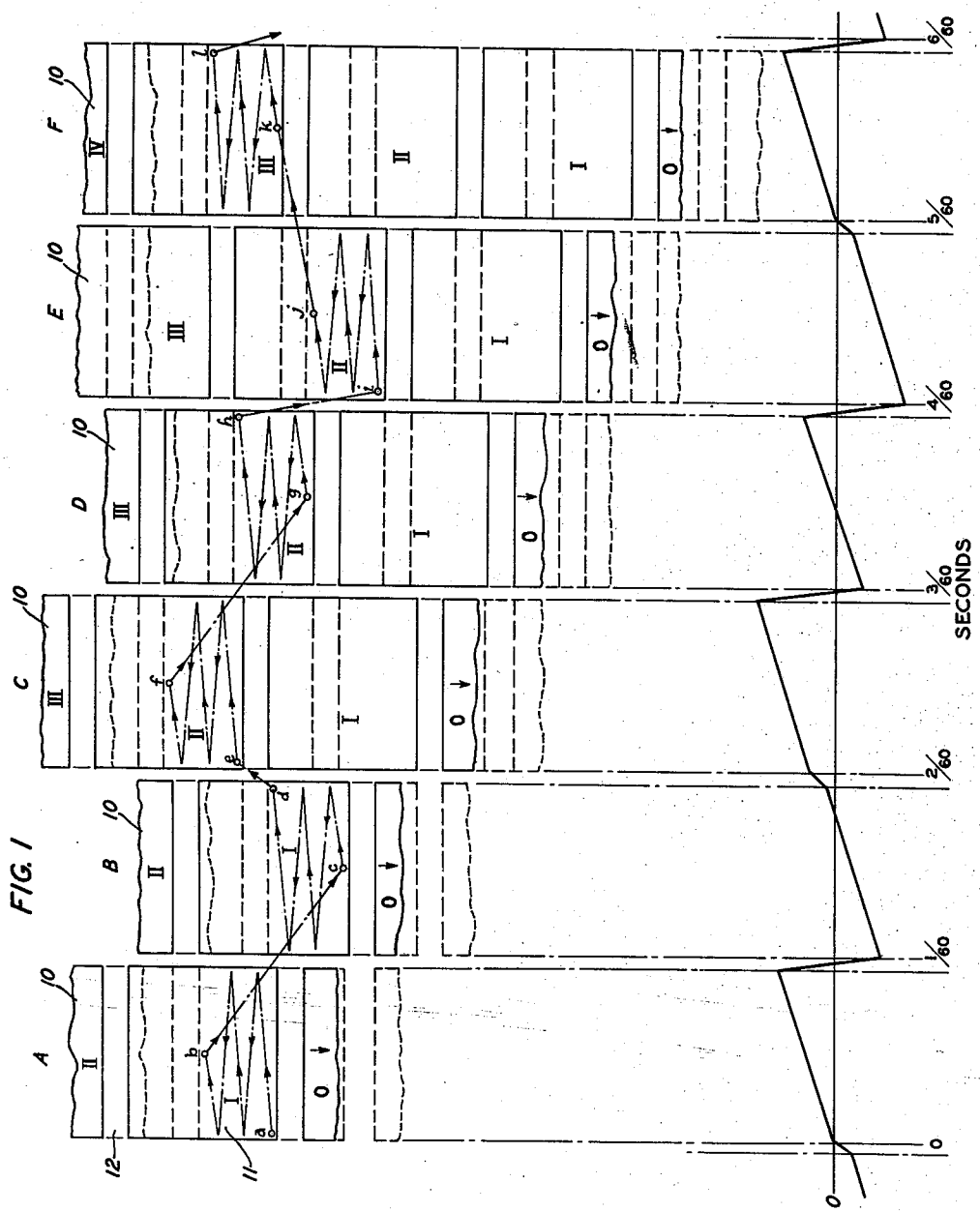


FIG. 1

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APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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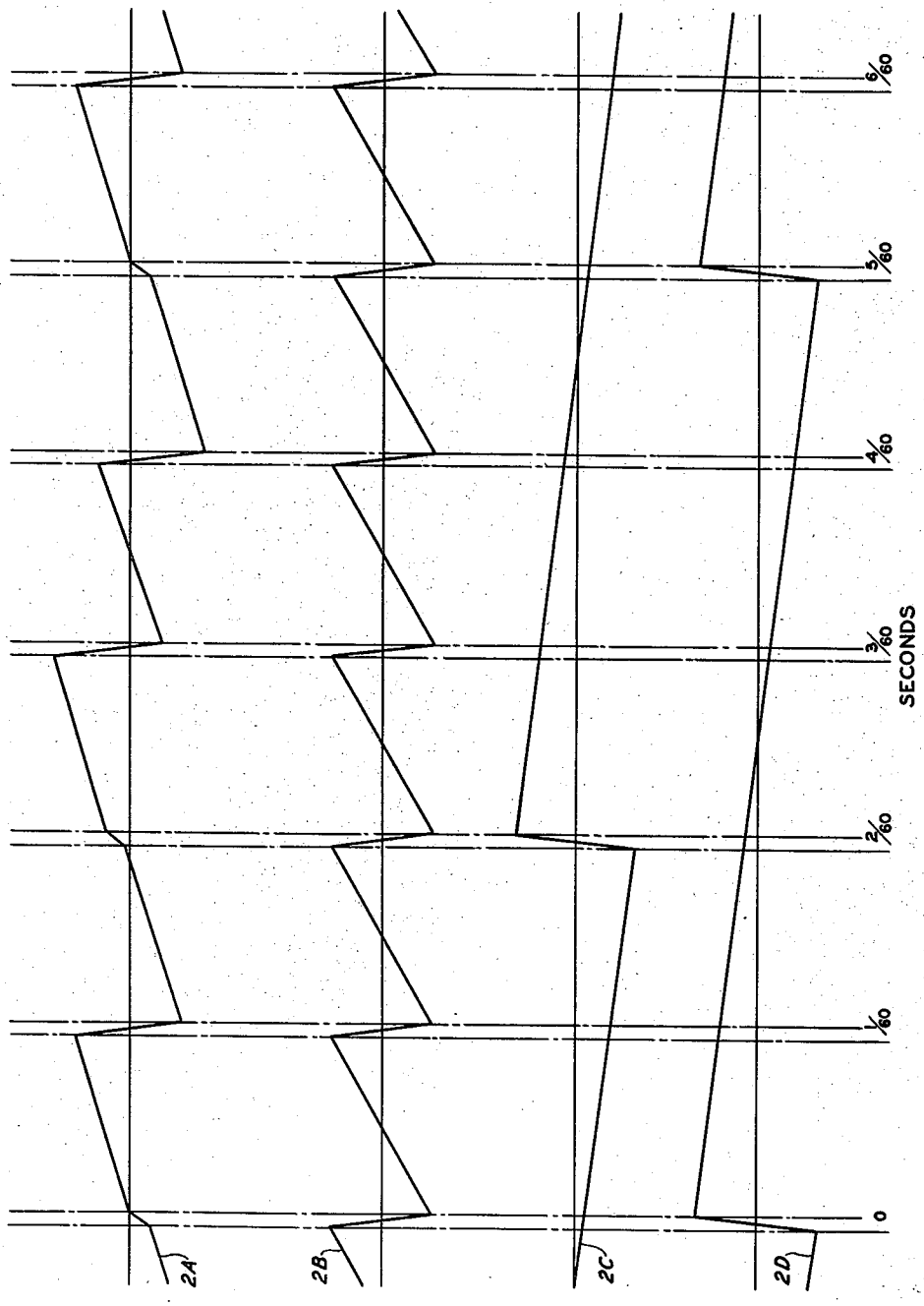


FIG. 2

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APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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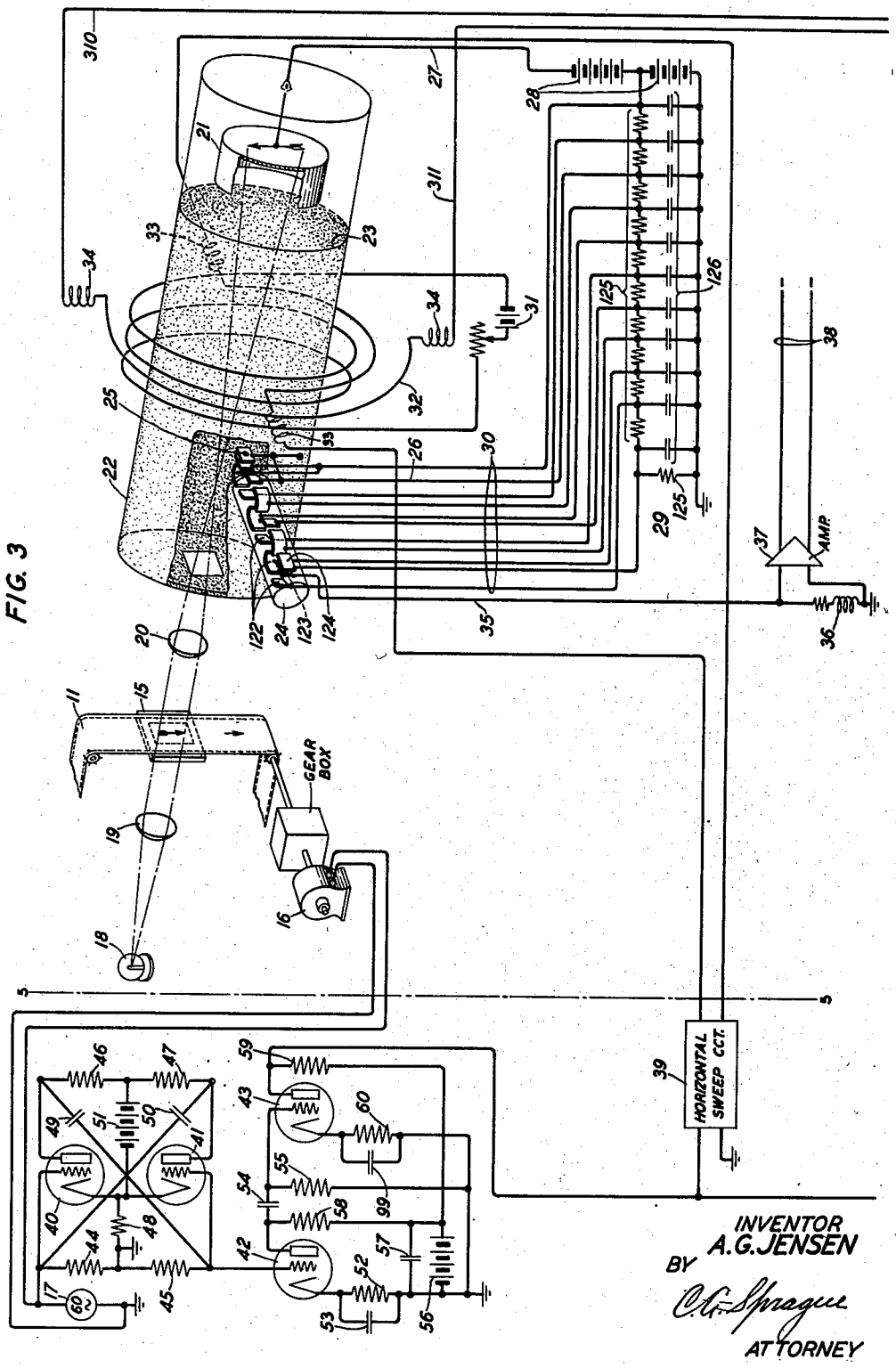


FIG. 3

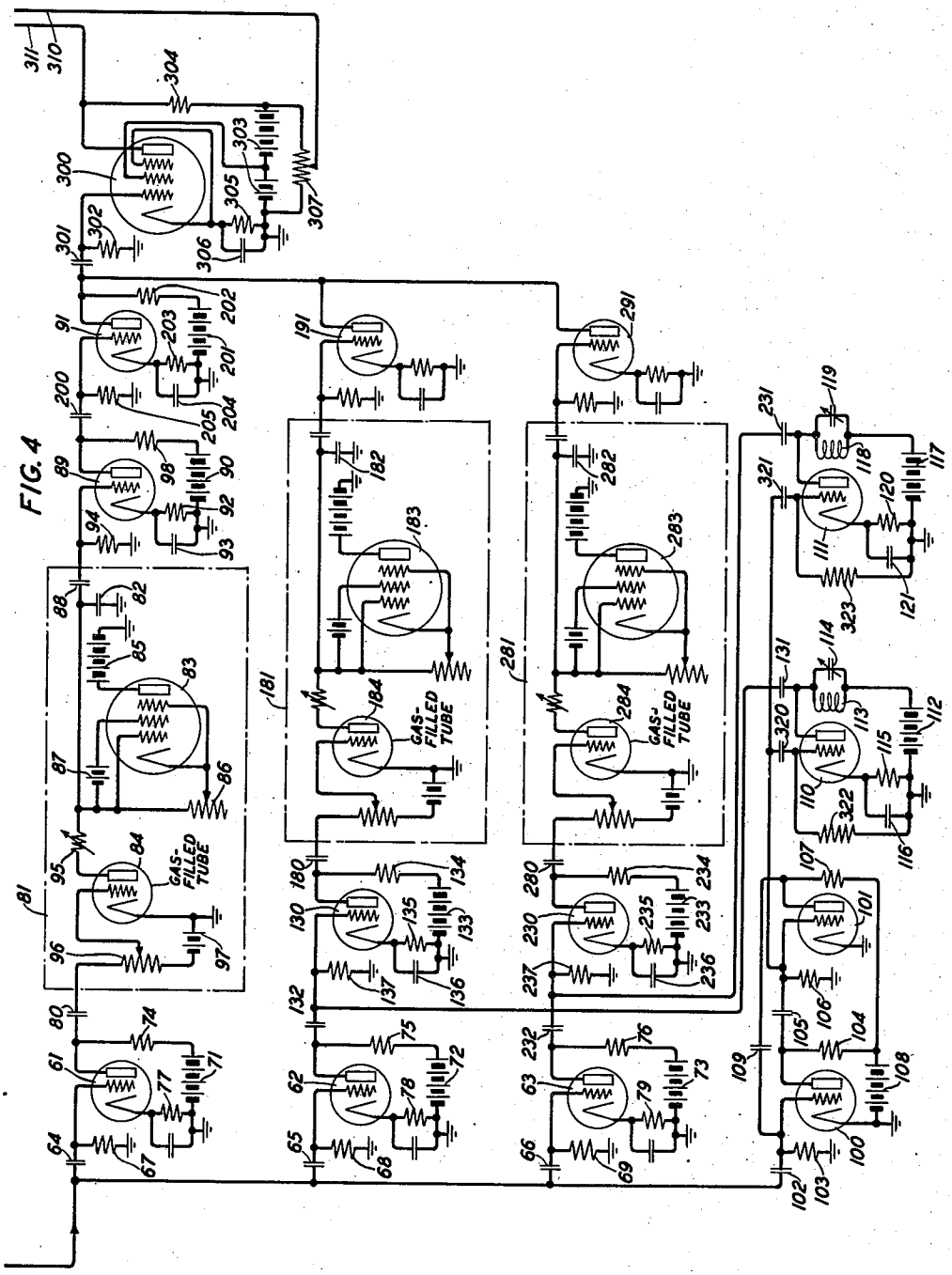
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APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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FIG. 4



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APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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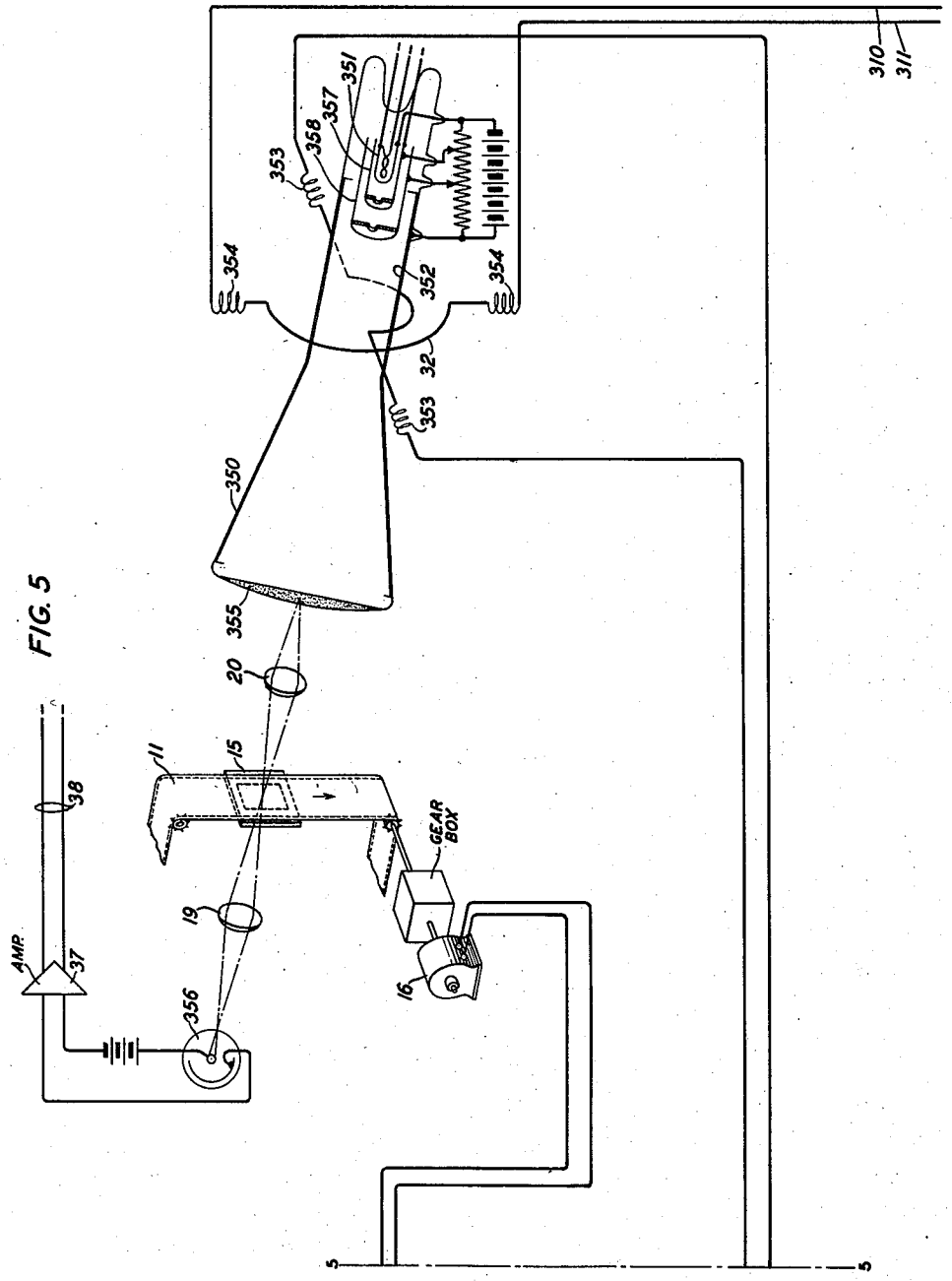


FIG. 5

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APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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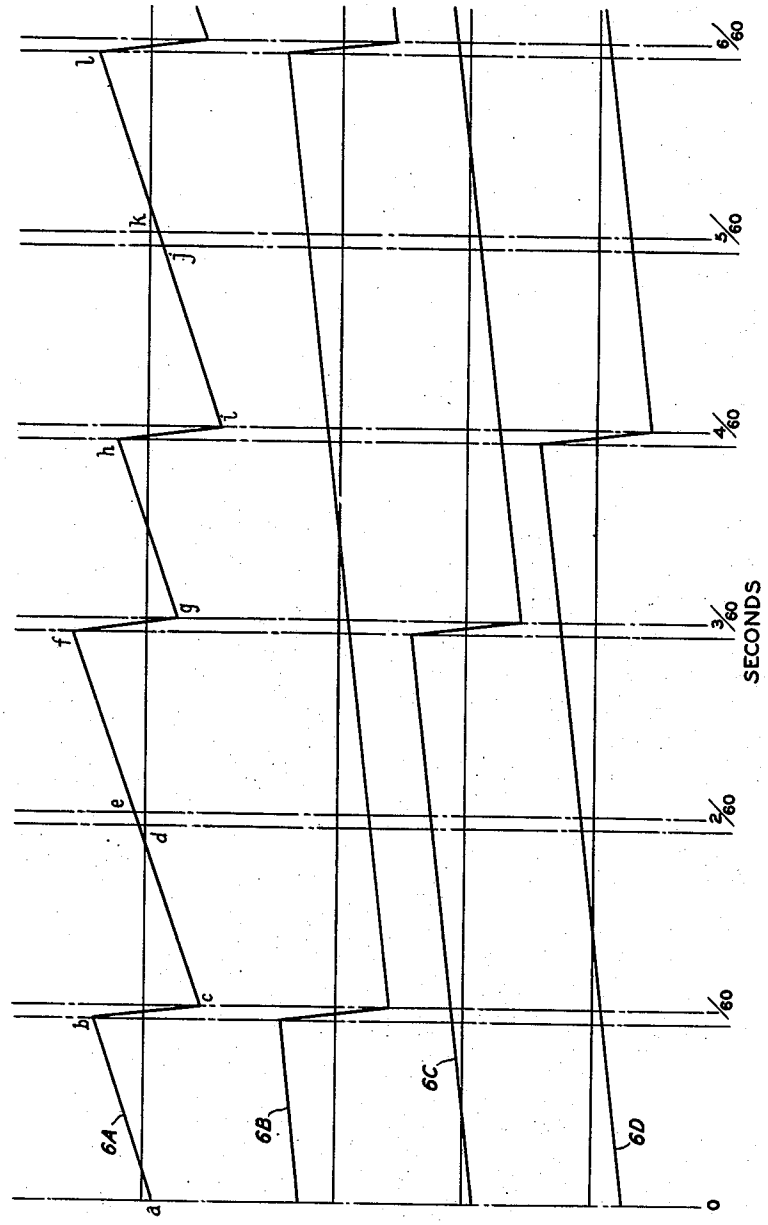


FIG. 6

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APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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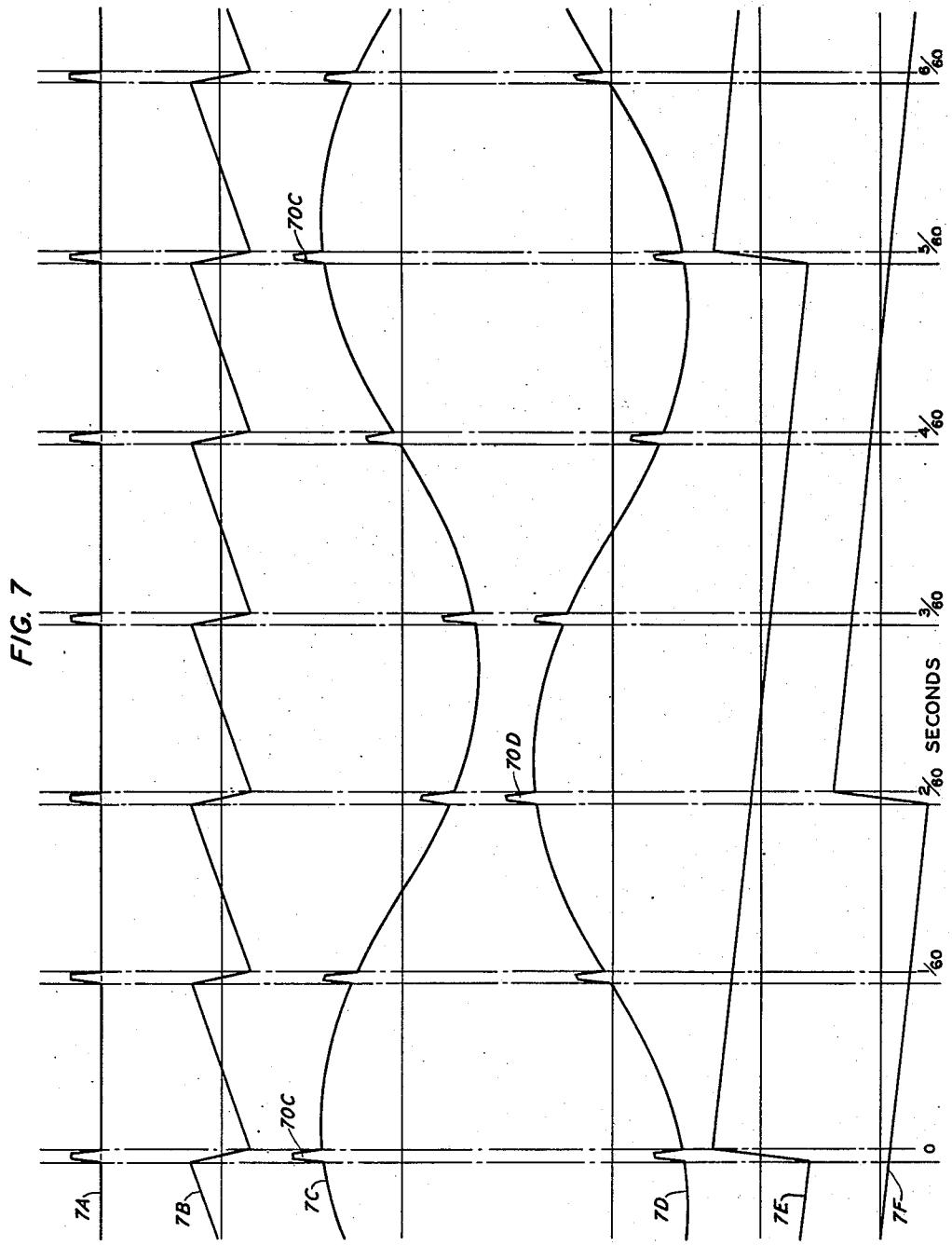


FIG. 7

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APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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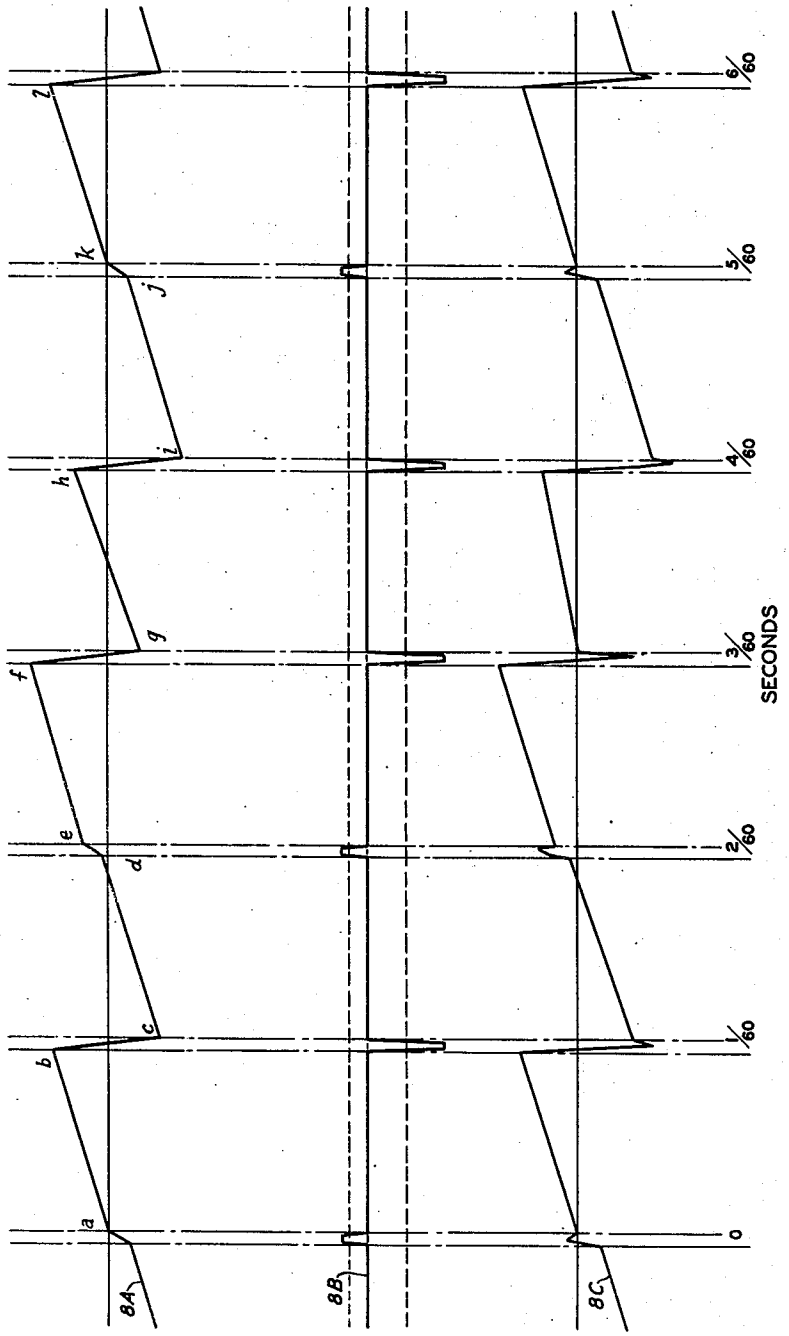


FIG. 8

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Patented Aug. 4, 1942

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UNITED STATES PATENT OFFICE

2,291,723

APPARATUS FOR AND METHOD OF GENERATING TELEVISION SIGNALS

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Application February 29, 1940, Serial No. 321,390

16 Claims. (Cl. 178—7.2)

This invention relates to signaling and particularly to apparatus for and a method of scanning motion picture film for generating television signals.

An object of the invention is to provide improved apparatus for scanning a motion picture film for television transmission.

Another object of the invention is to provide novel means for generating electric waves having a desired wave form.

A standard motion picture film is exposed and projected at the rate of 24 complete frames per second. In accordance with standards adopted by Radio Manufacturers' Association, a field is scanned at the rate of 60 field scans of 220½ lines each per second with the lines of one field scan interlaced with those of the preceding or following field scan, thus resulting in 30 complete frame scannings of 441 lines each per second. To produce a standard television signal when scanning standard motion picture film, therefore, it is desirable to scan the odd film frames of pictures twice, for example, and the even film frames three times, while the film is moved at the rate of 24 frames per second. Thus the film is scanned at the rate of 60 field scans of 220½ lines each per second or 30 complete frame scannings of 441 lines, interlaced, per second.

It has been proposed heretofore to scan standard motion picture film at the rate of 60 field scans per second by scanning alternate film frames three times and the remaining film frames twice. One method which has been proposed requires that the film be moved forward intermittently at non-uniform intervals. This method has the disadvantage that complex mechanical equipment is required to produce the non-uniform film motion and that the non-uniform intermittent film motion causes the film to wear rapidly. In accordance with another method which has been proposed for scanning alternate film frames three times and the remaining film frames twice, the film is moved continuously at a uniform rate. This prior method requires the use of five prisms for splitting an image projected from the film into five images and a rotating apertured shutter for directing light from the prisms one at a time in succession upon the cathode of a cathode ray tube in such manner that the successive images projected upon the cathode occupy the same position thereon at the beginning of each field scanning period.

The method of scanning standard motion picture film for television transmission herein described has the advantage over prior art methods that the film is moved continuously at a uniform rate and that it does not require the use of optical image splitting apparatus or mechanically moving light directing apparatus.

In accordance with applicant's invention, a motion picture film is scanned by moving the film continuously at a constant rate and by applying to a cathode ray scanning device a vertical deflecting field such that certain frames of the film are scanned an even plurality of times and other frames an odd plurality of times, the usual horizontal deflecting field also being applied to the cathode ray scanning device for causing the film to be scanned along parallel lines substantially perpendicular to the direction of movement of the film. There is applied to the cathode ray tube a vertical deflecting field substantially in the form of a saw-toothed wave of varying amplitude to cause the cathode ray beam to be deflected through different distances during different periods, respectively, occurring between successive return or non-scanning deflections of the cathode ray beam. The vertical scanning deflections may be such, for example, that two field scans occur during each of two successive scanning deflections while a single field scan occurs during the next succeeding vertical deflection, the return deflections occurring between successive scanning deflections being of equal amplitude.

In accordance with a preferred specific embodiment of the invention herein described for the purpose of illustration, a motion picture film is moved continuously at the rate of 24 frames or pictures per second through the film gate of a motion picture projector where the film is illuminated and light from the film is projected upon the cathode of a cathode ray image dissector tube to the horizontal deflecting coils of which is applied a saw-toothed sweep current of 13,230 cycles per second. The substantially saw-toothed wave which is applied to the vertical deflecting coils is produced by combining a plurality of saw-toothed waves, one 60 cycle saw-toothed wave and two 12 cycle saw-toothed waves, the amplitude and phase relationship of the waves being controlled so as to obtain a desired vertical sweep wave. The saw-toothed waves are generated under control of 60 cycle alternating current, or a harmonic thereof, which also controls the motor of the motion picture projector. The saw-toothed wave component or components of one frequency are characterized by a relatively slow increase in

amplitude followed by an abrupt decrease in amplitude while a component or components of the other frequency are characterized by a relatively slow decrease in amplitude followed by an abrupt increase in amplitude. Preferably, the blank lines or so-called "frame lines" occurring between pictures of the motion picture film are not scanned. To bring about this result, the amplitude of the 60 cycle saw-toothed wave component is reduced, thus causing the rate of change of amplitude with respect to time of the resultant wave to be decreased during periods when picture portions are being scanned and increased during periods between the scanning of successive pictures.

In accordance with an alternative embodiment of the invention, there is employed a cathode ray device for illuminating the film an elemental area at a time, light from the illuminated elemental areas being received by a light sensitive image current generating device of the electron multiplier type, for example. The deflection of the cathode ray beam is controlled in the same manner in which the deflection of the cathode ray beam of the image dissector tube is controlled.

The invention will now be described with reference to the accompanying drawings in which:

Fig. 1 is a diagram to which reference will be made in describing the scanning method and apparatus in accordance with the present invention;

Fig. 2 consists of curves to which reference will be made in describing the invention;

Figs. 3 and 4, when Fig. 3 is placed above Fig. 4, constitute a diagrammatic view of motion picture film scanning apparatus in accordance with the present invention;

Fig. 5 is a diagrammatic view of a modification of the portion of the film scanning apparatus shown to the right of line 5—5 as viewed in Fig. 3; and

Figs. 6 to 8 are curves to which reference will be made in connection with the description of the scanning method and apparatus in accordance with the invention.

In the upper portion of Fig. 1 is shown a motion picture film 10 (the usual sound track being omitted for simplicity) in six successive positions designated A to F, inclusive, the film being in these positions at the starting times of six successive field scanning periods. The successive frames of the film are designated by the Roman numerals I, II, III, etc. The film is moved in the direction of the arrows continuously at the rate of 24 picture frames per second, for example. Each frame of the film consists of a picture portion 11 and a blank space or frame line 12 between that picture portion and the following picture portion. It will here be assumed that there is employed a cathode ray device for illuminating the film an elemental area at a time, as disclosed in Fig. 5. At zero time the film is in position A and scanning of frame I is initiated at the elemental area *a* in the lower left-hand corner of frame I. While the film is in motion, the cathode ray beam of the cathode ray scanning device is repeatedly deflected horizontally, that is, in a direction substantially perpendicular to the direction of motion of the film, and rapidly returned to its starting position between successive scanning deflections to cause the scanning of the film along successive transverse lines as the film is moved vertically, in the usual well-known manner. The cathode ray beam is also simultaneously deflected vertically in one direction parallel to the direction of motion of the film and, at intervals, the beam is deflected rapidly in the opposite direction to cause the light spot on the film to move vertically in the direction opposite to the direction of motion of the film during each field scanning period, as will be described below. The horizontal deflections occur at the rate of 13,230 per second which corresponds to 441 lines in a complete frame scanning period of 1/30 second or 220½ lines in a field scanning period of 1/60 second. Therefore, 220½ lines elapse between the beginning of the field scanning period A and the beginning of the succeeding field scanning period B, and the scanning during the period B will begin with elemental area *c* in the middle of a scanning line as shown diagrammatically by the dot-dash line *a*—*i*, thus resulting in the scanning lines of alternate field scans being interlaced.

In standard motion picture film the dimension of the frame lines 12 along the length of the film is about 15 per cent of the length of the entire frame consisting of a picture portion 11 and a frame line 12, while in accordance with the R. M. A. standards there is a vertical blanking period between successive field scans of 7 per cent of the field scanning period of 1/60 second. In order to avoid waste of transmission time, it is desirable to scan the picture portion only of a frame during 93 per cent of a field scanning period and allowing the remaining 7 per cent of the field scanning period between the time of scanning the last scanned elemental area of one field scanning period and the time of scanning the first elemental area in the succeeding field scanning period.

For the sake of simplicity it will be assumed that as the scanning light spot on the film moves along its vertical component in the direction opposite to the direction of motion of the film (from *a* to *b*, for example) the cathode ray beam is also deflected vertically in the direction opposite to the direction of motion of the film although actually the deflection of the cathode ray beam in one direction may cause the light spot to move in the opposite direction. In order that the field scannings may occur at the rate of 60 field scans per second, while the film is moved at the rate of 24 frames per second, the odd frames, for example, are scanned twice and the even frames three times, that is, there are five field scans during 1/12 second while the film moves through a distance equal to the length of two frames. This will be apparent from Fig. 1. During 93 per cent of field scanning period A, the cathode ray beam is deflected vertically in a direction opposite to the motion of the film from *a* to *b* and during the remaining 7 per cent of period A the beam is deflected vertically in the direction of motion of the film to *c*. During the vertical motion from *b* to *c* the beam is also deflected horizontally at the usual rate of 13,230 per second but for the sake of simplicity this horizontal component is omitted in the drawings. Point *b* does not necessarily fall in the middle of a horizontal line but point *c* does, corresponding to a value of 220½ line deflections during the scanning of a complete picture frame plus frame interval. During this field scanning period the film is moving from position A to position B. The picture portion of frame I is then scanned a second time during 93 per cent of the second field scanning period B

due to the movement of the film and the deflection of the cathode ray beam from *c* to *d* in the direction opposite to the direction of movement of the film. During the remaining 7 per cent of this field scanning period, the beam is deflected in the same direction but at a higher rate from the last scanned elemental area *d* of frame I to the first scanned elemental area *e* of frame II. Similarly, the cathode ray beam is deflected from *e* to *f* and returned to *g*, deflected from *g* to *h* and returned to *i*, and deflected from *i* to *j* for scanning frame II three times. The deflection of the beam is then continued in the scanning direction to *k* during the final 7 per cent of period E, the point *k* being in horizontal alignment with point *a*, and the deflection is then continued to 1, which is in horizontal alignment with *b*, during the first field scanning period of frame III.

The form of the voltage of current wave for vertically deflecting a scanning cathode ray beam in the manner indicated above is shown in the lower portion of Fig. 1, the scale of vertical deflection being in arbitrary units and the time scale being in seconds. This vertical deflecting wave may be analyzed into a plurality of regular saw-toothed wave components, as shown in Fig. 2 and if desired, of course, a direct component may be added. Curve 2A is a duplicate of the wave shown in Fig. 1 and curves 2B, 2C and 2D are the regular saw-toothed wave components into which the wave 2A may be analyzed, the wave 2B being a 60 cycle saw-toothed wave and waves 2C and 2D being 12 cycle saw-toothed waves. In the 60 cycle wave, it will be noted, the amplitude rises relatively slowly and then decreases abruptly, while in the 12 cycle waves the amplitude rises abruptly and decreases relatively slowly. The two 12 cycle waves are out of phase with respect to each other, the wave 2C lagging wave 2D by ⅖ cycle or 1/30 second.

Referring now to Figs. 3 and 4, the film 11 is driven continuously over the film gate 15 at a constant rate of 24 frames per second, for example, by any suitable mechanism including a synchronous motor 16 which is energized from the 60 cycle power source 17. Light from source 18 is directed upon the portion of the film within the film by a condensing lens 19 and the projector lens 20 projects an image of the portion of the film within the film gate upon the cathode 21 of a cathode ray tube 22. As indicated by the arrows, the image on the cathode is inverted with respect to the picture on the film. This film moving and projecting apparatus may be an ordinary motion picture projector from which the intermittent motion mechanism and light shutter have been removed and having a film gate the heighth of which is about 1⅖ times the length of a motion picture frame in the direction of motion of the film.

The cathode ray tube 22 is a so-called image dissector, the image projected upon the light sensitive cathode 21 causing the emission of electrons from the elemental areas thereof in accordance with the light activation of the respective elemental areas. In addition to the cathode 21 there are provided within the evacuated glass housing of tube 22, an anode 23 in the form of a metallic coating on the inner surface of the housing and an electron multiplier 24 having multiplier plates 122, collector grid 123, anode 124 and a shield having a scanning aperture 25. An electromotive force is applied between anode 23 and cathode 21 through leads 26 and 27 from the circuit comprising battery 28, the positive terminal of which is grounded, and a network 29 made up of voltage dividing resistors 125 and condensers 126 as shown. Leads 30 from circuit 29 are connected to the multiplier segments 122 of the electron multiplier 24 for applying accelerating potentials between the segments or multiplier plates and to the anode 124 and collector grid 123. The electrons emitted from cathode 21 are focussed so as to form an electron image in the plane of the scanning aperture 25 by means of an axial magnetic field set up due to the current from source 31 flowing through the coil 32 surrounding the glass envelope and extending substantially the full length of the cathode ray tube. There are provided two pairs of deflecting coils, the horizontal or high frequency deflecting coils 33 and the vertical or low frequency deflecting coils 34. The magnetic fields set up when these deflecting coils are suitably energized cause the beam of electrons emitted from cathode 21 and therefore the electron image focussed in the plane of the scanning aperture 25 to be deflected along both horizontal and vertical coordinates. The motion of the electron image past the scanning aperture results in progressively selecting elemental areas of the image. Due to the bombardment of the first multiplier plate of the electron multiplier 24 by the electrons from different portions of cathode 21 in succession an image current is set up in the circuit including lead 35 connected to collector grid 123, the terminating impedance element 36 and ground. This image current may be amplified by the vacuum tube amplifier 37, if desired, and transmitted over a suitable medium such as the balanced line 38. If desired, of course, the output of the dissector tube may be utilized, with or without further amplification, to modulate a carrier current for transmission over a suitable line or by radio. In accordance with well-known television practice, moreover, synchronizing impulses may be combined with the image signaling current before transmission.

A 13,230 cycle saw-toothed wave is supplied by the horizontal sweep circuit 39 to the horizontal deflecting coils 33 for producing line scanning deflections of the cathode ray beam in succession and rapid return deflections between successive scanning deflections. This sweep circuit, which is not shown in detail, may comprise, for example, the well-known arrangement for charging a condenser at a constant rate through the anode circuit of a vacuum tube and a gas-filled or vacuum tube arrangement for quickly discharging the condenser at regular intervals under control of steep wave front impulses. For this purpose there may be employed the square-top impulses of brief duration occurring at the rate of 60 per second produced by the circuit comprising vacuum tubes 40, 41, 42 and 43. The usual cathode heating batteries for the discharge tubes of Figs. 3 and 4 are omitted from the drawings to simplify the disclosure. Tubes 40 and 41, together with the associated circuit made up of resistors 44, 45, 46, 47, 48, condensers 49 and 50 and anode battery 51 form a relaxation oscillator-multivibrator circuit with its free fundamental frequency adjusted slightly below the 60 cycle synchronizong control frequency from source 17 applied to the grid cathode circuit of tube 40. The condenser 49 is charged by current from battery 51 through a circuit including resistors 46, 45 and 48, and it is discharged, when the grid of tube 40 becomes positive with respect to its

cathode due to the potential of source 17, through a circuit including the space current path of tube 40, resistor 48 and resistor 45. While condenser 49 is being discharged, the grid of tube 41 is at a negative potential with respect to its cathode due to the potential drop across resistors 48 and 45 and the condenser 50 is charged by current from battery 51 through a circuit including resistors 47, 44 and 48. When the discharge current of condenser 49 ceases to flow or is reduced to a critical value, the grid of tube 41 is no longer sufficiently negative with respect to its cathode to prevent the flow of space current in tube 41, and the condenser 50 discharges through a circuit including the space current path of tube 41 and resistors 48 and 44. The input circuit of tube 41 is connected to the input circuit of tube 42, the grids being directly connected, the cathode of tube 41 being grounded through resistor 48 and the cathode of tube 42 being connected to ground through the grid biasing resistor 52 shunted by a condenser 53. The output of tube 42 is coupled to the input circuit of tube 43 through coupling condenser 54 and input resistor 55. Space current is supplied to tubes 42 and 43 by battery 56 shunted by condenser 57 through resistors 58 and 59, respectively, the negative terminal of the battery being grounded. Grid biasing resistor 60 shunted by condenser 99 is in the lead connecting the cathode of tube 43 to ground. The grid circuit of tube 42 is over-biased (due to the potential drop across resistor 52) so that substantially no anode current can flow except when the grid of tube 41 is driven positive while condenser 49 is being charged. During these charging periods of condenser 49 the grid of tube 42 becomes less negative (or it may become positive) with respect to its cathode to cause anode current to flow. As a result, the grid of tube 43 becomes more negative and the anode current through resistor 59 is reduced. Due to the discharging of condenser 49, a negative impulse is impressed upon the grid of tube 42 and therefore a positive impulse upon the grid of tube 43. The tube 43 acts as a limiting amplifier being current limited when tube 42 is non-conducting and driven to cut-off when tube 42 is conducting. Thus rectangular impulses of negative polarity are obtained at the anode of tube 43 while condenser 49 is being discharged. These impulses may be made of brief duration by making the time constant of the charging circuit of condenser 49 large compared with the time constant of the charging circuit for condenser 50.

Instead of using 60 cycle impulses to control the line sweep circuit 39, there may be employed preferably a stable oscillator of 26,460 cycles from which is derived 13,230 cycle pulses, for directly controlling the horizontal sweep circuit and from which may be derived 60 cycle subharmonic current for controlling the speed of the film drive motor 16. This 60 cycle subharmonic current in this case would also be used in place of the 60 cycle generator 17.

The apparatus for generating the sweep current to be supplied to the vertical deflecting coils 34 will now be described. The brief impulses from the anode circuit of vacuum tube 43, occurring at the rate of 60 per second, are impressed upon the input circuits of broad band vacuum tube amplifiers 61, 62, 63 (Fig. 4) through coupling condensers 64, 65, 66, respectively, and input resistors 67, 68 and 69, respectively. There are provided for the amplifiers 61, 62 and 63 the anode batteries 71, 72 and 73, respectively, the anode resistors 74, 75 and 76, respectively, and grid biasing resistors 77, 78 and 79, respectively, which are shunted by condensers. The negative impulses impressed upon the input circuit of tube 61 cause amplified impulses of positive polarity to be produced at the anode of tube 61 and these impulses are impressed through coupling condenser 80 upon a sweep circuit 81 comprising condenser 82, constant current vacuum tube 83 and gas-filled tube 84.

The condenser 82 is charged at a constant rate by current from source 85 through the space current path of tube 83 and through variable resistor 86, one plate of the condenser and the negative battery terminal being grounded. The charging rate and, therefore, the amplitude of the potential to which condenser 82 is charged may be adjusted by changing the setting of the variable resistor 86. A battery 87 is provided for biasing the screen grid of tube 83 and the suppressor grid thereof is connected directly to the cathode. The condenser 82 is discharged periodically under control of the 60 cycle impulses through a variable resistor 95, for adjusting the discharge rate, the space discharge path of tube 84 and ground. The 60 cycle impulses are impressed upon the grid-cathode circuit of tube 84 through a potentiometer 96 which is connected in series with grid biasing battery 97. The positively charged plate of condenser 82 is connected through condenser 88 to the grid of phase inverter tube 89. Anode current supplied to this tube from battery 90 through anode resistor 98 and grid biasing resistor 92, shunted by condenser 93, the negative terminal of the battery being grounded. An input resistor 94 is connected between the grid of tube 89 and ground. The output circuit of tube 89 is connected through coupling condenser 200 to the input circuit of mixer tube 91. This tube is supplied with anode current from battery 201 through anode resistor 202 and grid biasing resistor 203 which is shunted by a condenser 204. One terminal of input resistor 205 is connected to the grid of tube 91 and the other terminal thereof to ground, the negative terminal of battery 201 also being grounded. This branch circuit including tube 91 supplies a 60 cycle saw-toothed wave component 2B of the complex vertical deflection voltage or current 2A in Fig. 2.

The 60 cycle rectangular impulses obtained from the output of vacuum tube 43 are also impressed upon a multivibrator circuit comprising vacuum tubes 100 and 101 for generating 12 cycle impulses. The circuit comprises input condenser 102, input resistor 103 and anode resistor 104 for tube 100 and input condenser 105, input resistor 106 and anode resistor 107 for tube 101, anode current being supplied to both tubes from battery 108. The anode of tube 101 is coupled to the grid of tube 100 through a condenser 109. The grid of tube 101 is connected through condensers 320 and 321 to the grids of tubes 110 and 111, respectively, which produce 12 cycle sine waves, out of phase with respect to each other, under control of the multivibrator output. The grids of tubes 110 and 111 are also connected through grid leak resistors 322 and 323, respectively, to ground. Anode current is supplied to tube 110 from battery 112 through a circuit comprising an inductance element 113 shunted by variable condenser 114 and grid biasing resistor 115 shunted by condenser 116, while anode current for tube 111 is supplied from battery 117 through a circuit comprising inductance element

118 shunted by variable condenser 119 and grid biasing resistor 120 shunted by condenser 121. The condensers 114 and 119 may be adjusted to obtain the desired phase relationship between the 12 cycle sine waves obtained from tubes 110 and 111.

The 12 cycle sine wave from the output of tube 110 together with the 60 cycle pulses from the output of tube 62 are impressed upon the input of mixer tube 130 through coupling condensers 131 and 132, respectively, for producing 12 cycle impulses at the output of tube 130. The circuit of tube 130 comprises anode battery 133, anode resistor 134, grid biasing resistor 135, grid condenser 136 and input resistor 137.

The output of mixer tube 130 is connected through condenser 180 to the sweep circuit 181 comprising condenser 182, constant current tube 183 and gas-filled tube 184. The sweep circuit 181 is like the sweep circuit 81 except for the circuit constants and there is produced at the output of sweep circuit 181 a 12 cycle saw-toothed wave which is impressed upon the input circuit of mixer tube 191 like the mixer tube 91. The tube 191 is supplied with anode current from battery 201 through resistor 202.

The 12 cycle sine wave from the output of tube 111 and 60 cycle impulses from the output of tube 63 are supplied to the input circuit of mixer tube 230 through condensers 231 and 232, respectively. The circuit of tube 230 comprises anode battery 233, anode resistor 234, grid biasing resistor 235, grid condenser 236 and input resistor 237.

The 12 cycle impulses from the output of tube 230 are impressed through condenser 280 upon the sweep circuit 281 comprising condenser 282, constant current tube 283 and gas-filled tube 284, this sweep circuit being like the sweep circuit 181. The 12 cycle saw-toothed wave produced by the sweep circuit 281 is impressed upon the input circuit of mixer tube 291 like mixer tubes 91 and 191. The tube 291, like tubes 91 and 191, is supplied with anode current from battery 201 through resistor 202.

The current from battery 201 flowing through resistor 202 flows through the space discharge paths of vacuum tubes 91, 191 and 291 and this current varies in accordance with the potentials impressed upon the grid-cathode circuits of these tubes. Therefore, the electromotive force measured between ground and the anodes of tubes 91, 191 and 291 which are connected together has a complex or irregular saw-toothed wave form having as components a 60 cycle saw-toothed wave 2B, from the circuit of tube 91 and two 12 cycle saw-toothed waves, 2C and 2D, out of phase with respect to each other, from the circuits of tubes 191 and 291, respectively. This irregular saw-toothed wave is impressed upon the input circuit of amplifier tube 300 through coupling condenser 301 across the input resistor 302. Anode current is supplied to tube 300 from battery 303 through anode resistor 304, grid biasing resistor 305, shunted by condenser 306. The suppressor grid of tube 300 is connected to the cathode of the tube and a portion of battery 303 supplies a positive bias to the screen grid of tube 300. A potentiometer 307 is connected across battery 303 and the variable tap of the potentiometer is connected to one terminal of the vertical sweep coils 34 through lead 310, the other terminal of the coils being connected to the anode of tube 300 through lead 311.

The setting of potentiometer 307 is such that, when no varying electromotive force from mixer tubes 91, 191 and 291 is impressed upon the grid-cathode circuit of tube 300, the electromotive force impressed upon the deflecting coils 34 and the steady current flowing through the coils will be zero or such a value that the cathode ray beam is in its central position, that is, so that the electrons from the central portion of the cathode impinge upon the scanning aperture 25. When an alternating saw-toothed wave 2A is then impressed upon the input circuit of tube 300 the cathode ray beam will be deflected along its vertical coordinate in such a way that the pictures of the motion picture film are scanned as described in connection with Fig. 1.

Referring again to the curves of Fig. 2, curve 2A shows the irregular saw-toothed wave which is applied to the input circuit of tube 300 and to the vertical deflecting coils 34 of the image dissecting tube and this curve also depicts the alternating portion of the current from battery 201 flowing through resistive element 202 which is in series with the space current paths of vacuum tubes 91, 191 and 291, the phase reversals occurring in the circuit being not considered. Therefore, the curve 2A represents the sum of the alternating portions of the currents flowing in the space discharge paths of tubes 91, 191 and 291. The three components of the current represented by curve 2A are shown in curves 2B, 2C and 2D, the curve 2B showing the 60 cycle saw-toothed wave component flowing through tube 91 and curves 2C and 2D showing the 12 cycle saw-toothed wave components flowing through tubes 191 and 291, respectively. It will be noted that curve 2B has a gradually rising portion followed by a more rapid falling portion, while curves 2C and CD each has a gradual falling portion followed by a more rapid rising portion. It will also be noted that while curves 2C and 2D have the same amplitude, the amplitude of curve 2B is made somewhat less than that of curves 2C and 2D in order to avoid scanning the picture frame lines. These relative amplitudes can be controlled as desired by adjusting the variable resistor 86 of sweep circuit 81 and the corresponding resistors of sweep circuits 181 and 281. If desired, the amplitude of the 60 cycle saw-toothed component 2B may be further decreased at times for the purpose of producing an image current representative of an enlargement or close-up of a portion of a picture or of portions of pictures. If, for example, curve 2B is decreased to about two-fifths of its normal amplitude, only the lower two-fifths of each frame will be scanned and the reproduced image will be magnified 2½ times. In thus changing the magnification at the receiver it will be desirable, of course, to change also the length of the horizontal sweep at the transmitter at the same time in order to maintain proper picture proportions. It is also possible, if desired, to scan a picture while the film is stationary by shutting off or reducing to zero the components 2C and 2D obtained from the circuits including tubes 191 and 291, respectively, and controlling the vertical deflection of the cathode ray beam only by the 60 cycle saw-toothed component 2B.

Instead of combining a 60 cycle saw-toothed component and two out-of-phase 12 cycle saw-toothed components for producing the vertical deflecting wave, three 12 cycle out-of-phase saw-toothed components 6B, 6C and 6D may be combined as shown in Fig. 6 to give the resultant wave 6A. Obviously the resultant desired wave may be analyzed into still other components, if

desired, some of which are square-topped wave components, for example, and these components may be combined to give the desired vertical sweep wave.

The method of generating the two 12 cycle saw-toothed wave components 2C and 2D by means of the apparatus shown in Fig. 4, will now be described, reference being made to the curves of Fig. 7. Curve 7A shows the 60 cycle impulses which are applied to the input circuits of tubes 61, 62 and 63 and to the multivibrator circuit 100, 101. These impulses are impressed directly upon the circuit including the sweep circuit 81 to produce 60 cycle saw-toothed wave component 7B. These 60 cycle impulses are also superposed upon the 12 cycle sine wave obtained from the tuned circuit 113, 114 at the input circuit of tube 130. It will be noted that, during each cycle of the sine wave, one of the impulses 70C superposed upon the sine wave is at a higher amplitude than the remaining impulses. This maximum impulse causes the space discharge path of gas-filled tube 184 in sweep circuit 181 to break down, thus causing the sweep condenser 182 to discharge. There is thus produced by the circuit 181 the saw-toothed wave component, similar to 7E but opposite in phase, having a portion of rapidly decreasing amplitude occurring at the time that the impulse 70C occurs. Similarly the 60 cycle impulses are superposed upon the 12 cycle sine wave from tuned circuit 118, 119 in the input circuit of tube 230 to produce the wave 7D having an impulse 70D at a predominant amplitude occurring 1/30 second later than the impulse 70C, and the impulses 70D control the generation by sweep circuit 281 of a saw-toothed wave component similar to 7F but opposite in phase. The 12 cycle waves produced by the sweep circuits 181 and 281 are reversed in phase by the tubes 191 and 291, respectively, to produce the wave components 7E and 7F, respectively.

When magnetic beam deflecting coils are used, as shown in Figs. 3 and 5, it is sometimes advantageous to make the sweep voltage impressed upon the final amplifier 300 overshoot somewhat at the points of a sudden change of amplitude of the saw-toothed wave 2A in order to counteract the tendency for the sweep coils to set up transients at these points. This may be accomplished as illustrated by the curves of Fig. 8 by passing wave 8A (like 2A) through a conventional pulse generating circuit to produce the impulse wave 8B, the amplitude of which varies in accordance with the rate of change of amplitude of wave 8A. The impulses of wave 8B, after being passed through a limiting amplifier to limit the amplitude to the values shown by the dash line, may be added in proper phase to the wave 8A to obtain the voltage wave 8C to be impressed upon the input circuit of the final amplifier 300.

If desired, of course, a cathode ray light producing tube together with a light sensitive device may be employed for scanning the motion picture film instead of the image dissector tube shown in Fig. 3. Fig. 5 shows such a modification of the arrangement shown to the right of line 5—5 of Fig. 3. In Fig. 5 the cathode ray tube 350 having a cathode 351, anode 352, auxiliary anodes 357 and 358, horizontal deflecting coils 353, vertical deflecting coils 354, and a coating 355 of fluorescent material produces a spot of light for illuminating the film an elemental area at a time. As the film 11 is moved continuously at a constant rate through the film frame 15, light from the cathode ray tube 350 focussed upon the film 11 by lens 20 illuminates different elemental areas thereof in succession. Light from the illuminated elemental areas is focussed by lens 19 upon a light sensitive electric device, for example, a photoelectric cell 356, although a light sensitive electron multiplier could be used, and the image current produced by the device 356 is amplified by amplifier 37 and thence transmitted over line 38. The cathode ray beam produced in tube 350 is deflected along horizontal and vertical coordinates in a similar manner to that in which the cathode ray beam produced in tube 22, Fig. 3, is deflected. For this purpose the usual saw-toothed horizontal deflection voltage from source 39 is applied to the horizontal deflecting coils 353 and an irregular saw-toothed current as shown in Fig. 2A is applied from leads 310, 311 to the vertical deflecting coils 354.

The elemental areas of the film 10 are scanned in succession in the manner described in connection with Fig. 1 whether the film is scanned by illuminating an elemental area of the film at a time, as in Fig. 5, or the film is scanned by means of an image dissector tube shown in Fig. 3. It will be noted, however, that in Fig. 3 the image projected upon the cathode 21 and, therefore, the electron image produced in the plane of aperture 25, is inverted with respect to the picture on the film and that as the film moves down, as viewed in the figure, the image on the cathode 21 and the electron image move up. If no vertical deflecting current, such as shown by curve 2A, were applied to the coils 34 of the dissector tube, the electron image would move up through a distance of about 2/5 frame with respect to the stationary aperture 25 in a field scanning period of 1/60 second. However, the deflecting current applied to the coils 34 causes the electron beam to be moved up an additional 3/5 frame distance, thus causing the electron image to move up a total distance of one frame during a frame scanning period.

What is claimed is:

1. The method of scanning motion picture film with an electronic device comprising continuously moving the motion picture film at a substantially uniform rate, repeatedly deflecting the electron beam produced in said device along one coordinate of motion at a substantially uniform rate in one direction for effecting scanning along a linear path and more rapidly in the opposite direction for returning the electron beam between successive line scannings and repeatedly deflecting the electron beam along a second coordinate of motion substantially perpendicular to the first coordinate in one direction for effecting scanning of different linear elements in succession of picture portions of the film, more rapidly deflecting the beam in the same direction while the beam is traversing portions of the films between successive picture portions, and at intervals deflecting the cathode beam in the direction opposite to the direction of the scanning deflections for returning the cathode beam to a position for starting the scanning of a picture portion.

2. The method of scanning motion picture film with an electronic device comprising continuously moving the motion picture film at a substantially uniform rate, repeatedly deflecting the electron beam produced in said device along one coordinate of motion at a substantially uniform rate in one direction for effecting scanning along a linear path and more rapidly in the opposite direction for returning the electron beam between

successive line scannings, repeatedly deflecting the electron beam along a second coordinate of motion substantially perpendicular to the first coordinate in one direction for effecting scanning of different linear elements in succession and more rapidly in the opposite direction for returning the electron beam between successive scanning deflections along said second coordinate, the scanning deflections along said second coordinate being non-uniform in duration and in extent, and changing the deflection rate of said electron beam along said second coordinate during some of the scanning deflections.

3. The method of scanning motion picture film which comprises continuously moving the film at a substantially constant rate, deflecting a cathode ray beam for scanning said film while in motion, generating at least four electrical waves of regular saw-toothed wave form and utilizing all of said waves to produce a wave of irregular saw-toothed wave form for controlling the deflection of said cathode ray beam.

4. The method of scanning motion picture film which comprises continuously moving the film at a substantially constant rate, deflecting a cathode ray beam for scanning said film while in motion, generating a plurality of electric waves of saw-toothed form, at least two of said waves having the same frequency but being displaced in phase by an amount to cause the peaks of one of the waves to be displaced in time with respect to the peaks of the other of said waves and utilizing all of said waves to produce a wave of irregular saw-toothed wave form for controlling the deflection of said cathode ray beam.

5. The method of scanning motion picture film which comprises continuously moving the film at a substantially constant rate, deflecting a cathode ray beam for scanning said film and generating three electrical waves of saw-toothed wave form for controlling the deflection of the cathode ray beam along a coordinate substantially parallel to the direction of motion of said film, two of said waves being of the same frequency but displaced in phase by an amount to cause the peaks of said waves to be displaced in time and a third wave being of a different frequency, the wave or waves of one frequency being characterized by a relatively slow increase in amplitude followed by an abrupt decrease in amplitude and the wave or waves of the other frequency being characterized by a relatively slow decrease in amplitude followed by an abrupt increase in amplitude.

6. The method of scanning motion picture film which comprises moving the film continuously at a uniform rate, deflecting a cathode ray beam in one direction along a coordinate parallel to the direction of motion of the film at a certain rate during periods of scanning successive picture portions of the film, and deflecting the beam in the same direction at an increased rate during a period between said picture scanning periods.

7. In combination, a source of electric impulses which recur at a certain frequency, means under control of said impulses for producing a first regular saw-tooth wave of said frequency, means under control of said impulses for producing a second regular saw-toothed wave of a frequency which is a submultiple of said first-mentioned frequency, means for producing a third regular saw-toothed wave like said second saw-toothed wave but out of phase with respect thereto, and means for mixing said three saw-toothed waves for producing an irregular saw-toothed wave.

8. In combination, a source of electric impulses recurring at a certain frequency, a second source and a third source of electric impulses which recur at a frequency which is a submultiple of said first frequency and which are out of phase with respect to each other, a plurality of means under control of said sources of impulses, respectively, for generating corresponding regular saw-toothed electric waves, and means for combining said saw-toothed waves to produce a desired resultant irregular saw-toothed electric wave.

9. In combination, means for generating three electric waves of regular saw-toothed wave form, means for reversing the phase of one of said waves with respect to the others of said waves and means for combining the wave of reversed phase with the others of said waves to produce an electric wave of irregular saw-toothed wave form.

10. In combination, means for generating an electric wave of regular saw-toothed wave form having a certain fundamental frequency, means for generating a second and a third electric wave of regular saw-toothed wave form having a different fundamental frequency, the wave or waves of one frequency being characterized by a rate of change of amplitude with respect to time which is positive and of relatively low value over a portion of a cycle and which is negative and of relatively high value over the remainder of the cycle and the wave or waves of the other frequency being characterized by a rate of change of amplitude with respect to time which is negative and of relatively low value over a portion of a cycle and which is positive and of relatively high value over the remainder of the cycle, and means for combining said three waves to produce a desired resultant wave of irregular saw-toothed wave form.

11. A combination in accordance with claim 10 in which the two saw-toothed waves having the same frequency are out of phase with respect to each other and of equal amplitude.

12. Motion picture film scanning apparatus for television transmission comprising means for moving the film continuously at a uniform rate, means for generating a cathode ray beam for scanning the pictures while the film is in motion, horizontal deflecting means for deflecting the cathode ray beam along a coordinate substantially perpendicular to the direction of motion of the film, vertical deflecting means for deflecting the cathode ray beam along a coordinate substantially parallel to the direction of motion of the film, a source of substantially constant frequency alternating current for controlling said film moving means, means under control of said alternating current source for producing a high frequency substantially saw-toothed wave the fundamental frequency of which is a multiple of the frequency of said source for controlling said horizontal deflecting means, means under control of said alternating current source for generating three low frequency substantially saw-toothed waves each having a fundamental frequency which is a submultiple of the fundamental frequency of said high frequency saw-toothed wave, means for varying the amplitude of each of said relatively low frequency saw-toothed waves, means under control of said three relatively low frequency saw-toothed waves for producing a composite wave having said three relatively low frequency saw-toothed wave compo-

nents, and means for applying said composite wave to said vertical deflecting means, thereby causing alternate picture frames to be scanned an even plurality of times and the remaining picture frames to be scanned an odd plurality of times.

13. Motion picture film scanning apparatus for television transmission comprising means for moving the film continuously at a uniform rate, means for generating a cathode ray beam for scanning the pictures while the film is in motion, means for deflecting the cathode ray beam along a coordinate substantially perpendicular to the direction of motion of the film, means for generating three substantially saw-toothed electric waves, means for varying the amplitude of each of said waves, means for producing a composite electric wave of irregular saw-toothed wave form having said three saw-toothed wave components, and means controlled by said composite wave for deflecting said cathode ray beam along a coordinate substantially parallel to the direction of motion of the film.

14. Motion picture film scanning apparatus for television transmission comprising a source of substantially constant frequency alternating current, means under control of said alternating current source for moving the film continuously at a uniform rate, means for generating a cathode ray beam for scanning the pictures recorded on the film while the film is in motion, means under control of said alternating current source for deflecting the cathode ray beam along a coordinate substantially perpendicular to the direction of motion of the film, means under control of said alternating current source for generating three substantially saw-toothed electric waves, means for varying the amplitude of each of said waves, means for producing a composite electric wave of irregular saw-toothed wave form having said three saw-toothed wave components, and means controlled by said composite wave for deflecting said cathode ray beam along a coordinate substantially parallel to the direction of motion of the film.

15. The method of scanning motion picture film with a cathode ray beam scanning device having means for deflecting the beam, which comprises moving the film continuously at a uniform rate, generating and applying to said deflecting means a first electric wave for deflecting the beam in a direction transverse to the direction of motion of the film, and generating and applying to said deflecting means a second electric wave portions of which have a certain slope to cause the deflection of the beam in a direction parallel to the direction of motion of the film during the periods of scanning successive pictures recorded on the film and other portions of which wave have a different slope for positioning the beam for commencing the scanning of a picture, each of said other portions having a slope greater than, and in the same sense as, said first mentioned slope for reducing the time elapsing between the completion of the scanning of a picture and commencement of scanning of an adjacent picture.

16. The method of scanning motion picture film with a cathode ray beam scanning device having beam deflecting means, which comprises moving the film continuously at a uniform rate, generating and applying to said deflecting means a first electric wave for deflecting the beam in a direction transverse to the direction of motion of the film to scan the film in parallel elemental strips, and generating and applying to said deflecting means a second wave comprising recurrent scanning portions of equal duration each having a slope to deflect the beam in a direction parallel to the direction of motion of the film whereby said slope and the speed of said film determine the period of scanning a picture, each of certain of said scanning portions of said wave being followed by a portion of much shorter duration and of much greater and reverse slope to position the beam for commencing another field scanning of the picture a scanning of which has just been completed under control of the preceding scanning portion with an offset from the preceding field scanning in the direction in which each of said elemental strips is scanned whereby interlacing of the field scannings of the same picture is effected, and each of the remaining ones of said scanning portions of said wave being followed by a portion having said short duration and a slope intermediate said two first mentioned slopes and in the same sense as the said first slope for positioning the beam for commencing the scanning of a succeeding picture portion.

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