May 26, 1942. A. V. LOUGHREN 2,284,219

SIGNAL WAVE FORM INDICATING SYSTEM

Filed Nov. 26, 1940 3 Sheets-Sheet 1

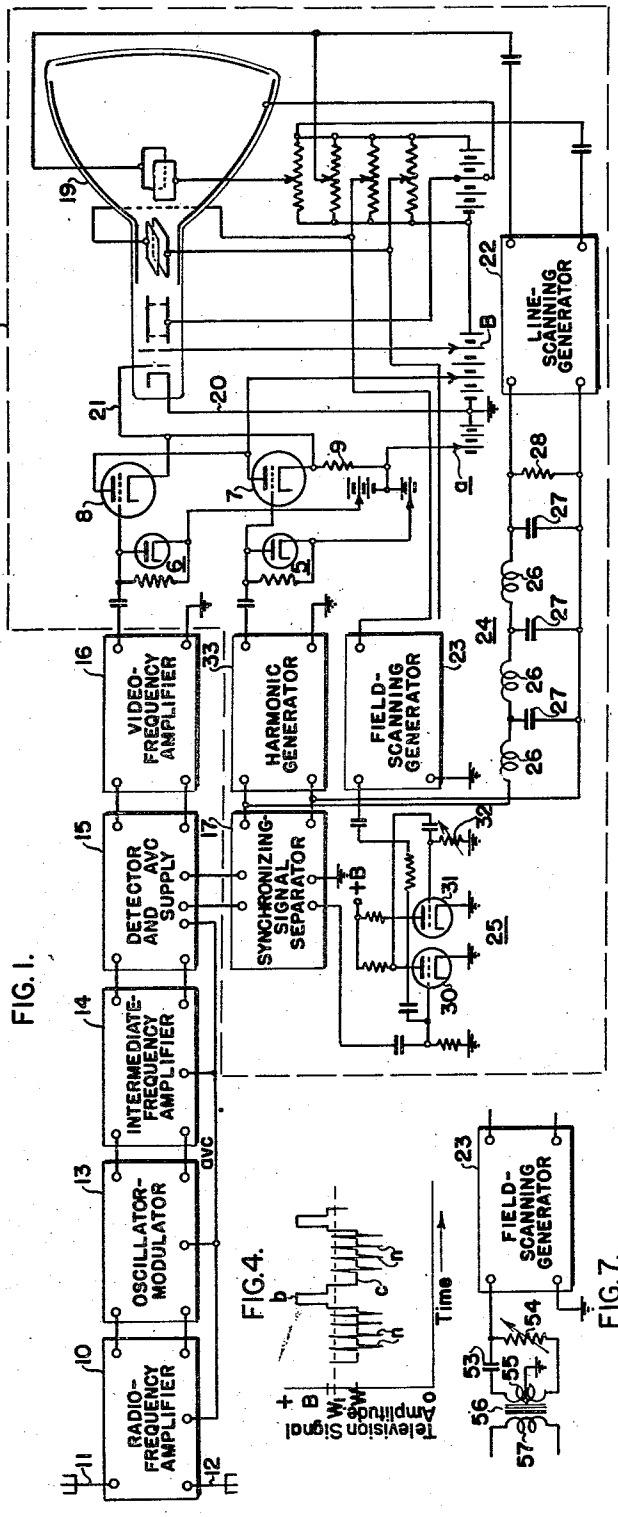


FIG. 1.

FIG. 4.

FIG. 7.

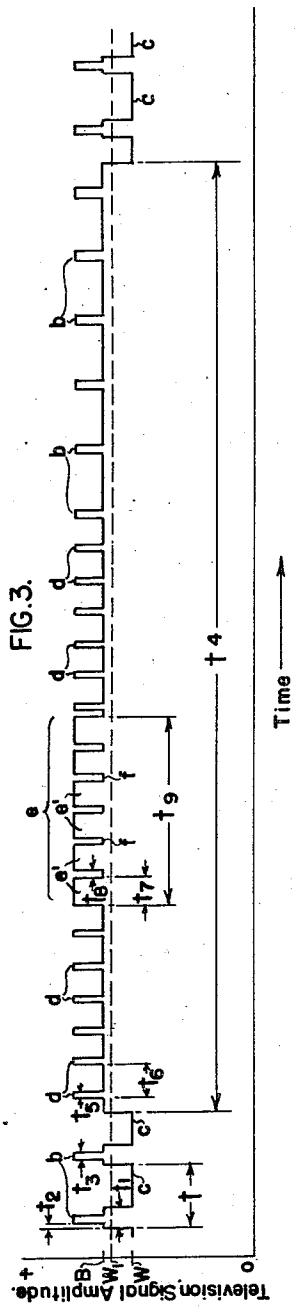


FIG. 3.

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SIGNAL WAVE FORM INDICATING SYSTEM

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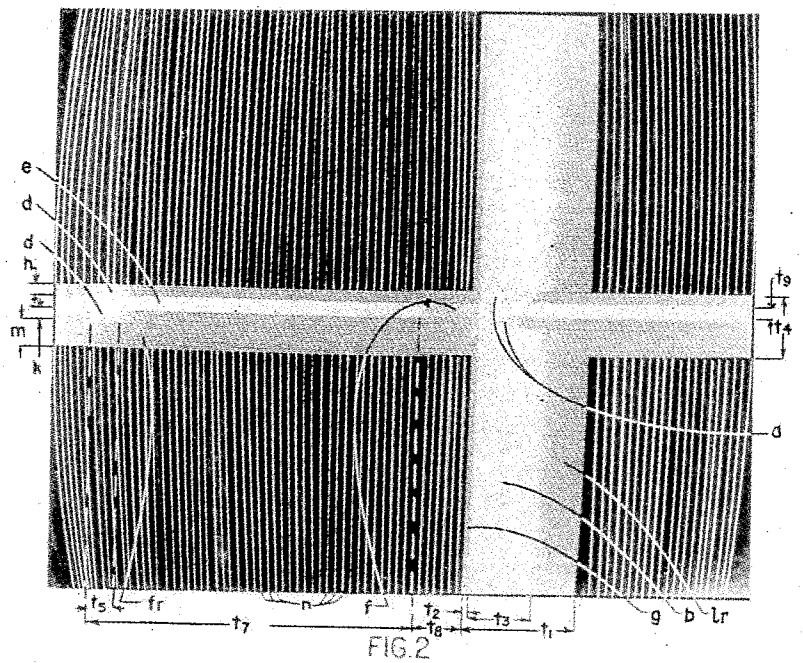


FIG.2

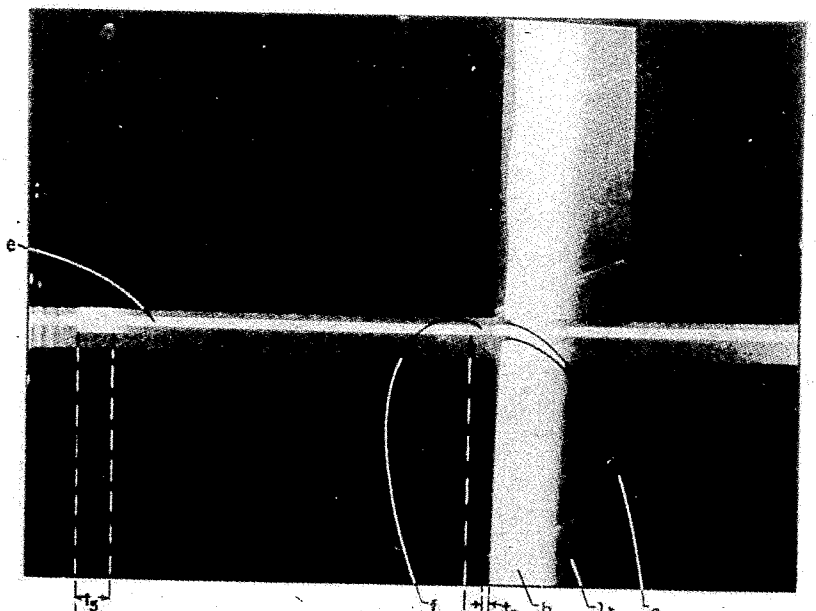


FIG.6.

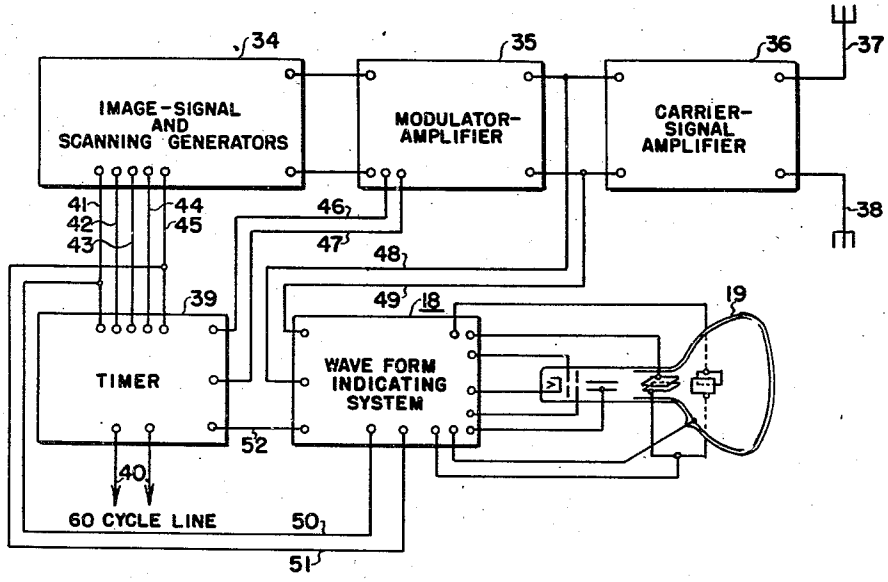
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FIG.5.



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2,284,219

UNITED STATES PATENT OFFICE

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SIGNAL WAVE FORM INDICATING SYSTEM

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Application November 26, 1940, Serial No. 367,248

24 Claims. (Cl. 171—95)

The present invention relates to an improved wave form indicating system and, particularly, to a system for visually indicating at least the synchronizing-signal portion of the wave form of a television signal.

The conventional television signal of the present day transmits two forms of information, each of equal importance to the satisfactory reproduction of the television image. One form of information corresponds to the details of the transmitted image itself and the other, the signal components assuring the proper synchronization of the operations of the transmitting and receiving apparatus. The proper composition of a television signal is highly important in order that the several types of information conveyed by the signal may be separated at the receiver and individually supplied to its several units to control the operation of each. The composition of the television signal can be ascertained by inspection of its wave form.

There has heretofore been no simple system available by which an inspection of the wave form of a television signal could be made in a simple and direct manner. Particularly is this true of the synchronizing information comprising the line-synchronizing and field-synchronizing components of the signal, usually in the form of line-frequency and field-frequency synchronizing pulses, the latter consisting of pulses of relatively long duration preceded and followed by equalizing pulses which are of twice the frequency of the line-synchronizing pulses and one-half their duration. The line-synchronizing pulses are positioned in the television signal at points corresponding to the intervals between successive lines of the television image, commonly known as the line-retrace intervals, while the field-synchronizing and equalizing pulses are positioned at points corresponding to the intervals between successive fields or series of lines forming an image, known as the field-retrace intervals. The particular positioning of the line-synchronizing pulses, the field-synchronizing pulses, and the equalizing pulses is important not only in the relation to the start and finish of the intervals in which each occurs, but also in regard to the relative phase of the field-synchronizing and equalizing pulses considered with respect to each other and to the line-synchronizing pulses. It is further important that the several types of synchronizing pulses have predetermined individual durations.

In examining the wave form of the synchronizing-signal components of a television signal, it has heretofore been necessary to examine successively, by the use of an oscilloscope, a large number of individual sections or portions of the television signal each corresponding to one line or a few lines of the transmitted image. These numerous examinations obviously necessitate a large number of individual adjustments of the oscilloscope apparatus, and this method of wave form investigation is frequently not satisfactory since changes may occur in the wave form between one or more of the several independent investigations. Furthermore, such successive investigations often do not show completely or accurately the phase relations between the several synchronizing-signal components. Consequently, it is highly desirable that there be provided an accurate single visual indication of the wave form of all synchronizing-signal components of the television signal in order that the composition of the signal may be easily, quickly, and accurately determined.

It is an object of the present invention, therefore, to provide a new and improved system for visually indicating at least a portion of the wave form of a television signal and one which avoids one or more of the above-mentioned disadvantages and limitations of the prior art wave form indicating systems.

It is an additional object of the invention to provide an indicating system which furnishes a single visual indication of the entire wave form of a television signal and particularly of the portions thereof which are essential to accurate synchronization between the transmitting and the receiving television apparatus.

It is a further object of the invention to provide an indicating system which furnishes a single visual indication of the wave form of all of the synchronizing-signal components of the television signal and particularly furnishes an indication of the relative phase relationships between the several synchronizing-signal components.

In accordance with the present invention, a system for visually indicating at least a portion of the wave form of a television signal comprises a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of the tube, the applied signal including synchronizing-signal components. The system includes means for periodically deflecting the ray of the tube in each of two directions normal to each other, means for controlling the deflecting means to maintain the deflections in synchronization with the synchronizing-signal components of the applied signal, and means for maintaining a predetermined phase displacement between one or both of the ray deflections and the corresponding synchronizing-signal components.

In accordance with a preferred form of the invention, a system of the type described includes two signal delay circuits, and means including the delay circuits for controlling the deflecting means to maintain the deflections in predeter-

mined phase-displaced synchronism with the synchronizing-signal components of the applied television signal.

For a better understanding of the invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

In the accompanying drawings, Fig. 1 is a circuit diagram, partially schematic, of a complete television carrier-signal receiver including a system embodying the invention for visually indicating at least a portion of the wave form of a received television signal; Fig. 2 illustrates a visual pattern produced by the wave form indicating system of the Fig. 1 arangement and indicating the wave form of the synchronizing-signal components of a television signal having proper composition; Fig. 3 is a graph of the wave form of a portion of a conventional negatively-modulated television signal and is used in explaining the manner of interpreting the pattern produced by the wave form indicating system; Fig. 4 is a graph of the wave form of a portion of a television signal and shows periodic time-reference oscillations superimposed on the television signal; Fig. 5 represents schematically a television transmitting apparatus having associated therewith as a monitoring device the wave form indicating system of the invention; Fig. 6 illustrates a pattern produced by the indicating system to indicate the wave form of a television signal having improper composition; and Fig. 7 is a partial circuit diagram of a modified form of the field-synchronizing portion of the indicating system of the invention.

Referring now more particularly to Fig. 1, there is represented schematically a television carrier-signal receiver including a wave form indicating system embodying the present invention in a preferred form. In general, the receiver includes a radio-frequency amplifier 10 having its input circuit connected to an antenna system 11, 12 and having its output circuit connected to an oscillator-modulator 13. Connected in cascade with the oscillator-modulator 13, in the order named, are an intermediate-frequency amplifier 14 of one or more stages, a detector and A. V. C. supply 15, and a video-frequency amplifier 16. The output circuit of the video-frequency amplifier 16 is coupled by way of an input circuit to the ray-control or modulation-control electrode of a cathode-ray tube 19 provided in a wave form indicating system 18, more fully described hereinafter. The output circuit of the detector of unit 15 also is coupled to a synchronizing-signal separator 17 included in unit 18. The A. V. C. supply of unit 15 is connected through the conductor designated as A. V. C. to the input circuits of one or more of the tubes of units 10, 13, and 14 in a conventional manner.

It will be understood that the various units just described may, with the exception of the wave form indicating system 18, be a conventional construction and operation, the details of which are well known in the art, rendering detailed description thereof unnecesary. Considering briefly the operation of this portion of the receiver and of the wave form indicating system 18 as a whole, and neglecting for the moment the detailed operation of the indicating system, presently to be described, a television modulated-carrier signal is received and amplified by the radio-frequency amplifier 10, converted to an intermediate-frequency carrier signal in the oscillator-modulator 13, amplified in the intermediate-frequency amplifier 14, and detected by the detector of unit 15 to derive the video and synchronizing-signal modulation components thereof. The modulation components are amplified by the video-frequency amplifier 16 and applied to the input circuit of the cathode-ray tube 19. The cathode-ray beam of tube 19 periodically is deflected in two directions normal to each other, but these deflections are maintained in predetermined phase-displaced synchronism, in a manner presently to be described in greater detail, with the synchronizing-signal components of the television signal applied to the synchronizing-signal separator 17 and to the cathode-ray tube 19. There is consequently formed on the screen of tube 19 a pattern representative of the synchronizing-signal components, since they are displaced in phase with respect to the retrace intervals of the signal input to the cathode-ray tube 19, during which the scanning ray is normally suppressed.

The automatic amplification control or A. V. C. bias derived from the A. V. C. supply of unit 15 is effective to control the amplification of one or more of the units 10, 13, and 14 to maintain the signal input to the detector of unit 15 within a relatively narrow range for a wide range of received signal intensities.

Referring now more particularly to the wave form indicating system 18 embodying the present invention in a preferred form, the cathode-ray tube 19 has an input circuit 20, 21 coupled across a cathode resistor 9 which is common to the output circuits of a video-frequency amplifier 8 and a harmonic-frequency amplifier 7. The input circuit of amplifier 8 is coupled to the output circuit of the video-frequency amplifier 16 and includes a network 6 which inserts a direct current component of the video-frequency signal at the grid of amplifier 8 using the synchronizing-signal pulse tips as its reference level. Thus, the ray-control electrode of tube 19 is adapted to have applied thereto by way of the input circuit 20, 21 the television modulation-signal output of video-frequency amplifier 16 to modulate the ray of the tube and the television signal includes synchronizing-signal components comprising line-frequency and field-frequency synchronizing pulses. In order to deflect the ray of tube 19 periodically and with substantially constant velocity in each of two directions normal to each other to produce a series of lines and a series of fields, there is provided deflecting means comprising a line-scanning generator 22 and a field-scanning generator 23, the outputs of which are respectively coupled to the line-deflecting and field-deflecting elements of tube 19, which may be deflecting plates, as indicated, or deflecting windings. The indicating system 18 includes also means responsive to the synchronizing-signal components of the television signal for controlling the generators 22 and 23 to maintain the cathode-ray deflections in synchronism with the synchronizing-signal components of the applied television signal. This means comprises the synchronizing-signal separator 17 having an input circuit coupled to the output circuit of the detector of unit 15 and having a pair of output circuits individually coupled to the scanning generators 22 and 23 to apply to these generators

the line-frequency and field-frequency synchronizing pulses, respectively.

The indicating system 18 additionally includes means for maintaining predetermined phase displacements between the cathode-ray deflections and corresponding ones of the synchronizing-signal components of the television signal applied to the tube 19, of such value as to remove the synchronizing-signal components from the retrace intervals of the cathode-ray deflections, comprising two signal delay circuits 24 and 25 which are individually included in the means for controlling the ray deflecting means. Specifically, the delay circuits 24 and 25 are included in the coupling circuits betwen the synchronizing-signal separator 17 and the respective scanning generators 22 and 23. The network 24 comprises a low-pass filter consisting of a plurality of series-inductance arms 26, 26, 26, a plurality of shunt-capacitance arms 27, 27, 27, and a terminating impedance 28 having a value equal to the image impedance of the network 24. The constants of network 24 are so proportioned that the network has a phase delay equal to a predetermined portion of the period of the line-synchronizing pulses.

The signal delay circuit 25 comprises a pair of vacuum-tube triodes 30 and 31 having input and output circuits cross-connected to form a multivibrator type of oscillation generator and means responsive to the field-synchronizing pulses for controlling the frequency of the generated oscillations. To this end, the input circuit of triode 30 is additionally coupled to the synchronizing-signal separator 17 to have applied thereto the field-frequency synchronizing pulses of the television signal. The output circuit of the triode 31 is coupled to the synchronizing circuit of the field-scanning generator 23 which circuit comprises means responsive to the wave form of the generated oscillations for controlling the ray-deflecting means to maintain the deflection fields in predetermined phase-displaced synchronism with respect to the field-synchronizing pulses. Circuit 25 generates oscillations having a substantially rectangular-pulse wave form and there is provided means for controlling the duration of the pulses of the generated wave comprising an adjustable resistor 32 coupled between the grid and cathode elements of the triode 31. Vacuum tubes 30 and 31 are energized from a source of space current indicated as +B.

The indicating system 18 also includes means for developing a periodic potential having a period equal to a predetermined fraction of the time required for one deflection of the ray across the screen of the tube and for additionally modulating the ray of tube 19 therewith to provide time-reference indicia on the screen of the cathode-ray tube. This means comprises a harmonic generator 33 having an input circuit coupled to the synchronizing-signal separator 17 to have applied thereto the line-synchronizing pulses of the television signal. The output circuit of generator 33 is coupled through means, the harmonic-frequency amplifier 7, to the input circuit 20, 21 of tube 19. This generator generates oscillations effectively of pulse-wave form having a frequency equal to a predetermined multiple or harmonic of the frequency of the line-synchronizing pulses. The input circuit of amplifier 7 includes a network 5 which so biases the grid of amplifier 7 as to maintain the peak amplitude of the output of the harmonic oscillations of generator 33 at a predetermined level at the grid of amplifier 7.

The indicating system 18 further includes means for so adjusting the level of the television signal as applied to the input circuit of tube 19 that either all or only predetermined portions of the amplitude range of the synchronizing-signal components are reproduced by the tube, or the level may be so adjusted that, in addition, all or predetermined portions of the television image are reproduced. This means comprises an adjustable contact *a* on the supply source for the several electrodes of tube 19, indicated as battery B, whereby the bias of the input electrodes of tube 19 is so adjusted that any selected level of the applied television signal is effective to extinguish the cathode-ray beam.

In considering the operation of the circuit just described, it will be assumed that there is applied from the video-frequency amplifier 16 to the input circuit of cathode-ray tube 19 a television signal having such polarity that the line-frequency and field-frequency synchronizing pulses of the television signal are reproduced as white on the screen of the cathode-ray tube; that is, the polarity of the applied television signal is such that the synchronizing-signal components increase the beam current of the cathode-ray tube, which is opposite the conventional television practice. The line-synchronizing pulses of the television signal are separated from the image-signal component and the field-synchronizing pulses by the synchronizing-signal separator 17 and are applied both to the harmonic generator 33 and to the input of the delay network 24. The harmonic generator 33 is of the type which generates oscillations having a frequency equal to that of the line-synchronizing pulses but having a wave form rich in harmonics. A desired harmonic, for example, the one-hundredth harmonic, is selected in the output of the harmonic generator and is applied through the harmonic-frequency amplifier 7 to the input circuit of cathode-ray tube 19 so that each line is reproduced on the screen of tube 19 as a series of bright dashes spaced across the cathode-ray tube screen and these dashes are in alignment and form, in a manner to be hereinafter more fully described, a series of bright lines normal to the line-scanning direction. These lines are useful as an accurate means of measuring the durations and relative phase relationships of the synchronizing-signal components, the wave forms of which are indicated by the pattern produced on the screen of tube 19. The choice of any particular harmonic is a matter of convenience, the one-hundredth harmonic having the particular advantage that it permits reading time intervals directly in percentage of the line-synchronizing pulse period. The provision of time-reference lines in this manner is especially useful when the line deflections of the cathode ray of tube 19 do not have uniform velocity throughout the entire period of the line deflection. The use of a common cathode resistor 9 for amplifiers 7 and 8 permits amplifier 8 to bias amplifier 7 to cutoff at a predetermined level on the television signal. This predetermined level may be chosen by suitably proportioning the biases of amplifiers 7 and 8 to be the level corresponding to black in the television signal.

It will be seen that the delay network 24 comprises means for deriving line-synchronizing pulses displaced in phase with respect to the

line-synchronizing pulses of the television signal applied to tube 19, the magnitude of the phase displacement equalling the phase delay of the network. These derived synchronizing pulses are applied to a synchronizing means which may be considered as included in generator 22 and which is responsive thereto for controlling the line-scanning generator 22 to maintain a predetermined phase-displaced synchronism between the line-scanning deflections of the cathode-ray beam and the line-synchronizing pulses of the television signal applied to tube 19. Thus, the line-synchronizing pulses of the television signal are reproduced on the screen of tube 19 well within the picture area thereof as distinguished from the conventional reproduction, in which these pulses occur during the retrace interval of the scanning beam and in which the signal level during such intervals is such that the blanking pulses block out the scanning beam to prevent reproduction of the synchronizing pulses.

The field-synchronizing pulses from the synchronizing-signal separator 17 are applied to oscillator 25 to maintain the generated oscillations in synchronism with the field-synchronizing pulses. Assuming triode 30 to be conducting, at a time just prior to the time when a pulse is to be applied to its grid from triode 31, a synchronizing pulse is applied negatively thereto from the synchronizing-signal separator 17 which triggers the multivibrator, biasing triode 30 to cutoff. The potential of the anode of triode 30 thereupon rises to value +B and supplies a positive pulse to the grid of the then inert triode 31. Triode 31 immediately becomes conductive, whereby its anode potential becomes less positive, supplying a negative pulse to field-scanning generator 23 which is not affected since it responds to positive pulses only. After a predetermined interval, determined by the time constant of the grid circuit of triode 31, the charge leaks off the grid and triggers triode 31, biasing it to cutoff, whereupon its anode potential rises to value +B and supplies a positive pulse to drive field-scanning generator 23 and to trigger triode 30, rendering it conductive. Hence, it will be seen that the field-synchronizing arrangement includes means responsive to the field-synchronizing pulses for synchronizing the multivibrator at a predetermined point on half cycles of one polarity of the generated oscillations and means for synchronizing the field-frequency oscillator at a predetermined point on half cycles of opposite polarity of the generated oscillations. The synchronization of the field-scanning generator 23 is thus displaced in phase with respect to the field-synchronizing pulses applied to the triode 30. The resultant field-scanning deflections of the cathode-ray beam of tube 19, which are produced by the oscillations generated by generator 23, are consequently displaced in phase with respect to the field-synchronizing pulses of the television signal applied to the brilliancy-control electrode of the cathode-ray tube 19. As a result, the equalizing pulses and the field-synchronizing pulses of the television signal are reproduced on the screen of tube 19 well within the picture area thereof as distinguished from the conventional reproduction, in which these pulses occur during the retrace interval and are blocked-out from the reproduced television image.

The adjustable grid resistor 32 of oscillator 25 controls the relative durations of the positive and negative half-cycles of the generated oscillations. Since the grid resistor 32 may be so adjusted that the positive and negative half-cycles of the generated oscillations have unequal durations, the expression "half-cycles" as here used, and as used in the claims, is not strictly accurate but is used for want of more accurate terminology by which the positive and negative loops of the generated oscillations may be designated in terms of their "polarity." Adjustment of the value of grid resistor 32 thus effectively varies the magnitude of the phase shift between the field-scanning deflections of the ray of tube 19 and the field-synchronizing pulses of the television signal applied to the input electrodes of cathode-ray tube 19 and consequently varies the region within the picture area at which the equalizing pulses and field-synchronizing pulses are reproduced.

Fig. 2 illustrates the pattern produced on the screen of the cathode-ray tube 19 by a television signal having a wave form properly composed in accordance with the present standards approved by the Radio Manufacturers Association. As an aid in interpreting the pattern of this figure, reference is made to Fig. 3 which graphically illustrates the wave form of a television signal having proper composition. The television signal comprises line-synchronizing pulses *b* occurring during the interval between successive lines *c* of the image-signal component, the latter being here represented as an image signal corresponding to a uniformly white background of intensity W. Each line period has a duration *t* and each line-retrace interval has a duration t_1. To provide accurate synchronization, the leading edge of each line-synchronizing pulse occurs a time interval t_2 after the initiation of each line-retrace interval and has a duration t_3. Similarly, the field-retrace interval occupies a time t_4 during which interval a series of equalizing pulses *d* precede and follow a field-synchronizing pulse *e* of relatively long duration and periodically serrated at *f* to form a series of broad pulses *e'*, the serration of pulse *e* being provided to assist in maintaining line-frequency synchronization. The equalizing pulses have a duration t_5 approximately one-half the line-synchronizing pulse duration t_3 and a period t_6 one-half the period *t* of the line-synchronizing pulses. The duration of each of the broad pulses *e'* of the field-synchronizing pulse *e* is t_7 and the duration of each serration *f* is t_8. The duration of the field-synchronizing pulse *e* is t_9.

The pattern illustrated in Fig. 2 may be termed a pulse-cross pattern since the synchronizing-signal components of the television signal produce a white cross within the picture area. This white cross is superimposed upon a broader grey cross which is produced by the normal black level B, Fig. 3, of the television signal during the line-retrace and field-retrace intervals. To derive the pattern of Fig. 2, the adjustable contact *a* of battery B is set to bias the cathode-ray tube 19 to cutoff at a level W_1 of the television signal representing a dark grey shade level, a value of bias which suppresses the video-signal component of the signal. The line-retrace or blanking interval t_1 of the television signal is indicated on this pattern by the width t_1 of the wide vertical grey bar *lr* of the cross. The line-synchronizing pulses *b* produce the narrower vertical white bar *b* and their duration t_3 is indicated by its width t_3. The interval t_2 of Fig. 3 is indicated by the width t_2 of the narrow vertical grey strip *g* which lies to

the left of the white vertical bar. The equalizing pulses *d* produce the rectangular white areas *d*, *d* which lie immediately above and below the horizontal white bar of the cross, and their duration is indicated by the width t_5 of these areas. The broad pulses *e'* of the field-synchronizing pulse *e* produce the horizontal white bar *e* of the cross, and their duration is indicated by the length t_7 of the left-hand portion of the horizontal white bar. The interval of each serration *f* of the field-synchronizing pulse *e* is indicated by the length t_8 of the gap *f* which occurs in the horizontal white bar *e*. The field-retrace intervals t_4 produce the horizontal grey bar *fr* of the cross, and their duration is indicated in Fig. 2 by the width t_4 of the wide horizontal grey bar. The duration of the field-synchronizing pulse *e* is indicated by the width t_9 of the narrow horizontal white bar *e* of the cross pattern. The widths *h* and *k* of the white rectangles *d*, *d* which lie respectively above and below the horizontal white bar *e* is a measure of the number of equalizing pulses *d* while the width *m* of the horizontal grey bar *fr* below the lower white rectangle *d* is a measure of the number of line-synchronizing pulses *b* which follow the equalizing pulses *d*.

It may be noted that the width t_4 of the horizontal grey bar may be increased appreciably over that shown in Fig. 2 by suitably increasing the amplitude of the oscillations generated by the field-scanning generator **23**. This has the advantage that the several intervals *m*, *k*, *h*, t_4, and t_9, and the number of pulses occurring during these intervals, may be more accurately established by counting the number of narrow white lines which form the horizontal grey bar *fr* and broader white lines which form the horizontal white bar *e*, the increased width of the horizontal grey bar making for greater ease in distinguishing the narrow and broader white lines from one another. The pattern of Fig. 2 was prepared in this manner while the pattern of Fig. 6, presently to be considered, was not.

Fig. 4 is a graph representing the wave form of two lines only of the television signal with the harmonic oscillations *n* of the harmonic generator **33** superimposed thereon. The peak amplitude of the harmonic oscillations *n* are stabilized at the black level of the television signal by the interrelated operation of amplifiers **7** and **8** and break up each line into a series of dashes, the dashes being aligned to produce the vertical white lines *n* on the pattern of Fig. 2. These lines are useful as an accurate means of measuring the durations and relative phase relationships of the synchronizing-signal components the wave forms of which are indicated by the pattern of Fig. 2.

An inspection of the pattern of Fig. 2 indicates that the wave form of the television signal which produced this pattern conforms to the above-mentioned standards of the Radio Manufacturers Association. The leading edges of the line-synchronizing pulses, the equalizing pulses, and the field-synchronizing pulses are properly timed, as indicated by the unbroken straight left-hand edge of the vertical white bar *b* of the cross pattern. The equalizing pulses have a duration t_5 one-half that of t_3 of the line-synchronizing pulses. The width t_2 of the vertical grey strip *g* of the vertical grey bar *lr* indicates that the line-synchronizing pulses *b* occur approximately $1/100$ of the line period after the initiation of each line-retrace interval. A close inspection of the horizontal grey bar *fr* shows that this bar is formed of six narrow white lines above and nineteen narrow white lines below the white bar *e*. The white lines above the horizontal white bar *e* indicate that there are twelve equalizing pulses in all preceding the field-synchronizing pulses, six of these equalizing pulses being formed by one field and six by a second field interlaced with the first field. The nineteen white lines below the horizontal white bar *e* indicate that there are twelve equalizing pulses following the field-synchronizing pulses, six equalizing pulses being formed by each of the interlaced fields, and that there are 6½ line-synchronizing pulses in each of the two interlaced fields following the last group of equalizing pulses. An inspection of the horizontal white bar *e* shows that this bar is formed of six broader white lines which are broken by the gap *f* to form twelve line sections, thereby indicating that there are six broad pulses *e'* in each field-synchronizing pulse *e* of the interlaced fields.

In the foregoing described operation of the invention, it was stated that the video-signal component of the television signal is suppressed by so adjusting the adjustable contact *a* of battery B that tube **19** is biased to cutoff at the level W_1, Fig. 3, of the television signal. It will be evident that the contact *a* may also be so adjusted that the entire television signal including its video-signal component is reproduced on the screen of tube **19**, as in Fig. 6 presently to be described. The synchronizing-signal components of the television signal may alone be reproduced, as a white cross on the black background, by adjustment of the contact *a* to bias the input electrodes of tube **19** to cutoff at the level B, Fig. 3, of the television signal. By applying the television signal with conventional polarity to the input electrodes of tube **19**, which polarity is opposite to that assumed in the foregoing described operation of the invention, the synchronizing-signal components may be reproduced as a black cross within the picture area by so adjusting the contact *a* that tube **19** is biased to cutoff at a predetermined amplitude on the synchronizing-signal pulses.

Fig. 5 represents schematically a use of the wave form indicating system of the invention in monitoring the wave form of the television signal at the television transmitter. The transmitter includes an image-signal and scanning generator unit **34** comprising a suitable video-frequency amplifier. Connected in cascade to the output of the image-signal generator **34**, in the order named, are a modulator-amplifier **35**, a carrier-signal amplifier **36**, and an antenna system **37**, **38**. A timer **39** is energized from a 60-cycle alternating current power supply **40**, and generates periodic pulse potentials of suitable wave forms having frequencies of 60 cycles, 13,230 cycles, and 26,460 cycles. These potentials are applied to the image-signal generator **34** through conductors **41**—**45**, inclusive, to control its operation. Line-synchronizing and field-synchronizing pulses generated by timer **39** are also applied through conductors **46** and **47** to the modulator-amplifier **35** where they are combined with the image signal to provide a composite television signal which is used to modulate a carrier signal generated therein which is applied to the carrier-signal amplifier **36**. The output of the modulator-amplifier **35** is coupled by conductors **48** and **49** to the input circuit of the cathode-ray tube **19** of the wave

form indicating system 18. Synchronizing pulses having frequencies of 60 cycles and 26,460 cycles are coupled through conductors 50—52, inclusive, to phase-delay circuits of the wave form indicating system 18, such as the phase-delay circuits 24 and 25, respectively, of the unit 18 of Fig. 1.

It will be understood that the various units just described may, with the exception of the wave form indicating system 18, be of a conventional construction and operation the details of which are well known in the art, rendering further detailed description thereof unnecessary. Considering briefly the operation of the transmitter as a whole, and referring to the above detailed description for the operation of the wave form indicating system 18, an image signal is developed by the generator 34 and is applied to the modulator-amplifier 35. The latter combines the image signal with the line-synchronizing and field-synchronizing pulses applied thereto from the timer 39 and modulates a carrier signal developed therein with the composite television signal thus formed. The modulated-carrier signal is amplified by the carrier-signal amplifier 36 and radiated by the antenna system 37, 38. The wave form indicating system 18 monitors the output of the modulator-amplifier 35 and produces on the screen of the cathode-ray tube 19 a pulse-cross pattern which indicates the wave form of the composite television signal.

Fig. 6 illustrates a pulse-cross pattern produced by a television signal improperly composed due to an improper adjustment of the transmitting arrangement of Fig. 5. It will be noted that in the pulse-cross pattern of Fig. 6 there is a decided waver in the left-hand edge of the vertical white bar *b* which indicates a variation of the interval t_2 between the leading edge of the line-synchronizing pulses and the initiation of the line-retrace intervals. Since the left-hand edge of the vertical grey bar *lr* is linear, the nonlinearity of the edge of the vertical white bar indicates a periodic phase shift in the derivation of the 13,230-cycle line-synchronizing pulses from the 26,460-cycle oscillator of the timer. It is further evident that the vertical white bar *b* has a decided break in its left-hand edge at the center thereof. The depressed portions *o* of this break indicate that the equalizing pulses *d* are improperly delayed in phase with respect to the line-synchronizing pulses *b*. The vertical synchronizing pluses *e* are advanced in phase with respect to the line-synchronizing pulses *b* as evidenced by the termination of the gap *f* in the horizontal white bar *e* in advance of the left-hand edge of the vertical white bar *b*. The short duration of the gap *f* in the horizontal white bar *e* indicates that the duration t_7 of the broad pulses *e'* is too long, a condition leading to improper line-frequency synchronization at the receiver. And, lastly, the pattern of Fig. 6 indicates that the wave form of the equalizing pulses *d* is improper in that the duration t_8 of these pulses is materially longer than one-half the duration t_3 of the line-synchronizing pulses *b*. This condition also may contribute to improper synchronization at the receiver.

Fig. 7 is a circuit diagram of a modified form of field-synchronizing system which may, in certain instances, be used in place of the delay circuit 25 shown in the Fig. 1 arrangement of the wave form indicating system 18. This modification may be used where the transmitter and receiver are connected to the same alternating current power-supply system or may be used at the transmitter in lieu of synchronizing the indicating system 18 from the timer 39 of the transmitting apparatus. In this modification, a phase-shifting means or network comprising a condenser 53 and an adjustable resistor 54 is connected across the secondary winding 55 of a transformer 56, the primary 57 of which comprises a supply circuit which is connected to an alternating current power-supply main having a frequency equal to that of the field-synchronizing component of the television signal. A center tap on the winding 55 is grounded and the synchronizing circuit of the field-scanning generator 23 is coupled between the junction of the resistor 54 and the condenser 53 of the phase-shifting network and ground.

In considering the operation of this modified form of field-synchronizing system, it will be evident that the alternating voltage developed between ground and the common terminal of the condenser 53 and resistor 54 has substantially a constant amplitude and phase shift with respect to the alternating voltage of the power-supply mains, the magnitude of the phase shift varying with the value of resistance of resistor 54. When the wave form indicating system 18 of the invention uses this modified form of field-synchronizing system for maintaining the deflection fields in predetermined phase-displaced synchronism with reference to the field-synchronizing components, the operation of the indicating system is otherwise essentially the same as in the arrangement of Figs. 1 or 5 and will not be repeated.

From the above description of the invention, it will be evident that a wave form indicating system embodying the invention has the advantages that it provides in a single visual pattern an indication of the complete wave form of a television signal and particularly of the portions thereof which are essential to accurate synchronization between the transmitting and receiving apparatus. The pattern not only provides an indication of the individual durations of the synchronizing-signal components and the durations of the line-retrace and field-retrace intervals, but additionally furnishes an indication of the relative phase relationships between the several synchronizing-signal components. Such phase relationships and time durations can be accurately determined by reference to the vertical white lines which are produced by the output of harmonic generator 33 and are spaced across the pattern from one side to the other.

Although the invention as above described has been utilized for producing a visual indication of at least a portion of the wave form of a television signal, it will be understood that the invention is applicable generally for visually indicating any electrical phenomenon so long as an electrical signal of periodic wave worm representative of the phenomenon is applied to the ray-control electrode of the cathode-ray tube included in the indicating arrangement to produce on the screen a visual trace indicative of the phenomenon.

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore,

aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, and means for maintaining a predetermined phase displacement between one of said deflections and a corresponding one of said synchronizing-signal components.

2. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, and means for maintaining predetermined phase displacements between said ray deflections and said synchronizing-signal components.

3. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, and means for delaying the phase of said ray deflections relative to corresponding ones of said synchronizing-signal components.

4. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components and being applied with such polarity to said input circuit that said synchronizing-signal components increase the beam current of said cathode-ray tube, means for periodically deflecting the ray of said tube in each of two directions normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, and means for maintaining a predetermined phase displacement between one of said deflections and a corresponding one of said synchronizing-signal components.

5. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, and means for maintaining a predetermined phase displacement between one of said deflections and a corresponding one of said synchronizing-signal components of such value as to remove said one synchronizing-signal component from the retrace interval of said one ray deflection.

6. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, means for maintaining a predetermined phase displacement between one of said deflections and a corresponding one of said synchronizing-signal components, and means for so adjusting the level in said input circuit of said applied signal that at least predetermined portions of said synchronizing-signal components are reproduced by said tube.

7. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having input electrodes connected in an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, means for maintaining a predetermined phase displacement between one of said deflections and a corresponding one of said synchronizing-signal components, and means for so biasing said input electrodes that at least predetermined portions of said synchronizing-signal components are reproduced by said tube.

8. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, a signal delay circuit, and means including said delay circuit for controlling one of said deflecting means to maintain a corresponding one of said deflections in predetermined phase-displaced synchronism with a corresponding one of said synchronizing-signal components.

9. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, two signal delay circuits, and means including said delay circuits for controlling said deflecting means to maintain said

deflections in predetermined phase-displaced synchronism with said synchronizing-signal components.

10. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components comprising line-frequency synchronizing pulses and field-frequency synchronizing pulses, means for periodically deflecting the ray of said tube in a first direction in synchronism with said line-frequency synchronizing pulses and periodically in a direction normal thereto in synchronism with said field-synchronizing pulses, a signal delay network having a phase delay equal to a predetermined portion of the period of said line-synchronizing pulses, and means including said delay network for controlling said deflecting means to maintain between said line deflections and said line-synchronizing pulses a phase delay equal to said predetermined portion of the period of said line-synchronizing pulses.

11. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components comprising line-synchronizing pulses, means for deriving synchronizing pulses displaced in phase with respect to said line-synchronizing pulses, means for periodically deflecting the ray of said tube in each of two directions normal to each other to produce a series of lines and a series of fields, and means responsive to said derived synchronizing pulses for controlling said deflecting means to maintain said line deflections in phase-displaced synchronism with said line-synchronizing pulses.

12. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including snychronizing-signal components comprising field-synchronizing pulses, means for periodically deflecting the ray of said tube in each of two directions normal to each other to produce a series of fields each consisting of a series of lines, an oscillator, means responsive to said field-synchronizing pulses for controlling the frequency of oscillations generated by said oscillator, and means responsive to said generated oscillations for controlling said deflecting means to maintain said series of fields in predetermined phase-displaced synchronism with respect to said field-synchronizing pulses.

13. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components comprising field-synchronizing pulses, means for periodically deflecting the ray of said tube in each of two directions normal to each other to produce a series of fields each consisting of a series of lines, an oscillator, means responsive to said field-synchronizing pulses for controlling the frequency of oscillations generated by said oscillator, means for controlling the wave form of said generated oscillations, and means responsive to the wave form of said generated oscillations for controlling said deflecting means to maintain said series of fields in predetermined phase-displaced relation with respect to said field-synchronizing pulses.

14. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components comprising field-synchronizing pulses, means for periodically deflecting the ray of said tube in a first direction, means including a field-frequency oscillator for periodically deflecting the ray of said tube in a direction normal to said first direction, a multivibrator for generating oscillations of substantially rectangular wave form, means responsive to said field-synchronizing pulses for synchronizing said multivibrator at a predetermined point on half-cycles of one polarity of said generated oscillations, and means for synchronizing said field-frequency oscillator at a predetermined point of the half-cycles of opposite polarity of said generated oscillations.

15. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including line-synchronizing and field-synchronizing signal components, means for periodically deflecting the ray of said tube in a first direction in synchronism with said line-synchronizing component, means including a field-frequency oscillator for periodically deflecting the ray of said tube in a direction normal to said first direction, a supply circuit adapted to have applied thereto an alternating voltage the frequency of which is equal to that of said field-synchronizing component, and phase-shifting means coupled to said supply circuit for controlling said field-frequency oscillator to maintain said deflections in said second direction in predetermined phase-displaced synchronism with respect to said field-synchronizing component.

16. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, means for maintaining a predetermined phase displacement between one of said deflections and a corresponding one of said synchronizing-signal components, and means for additionally modulating the ray of said tube at a predetermined frequency related to said synchronizing-signal components to provide time-reference indicia on the screen of said cathode-ray tube.

17. A system for visually indicating at least a portion of the wave form of a television signal comprising, a cathode-ray tube having an input circuit adapted to have applied thereto a television signal to modulate the ray of said tube, said applied signal including synchronizing-signal components, means for periodically deflecting the ray of said tube in each of two directions

normal to each other, means for controlling said deflecting means to maintain said deflections in synchronism with the synchronizing-signal components of said applied signal, means for maintaining a predetermined phase displacement between one of said deflections and a corresponding one of said synchronizing-signal components, means for generating oscillations having a frequency equal to a predetermined multiple of that of one of said synchronizing-signal components, and means for modulating the ray of said tube with said generated oscillations to provide time-reference indicia on the screen of said cathode-ray tube.

18. A system for visually indicating an electrical phenomenon comprising, a cathode-ray tube having a ray-control electrode adapted to have applied thereto an electrical signal representative of said phenomenon and to modulate the ray of said tube, means for deflecting the ray of said tube in one direction to produce on the screen of said tube a visual indication of said phenomenon, means for producing on the screen of said tube visual time-reference indicia from which the values of said phenomenon may be determined comprising means for developing a periodic potential having a period equal to a predetermined fraction of the time required for one deflection of said ray across the screen of said tube, and means responsive to said periodic potential for additionally modulating the ray of said tube.

19. A system for visually indicating an electrical phenomenon comprising, a cathode-ray tube having a ray-control electrode adapted to have applied thereto an electrical signal representative of said phenomenon and to modulate the ray of said tube, means for deflecting the ray of said tube in one direction with substantially constant velocity to produce on the screen of said tube a visual indication of said phenomenon, means for producing on the screen of said tube visual time-reference indicia from which the values of said phenomenon may be determined comprising means for developing a periodic potential having a period equal to a predetermined fraction of the time required for one deflection of said ray across the screen of said tube, and means responsive to said periodic potential for additionally modulating the ray of said tube.

20. A system for visually indicating an electrical phenomenon comprising, a cathode-ray tube having a ray-control electrode adapted to have applied thereto an electrical signal representative of said phenomenon and to modulate the ray of said tube, means for deflecting the ray of said tube in one direction to produce on the screen of said tube a visual trace indicative of said phenomenon, means for producing on the screen of said tube visual time-reference indicia from which the values of said phenomenon may be determined comprising means for developing a periodic potential having a period equal to a predetermined fraction of the time required for one deflection of said ray across the screen of said tube, and means responsive to said periodic potential for additionally modulating the ray of said tube.

21. A system for visually indicating an electrical phenomenon comprising, a cathode-ray tube having a ray-control electrode adapted to have applied thereto an electrical signal of periodic wave form representative of said phenomenon and to modulate the ray of said tube, means for periodically deflecting the ray of said tube in one direction to produce on the screen of said tube a visual indication of said phenomenon, means for producing on the screen of said tube visual time-reference indicia from which the values of said phenomenon may be determined comprising means for developing a periodic potential having a period equal to a predetermined fraction of the time required for one deflection of said ray across the screen of said tube, and means responsive to said periodic potential for additionally modulating the ray of said tube.

22. A system for visually indicating an electrical phenomenon comprising, a cathode-ray tube having a ray-control electrode adapted to have applied thereto an electrical signal of periodic wave form representative of said phenomenon and to modulate the ray of said tube, means for periodically deflecting the ray of said tube in one direction to produce on the screen of said tube a visual indication of said phenomenon, means for producing across the screen of said tube visual reference lines from which the values of said phenomenon may be determined comprising means for developing a periodic potential having a period equal to a predetermined fraction of the time required for one deflection of said ray across a screen of said tube, and means responsive to said periodic potential for additionally modulating the ray of said tube.

23. A system for visually indicating an electrical phenomenon comprising, a cathode-ray tube having a ray-control electrode adapted to have applied thereto an electrical signal representative of said phenomenon and to modulate the ray of said tube, means for deflecting the ray of said tube in one direction to produce on the screen of said tube a visual indication of said phenomenon, means for producing on the screen of said tube visual time-reference indicia from which the values of said phenomenon may be determined comprising means for developing a periodic potential effectively of pulse wave form and having a period equal to a predetermined fraction of the time required for one deflection of said ray across the screen of said tube, and means responsive to said periodic potential for additionally modulating the ray of said tube.

24. A system for visually indicating an electrical phenomenon comprising, a cathode-ray tube having a modulation-control electrode adapted to have applied thereto an electrical signal representative of said phenomenon and to modulate the ray of said tube, means for periodically deflecting the ray of said tube in two directions normal to each other to produce on the screen of said tube a visual indication of said phenomenon, means for producing across the screen of said tube visual reference lines from which the values of said phenomenon may be determined comprising means for deriving a periodic potential effectively of pulse wave form and having a period equal to a predetermined fraction of the time required for one deflection of said ray across the screen of said tube, and means for applying said periodic potential to said modulation-control electrode additionally to modulate the ray said tube.

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