Jan. 5, 1943. W. T. REA ET AL 2,307,237

TELEGRAPH SIGNAL DISTORTION MEASURING APPARATUS AND SYSTEM

Filed March 29, 1941 2 Sheets-Sheet 1

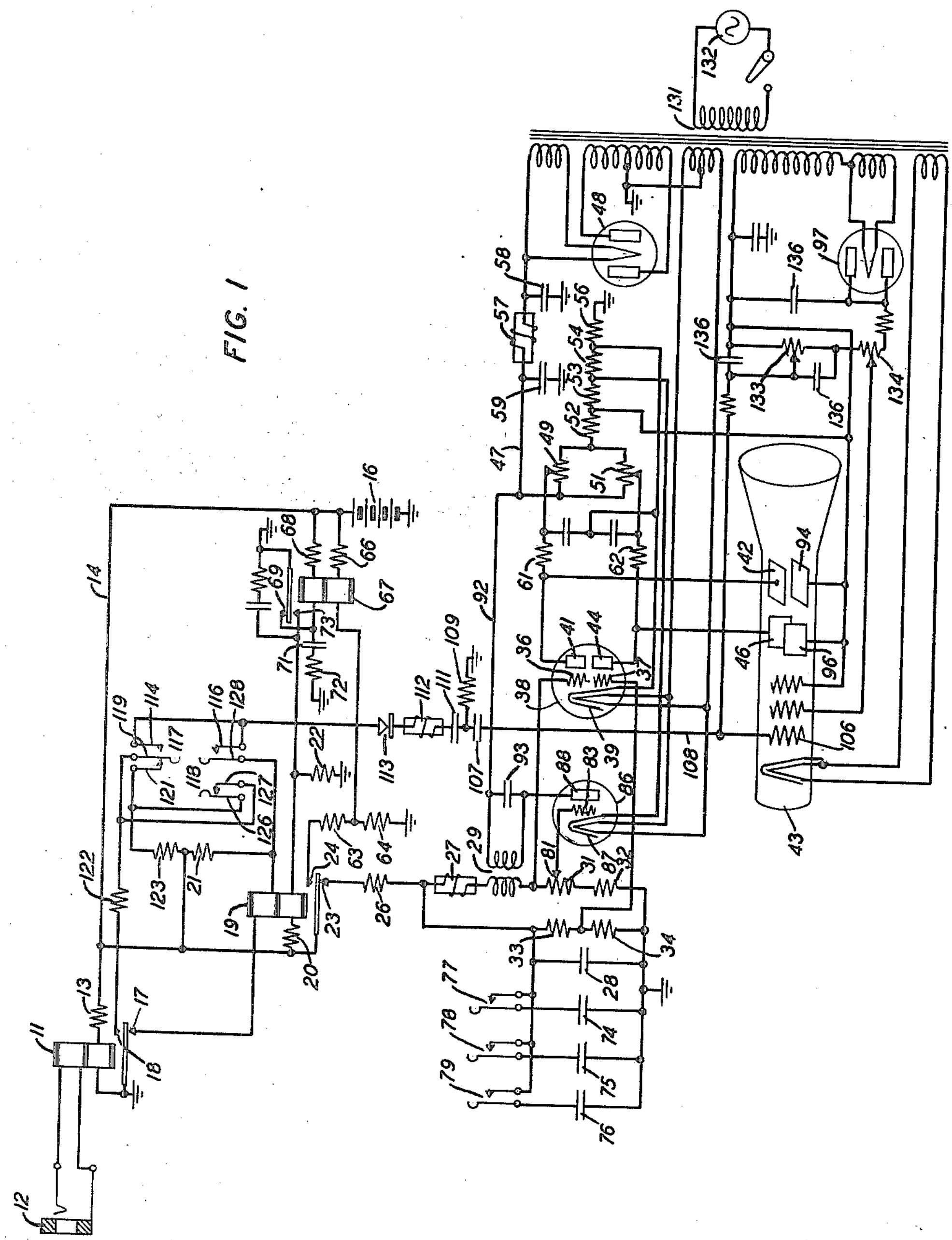

FIG. 1

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TELEGRAPH SIGNAL DISTORTION MEASURING APPARATUS AND SYSTEM

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FIG. 2

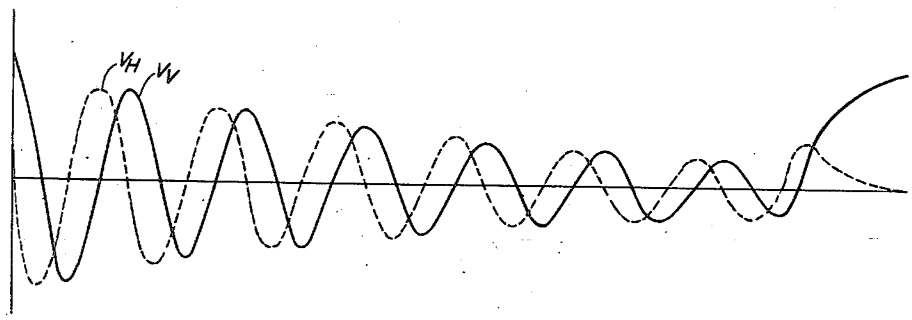


FIG. 3

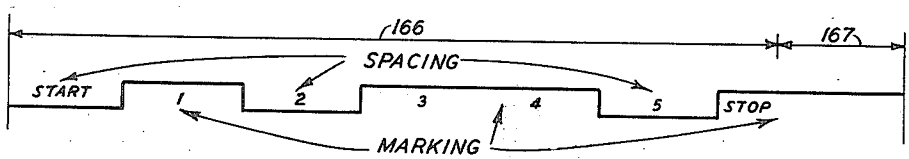
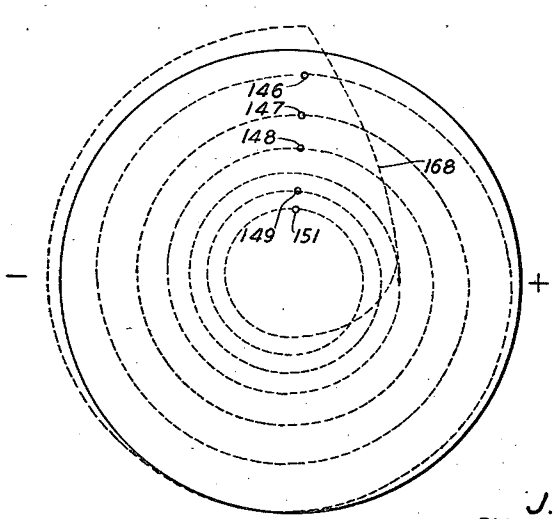


FIG. 4



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Patented Jan. 5, 1943

2,307,237

UNITED STATES PATENT OFFICE

2,307,237

TELEGRAPH SIGNAL DISTORTION MEASURING APPARATUS AND SYSTEM

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Application March 29, 1941, Serial No. 385,802

22 Claims. (Cl. 178—69)

This invention relates to telegraph testing equipment and, more particularly, to telegraph testing apparatus employing a cathode ray tube for indicating both the type and the amount of bias and distortion present in telegraph signals.

It is an object of this invention to provide a telegraph system with an indicating device which may be easily connected directly into a telegraph system while it is in service for indicating, without disturbing the transmission of signals, both the type and the amount of bias and distortion present in telegraph signals transmitted over the system.

It is also an object of the invention to provide a telegraph distortion indicator with a cathode ray tube for readily indicating both the type and the amount of bias and distortion possessed by each impulse of a telegraph permutation code signal combination, each impulse being assigned a different indicating area on the screen of the cathode ray tube.

Another object of the invention is to provide the telegraph distortion indicator with means for preventing the production of parasitic spots on the screen of the cathode ray tube that might otherwise be caused by the chattering of the armature of the receiving relay.

These and other objects of the invention are accomplished by providing the cathode ray tube of the distortion indicator with a damped sinusoidal oscillatory sweep circuit having two voltages 90 degrees in quadrature and designed to cause the cathode ray beam to follow a logarithmic spiral path at the rate of one revolution per pulse of the incoming signal and to make six and one-half revolutions for each five unit telegraph permutation code signal combination and an additional revolution for each additional unit of the code. These revolutions start outside the top edge of the tube's screen and move in a logarithmic spiral path curving in toward the center of the screen. Due to the decrement of the oscillatory circuit, the electron beam enters the indicating area of the screen approximately half way through the start pulse. The decrement, or damping, of the oscillatory circuit is controlled by a vacuum tube and the circuits are tuned to cause the beam to make a complete revolution in the time allotted to each impulse of the permutation code signal combination. This also controls the spacing between the adjacent turns of the spiral. Since the path of these revolutions ultimately approaches the center of the screen of the tube, means are provided for quickly returning the beam to its initial starting position at the outer edge of the tube for making another series of convolutions.

The potential applied to the intensity control electrode of the tube is made sufficiently negative so that ordinarily the beam is invisible. In response to each transition of the line current, a short positive impulse is applied to the intensity control electrode of the tube to produce a momentarily visible spot of light on the screen. In the case of an undistorted signal, there would be a row of visible spots, or flashes, along a radius of the screen. Distortion of the signals will cause displacement of the flashes from this line, the angular displacement being proportional to the amount of the bias and distortion. Consequently, the amount of bias and distortion may be read in terms of the percent of the displacement on a radial scale in which 100 per cent is equal to 360 degrees of arc. The type of bias and distortion is indicated by the position of the flash in respect to the normal radial line; that is, whether the flash is in advance of the radial line or behind it. A half wave copper-oxide rectifier, or varistor, is included in the intensity control circuit to prevent the production of parasitic spots on the screen that might otherwise be caused by the chattering of the contacts of the receiving relay.

These and other features of the invention will be described in detail in connection with the description of the drawings, in which:

Fig. 1 is a circuit diagram of the distortion indicator;

Fig. 2 is a graphical representation of the voltages applied to the electron beam deflecting electrode of the cathode ray tube;

Fig. 3 is a graphical representation of a start-stop permutation code signal combination; and,

Fig. 4 is a diagrammatic view showing the path of impingement of the electron beam upon the screen of the cathode ray tube.

Referring now to Fig. 1, the reference numeral 11 designates a signal responsive polarized relay. Across the operating winding of relay 11 input jack 12 is connected so that telegraph signals may be applied across the operating winding of the relay in the direction to oppose and overcome the effect of the biasing winding of the relay. The biasing winding is connected through resistor 13 to battery conductor 14, over which current is supplied from grounded battery 16. The armature of relay 11 is connected to ground and is operable between the contacts 17 and 18.

For convenience in describing the system, the armature is shown engaging the contact 17, and all other circuit conditions correspond thereto. This is the condition of relay 11 when responding to a marking impulse and although a source of telegraph signals has not been shown applied to jack 12, it is to be assumed that relay 11 is responding to a marking impulse. Relay contact 17 is connected to one end of the operating winding of a polarized relay 19, the other end of which is connected through resistor 21 and battery conductor 14 to grounded battery 16. The operating winding of polarized relay 19 thus is energized to oppose and overcome the biasing winding, one end of which is connected through resistor 20 to battery conductor 14 and the other end of which is connected through resistor 22 to ground.

The armature of polarized relay 19 is connected to battery conductor 14 and thus to battery 16 and is operable between contacts 23 and 24. The contact 23 which the armature of relay 19 engages when the operating winding of the relay is energized is connected through resistor 26 to one side of an oscillatory circuit which consists essentially of the inductance 27 and condenser 28 in parallel. The branch of the oscillatory circuit which contains the inductance 27 includes in series with the inductance the secondary winding of a feedback transformer 29 and resistors 31 and 32. The oscillatory circuit also includes potential divider resistors 33 and 34 in series across the condenser 28. The terminal of condenser 28 which is connected to the resistors 32 and 34 is connected to ground, whereby two paths for current through the armature of relay 19 and resistor 26 are provided, one extending through inductance 27, the secondary of transformer 29, resistors 31 and 32 to ground, and the other extending through resistors 33 and 34 to ground. Current through this network causes condenser 28 to become charged to the potential difference across the resistors 33 and 34 in series. The point of interconnection of the secondary of transformer 29 and the resistor 31 is connected to grid 36 and the point of interconnection of resistors 33 and 34 is connected to grid 37 of a twin triode amplifier tube 38 which is provided with the usual indirectly heated cathode 39.

The resistors 33 and 34 are of such value that when the receipt of a start signal permits the circuit to oscillate, the total resistance across said resistors causes the condenser voltage to be in quadrature with the voltage developed across resistors 31 and 32. That part of the voltage across condenser 28 which is represented by the potential difference across resistor 34 is applied to grid 37 of tube 38 and the potential difference across resistors 31 and 32 is applied to grid 36 of the tube. Thus the voltages of grids 36 and 37 are in quadrature.

Plate 41 of tube 38 which is controlled by grid 36 is connected to the vertical deflecting plate 42 of a cathode ray tube 43 and plate 44 of the tube 38, which is controlled by grid 37 is connected to the horizontal deflecting plate 46 of cathode ray tube 43. Plate potential for the plates 41 and 44 of tube 38 is obtained from high voltage conductor 47 of full wave rectifier tube 48 through potentiometers 49 and 51, respectively, at the high potential end of a voltage divider which consists of the paralleled potentiometers 49 and 51 in series with resistors 52, 53, 54 and 56, the latter of which represents the low potential end of the potential divider and has its free end connected to ground. High potential conductor 47 of the rectifier includes a filter consisting of the inductance 57 and condensers 58 and 59. Positive potential is applied from potentiometers 49 and 51 to plates 41 and 44, respectively, through the load resistors 61 and 62, respectively.

The contact 24 of polarized relay 19 is connected through resistors 63 and 64 to ground. One end of the biasing winding of a polarized relay 67 is connected through resistor 64 to ground and the other end is connected through resistor 66 to battery conductor 14. The operating winding of polarized relay 67 has one end connected to battery conductor 14 through resistor 68 and the other end of the winding is connected to back contact 69 of relay 67 and to one side of condenser 71 the other side of which is connected through resistor 72 to ground. The armature of relay 67, which is operable between contact 69 and a front contact 73 is connected to ground. From this it will be apparent that the operating winding of relay 67 may become energized through its armature and contact 73 or through a charging current for condenser 71.

The contact 73 of relay 67 is connected directly to the ground side of the biasing winding of relay 19. When the armature of relay 67 engages contact 73, the ground connection for the biasing winding of relay 19 supplied through resistor 22 is short-circuited and the biasing winding of relay 19 is connected directly to ground, whereby the current through that winding is increased. The increase is sufficient to give the biasing winding sole control over relay 19 so that its armature will be maintained in engagement with the contact 24 and will not be moved during subsequent energization of the operating winding of relay 19.

As previously stated, the voltages applied to grids 36 and 37 of amplifier tube 38 by the oscillatory circuit, the principal components of which are the condenser 28 and inductance 27, are in quadrature. The resistors associated with the oscillatory circuit are so proportioned that the voltages in quadrature phase are equal in amplitude. These voltages are amplified by the tube 38 and are applied to one each of the horizontal and vertical deflecting plates 46 and 42, respectively, of cathode ray tube 43. Other capacitances such as the condensers 74, 75 and 76, may be connected in parallel with the condenser 28 selectively by means of the keys 77, 78 and 79, respectively, to change the frequency of oscillation of the oscillatory circuit.

The resistor 31 previously identified as being in the circuit of grid 53 of amplifier tube 29, is in the form of a potentiometer and its slider 81 is connected to the grid 83 of a feedback amplifier tube 86 which may be a triode tube having an indirectly heated cathode 87. The plate 88 of tube 86 is connected to one end of the primary winding of transformer 29, the other end of which is connected by conductor 92 to the plate voltage conductor 47. A condenser 93 is connected across the primary winding of feedback transformer 29, and the function of the condenser 93 is to adjust the phase of the current in the feedback circuit which includes the plate of tube 86, so that it will be in phase with the current in the oscillatory circuit comprising the inductance 27 and the condensers 28, 74, 75 and 76 or whatever number of those condensers are connected in a parallel, so that the current fed back into the oscillatory circuit will be in phase with the current locally generated in the oscillatory circuit. The secondary of feedback transformer 27 being in series with inductance 27 in the oscillatory circuit, the currents traversing the primary winding of feedback transformer 27 are impressed upon the oscillatory circuit which feeds the grids 36 and 37 of amplifier tube 38.

In addition to the electrodes 42 and 46 the cathode ray tube 43 has two other electrodes 94 and 96 for controlling the deflection of the electron beam and the electrodes 94 and 96 are connected to the low potential side of a half wave rectifier which includes tube 97. The cathode ray tube also has an electrode 106 by which the intensity of the electron beam is controlled. This electrode is connected through conductor 108 and blocking condenser 107 to one side of condenser 111 and to one end of resistor 109, the other end of which is connected to ground. The other side of condenser 111 is connected to one end of the winding of a retardation coil 112. The other end of the winding of retardation coil 112 is connected to one terminal of a half wave copper-oxide rectifier 113 and the other terminal of the rectifier is connected to the right-hand stationary springs 114 and 116 of single and double keys 117 and 118, respectively. The half wave rectifier 113 is sometimes called a varistor due to the fact that it readily passes direct current in one direction and greatly retards passage of direct current in the other direction. Thus it may be considered as having the characteristics of a variable resistor offering low resistance to the passage of current in one direction and extremely high resistance to the passage of current in the other direction.

The key 117 is a single-pole double-throw key, the swinger 119 of which is biased to engage the left-hand stationary spring 121. Swinger 119 is connected to the contact 18 of polarized relay 11 through resistor 122 and the left-hand stationary spring 121 is connected through resistor 123 to battery conductor 14. Stationary spring 121 is also connected to the left-hand swinger spring 126 of key 118 which is a double-throw key. The stationary spring 127 with which swinger 126 cooperates and into engagement with which the swinger 126 is normally biased, is connected to swinger 119 of key 117 and thus through resistor 122 to contact 18 of polarized relay 11. The right-hand swinger spring 128 of key 118 is connected to the point of interconnection of the operating winding of relay 19 and the resistor 21.

A power supply for the cathode ray tube 43 comprises a transformer 131, the primary winding of which is connected to a source of alternating current 132, the rectifier tube 97 connected across the high voltage secondary winding of transformer 131 as a half wave rectifier, potentiometers 133 and 134 connected between the plates of rectifier tube 97 and the high voltage winding of transformer 131 for supplying the proper biasing voltages to the intensity control electrode 106 and focussing electrode of the cathode ray tube, and filter condensers 136 for filtering out the alternating components of the output of rectifier tube 97. The transformer 131 also supplies current for operating the rectifier 48 and the cathode heaters of amplifier tubes 38 and 86 of cathode ray tube 43.

The control exercised over the cathode ray tube 43 by the system hereinbefore described affects the intensity of the beam of electrons and the deflection of that beam. The intensity of the beam is controlled by the control grid 106. The deflection of the beam is controlled jointly by the pair of horizontal deflecting plates 46 and 96 and the pair of vertical deflecting plates 42 and 94. For the purposes of the description of the operation of the system, it will first be assumed that a rest impulse which is a steady marking condition is applied through the jack 12 to the operating winding of polarized relay 11. It will also be assumed that neither of the keys 117 and 118 is operated and therefore that they remain in the condition shown in Fig. 1.

With operating winding of polarized relay 11 energized, the effect of the biasing winding is overcome and the armature of the relay is held in engagement with the back contact 17. Thus ground is connected through contact 17 and through the operating winding of polarized relay 19, through resistor 21 to grounded battery 16, whereby the operating winding of polarized relay 19 overcomes the effect of the biasing winding and the armature is held in engagement with back contact 23. Since battery 16 is connected to the armature of polarized relay 19, positive battery is connected to the armature and through contact 23 and resistor 26 to the oscillatory circuit consisting essentially of the inductance 27 and as many of the condensers 28, 74, 75 and 76 as are connected into the circuit by having their keys 77, 78 and 79 closed. The flow of current is from grounded battery 16 through the armature of polarized relay 19, contact 23, resistors 26, 33 and 34 to ground, and through inductance 27, secondary of transformer 29, and resistors 31 and 32 to ground. The flow of current maintains a charge on the condensers at least one of which, having the reference numeral 28, is permanently connected in the oscillatory circuit. The potential difference across the resistor 34 due to the flow of current therethrough provides a biasing voltage for the grid 37 of amplifier tube 38, and the flow of plate current through load resistor 62 of plate 44 provides a steady potential of low value across the horizontal deflecting plates 46 and 96 of cathode ray tube 43 with plate 46 slightly negative with respect to plate 96. Since current also flows through inductance 27, secondary of transformer 29, and resistors 31 and 32 to ground, the potential difference across resistors 31 and 32 establishes a biasing potential for the grid 36 of amplifier tube 38 at a certain level above ground and this bias is preferably of a relatively high value so that considerable plate current flows through the load resistor 61 of plate 41 and affords a high negative potential upon the vertical deflector plate 42 of cathode ray tube 43 with reference to the potential of deflector plate 94 which is connected to the junction of resistors 52 and 53. In actual practice, the potential difference between horizontal deflecting plates 46 and 96 is very low so as to deflect the electron beam in the cathode ray tube 43 horizontally only to an insignificant extent and the potential difference between vertical deflecting plates 42 and 94 is sufficiently high to deflect the beam beyond the limits of the screen of the cathode ray tube. Thus the beam is deflected almost vertically and its point of impingement is outside the limits of the screen.

The polarized relay 67 has its operating winding energized by current from grounded battery 16 through resistor 68, operating winding of relay 67, back contact 69 of the relay and armature to ground. The biasing winding of polarized relay 67 is also energized from battery 16 through resistor 66, biasing winding of the relay and resistor 64 to ground, and the biasing winding overcomes operating winding and holds the armature on contact 69.

Upon the transmission of a start-stop permutation code signal combination through jack 12, the start impulse, which is of spacing nature, cuts off the current through the operating winding of relay 11, in the case of current-no-current signals, or reverses the current through that winding, in the case of polar signals. When polar signals are received, the biasing winding is left open and is not used. In either case the armature of polarized relay 11 moves out of engagement with contact 17 and into engagement with contact 18. Thus the circuit of the operating winding of polarized relay 19 is interrupted and the armature of that relay moves out of engagement with contact 23 and into engagement with contact 24. Battery is thus removed from the oscillatory circuit and is connected through contact 24 and through resistor 63 and resistor 64 to ground. The resistor 63 is thus placed in parallel with the resistor 66 and the biasing winding of relay 67 between grounded battery 16 and resistor 64. The resistance value of resistor 63 is relatively low as compared with the combined resistance of resistor 66 and biasing winding of relay 67 in series, so that a part of the current through resistor 66 is diverted through resistor 63 and the current through the biasing winding of relay 67 is materially reduced. The operating winding of relay 67 thus assumes control of the armature and moves the armature into engagement with the front contact 73. As the armature moves out of engagement with contact 69, ground is disconnected from the operating winding of relay 67 but that winding continues to be energized for an interval, due to a charging current for condenser 71 flowing from grounded battery 16 through resistor 68, operating winding of polarized relay 67, condenser 71 and resistor 72 to ground. When the armature of polarized relay 67 has moved into engagement with the front contact 73, ground is connected through the armature and contact 73 directly to the biasing winding of polarized relay 19, short-circuiting the resistor 22 through which the biasing winding of relay 19 previously received energizing current. The current through the biasing winding of relay 19 is thus increased to such a value that the operating winding of relay 19 cannot move the armature of that relay into engagement with contact 23 as long as the armature of relay 67 remains in engagement with contact 73.

The removal of battery from the oscillatory circuit due to movement of the armature of polarized relay 19 out of engagement with contact 23 permits inductance 27 and the condenser or condensers included in the oscillatory circuit to set up oscillations. Since the grids 36 and 37 of amplifier tube 38 are connected respectively to the inductive and capacitative branches of the oscillatory circuit, biasing voltages are applied to the grids in accordance with the oscillatory current. The plates 41 and 44 controlled respectively by the grids 36 and 37 of amplifier tube 38 are connected to the vertical and horizontal beam deflecting plates, respectively, of cathode ray tube 43 so that potentials are applied to the plates 42 and 46 corresponding to the oscillatory current. The combination of resistors in the oscillatory circuit is such as to apply to the vertical deflecting plate, a voltage which is in quadrature with and equal in magnitude to the potential applied to the horizontal deflecting plate. The constants of the oscillatory circuit are such that the circuit oscillates at an integral number of cycles, one or more, per impulse of the incoming permutation code signal. As long as the armature of polarized relay 19 remains out of engagement with the contact 23, no energy from battery 16 is put into the oscillatory circuit and therefore the energy within the circuit decreases steadily and logarithmically as oscillation continues. The result of these conditions of the oscillatory circuit is that the electron beam traces on the screen of the cathode ray tube 43 a logarithmic spiral at the rate of one or more complete revolutions per impulse of the incoming signal.

Since the potentiometer resistor 31 and the secondary of feedback transformer 29 are connected in the oscillatory circuit, oscillatory current flows in this circuit. The slider 81 of potentiometer resistor 31 takes off a part of the voltage through the potentiometer 31 and applies it to the grid of amplifier tube 86. Plate current results in the plate circuit of amplifier tube 86 and this current is oscillatory in accordance with the oscillating potential derived by the slider 81 of potentiometer 31. Since the primary of feedback transformer 29 is included in the plate circuit of amplifier tube 86, the transformer feeds oscillatory energy into its secondary winding and thus into the oscillatory circuit through the resistors 31 and 32 and through the inductance 27. The condenser 93 which shunts the primary winding of feedback transformer 91 adjusts the phase of the oscillatory current fed into the secondary circuit of transformer 29 so that the current delivered to the oscillatory circuit by amplifier tube 86 is in phase with the original oscillatory current in the oscillatory circuit. Thus the feedback circuit acts as a negative resistance and lowers the decrement of the oscillatory circuit. In practice the gain of the feedback circuit is so adjusted as to compensate for the difference between the direct current resistance of the inductive branch of the oscillatory circuit and its resistive component at the frequency of oscillation.

In Fig. 2 the solid line represents the oscillatory voltage applied between the vertical deflecting plates 42 and 94 and the broken line represents the oscillatory voltage applied between the horizontal deflecting plates 46 and 96. It will be noted that as previously stated, the voltage which controls horizontal deflection of the electron beam leads the voltage which controls vertical deflection of the beam by 90 degrees. It will also be noted that the magnitude of the oscillatory voltages diminishes logarithmically throughout the interval allotted to a complete start-stop permutation code signal combination.

In Fig. 4 the broken line indicates the path of the electron beam produced by the voltages derived from the sweep circuit, which includes the oscillatory circuit, the deflection voltage amplifier and the feedback amplifier. As previously stated the electron beam path, which is indicated by the broken line, is in the form of a logarithmic spiral, each convolution of which is completed in the interval allotted to one impulse of a permutation code combination. It will be noted that there are six full convolutions and a fraction of a seventh, which represent the start impulse, the five code impulses and the stop impulse. The starting point of the beam is located outside the screen of the tube in order that the transition from marking condition of the stop impulse to spacing condition of the start impulse shall not produce a visible spot on the screen. After a part of the convolution representing the stop impulse has been traced, the electron beam is returned to the initial position by means and in a manner which will now be described.

The values of condenser 71 and resistors 72 and 68 are so chosen that the charging current for condenser 71 which effected the completion of the travel of the armature of polarized relay 67 from contact 69 to contact 73 and which holds the armature in that position, decreases to the value of the current through the biasing winding of the relay by the time the middle of the stop impulse of the received permutation code signal has been reached. Further decrease of the charging current for condenser 71 decreases the control of the operating winding of the relay over its armature and permits the biasing winding to assume control, whereupon the armature is returned to engagement with contact 69. At this time the armature of polarized relay 11, which has been following the permutation code signal to control the intensity of the electron beam in a manner which will be described later, has returned to engagement with contact 17 as a result of the energization of the operating winding of relay 11 by the stop impulse. The restoration of the armature of polarized relay 67 to engagement with contact 69 results in the reduction of current in the biasing winding of polarized relay 19 due to removal of the shunt around resistor 22 and the energized operating winding of relay 19 restores its armature to engagement with contact 23. Thus battery is applied to the oscillatory circuit, battery current again flows through resistors 31, 32, 33 and 34, the inductance 27 and the transformer winding, and the condenser 28 and any others of the condensers 74, 75 and 76 that are connected in parallel with condenser 28 are restored to fully charged condition. Oscillation in the oscillatory circuit is thus terminated and the resistor 26 is of such value that the currents and voltages of the oscillatory circuit are caused to return to their steady state in a critically damped manner so that the system will be restored rapidly to the initial condition, applying to the horizontal and vertical electron beam deflecting plates 46 and 42, the potentials which they had at the beginning of the signal, whereby the electron beam is restored to its initial position at the top and outside limits of the screen of the cathode ray tube, which is represented by the solid line circuit in Fig. 4. The damping is such that the beam will be restored to initial position in one impulse interval, whereas the discharging time during which the beam is rotated is as long as a full code combination interval.

It will be apparent from the foregoing description that the path traversed by the electron beam of the cathode ray tube 43 is the same for all signal combinations received and is entirely independent of the combinations of marking and spacing impulses which make up the signal. The tracing of the path by the electron beam is initiated by the start impulse of a received permutation code signal combination and thereafter the path is derived solely from the operation of the oscillatory circuit. The composition of the signals is utilized for controlling the intensity of the electron beam and it is the control of the intensity of the beam that causes it to become visible upon the screen of the cathode ray tube 43. Normally the control grid 106 is biased negatively to a sufficient extent that the beam would not be visible upon the screen even if tracing a path within the area of the screen, it being remembered that when the polarized relay 11 is responsive to a steady marking condition not representing a group of impulses of a start-stop code signal combination, the beam is deflected outside the limits of the screen. The point of impingement of the electron beam upon the screen is rendered visible by making the control grid 106 more positive and is restored to invisibility by reducing the potential on the control grid.

Potentials for rendering the control grid 106 more positive and therefore rendering the point of impingement of the electron beam upon the screen of cathode ray tube 43 visible are applied through the contacts 114 or 116 of the keys 117 and 118, respectively, and through half wave rectifier 113, retardation coil 112 and condensers 111 and 107. The positive impulses for rendering the point of impingement of the electron beam visible are produced in response to transitions from marking to spacing or spacing to marking condition of the polarized receiving relay 11, and the key 118 is arranged to permit observation of transitions from marking to spacing condition whereas the key 117 is arranged to permit observation of transitions from spacing to marking. It will first be assumed that key 118 is operated, moving its contact tongue 128 into engagement with contact spring 116 and contact spring 126 out of engagement with spring 127, and that key 117 remains unoperated. With the armature of polarized relay 11 in engagement with contact 17 in response to a marking signal, current will flow through the previously described energizing circuit of polarized relay 19 which includes the resistor 21. The resistance value of the operating winding of relay 19 is a small fraction of the resistance value of resistor 21 so that the potential difference across the operating winding of relay 19 causes the spring 128 of key 118 to be at a potential slightly above ground potential. This potential is supplied through half wave rectifier 113 and inductance 112 to condenser 111, and is not sufficient to raise the potential of control grid 106 of the cathode ray tube to a value that will render the electron beam visible. When polarized relay 11 responds to a spacing signal and the armature of the relay is moved out of engagement with contact 17, the circuit of the operating winding of relay 19 is interrupted and therefore current ceases to flow through resistor 21. When the armature of relay 11 engages contact 18, current flows from battery 16 through battery conductor 14, resistor 123, springs 121 and 119 of key 117, resistor 122, contact 18 of relay 11 and armature of that relay to ground. The resistance value of resistor 123 is the same as that of resistor 21 and the resistance value of resistor 122 is the same as that of the operating winding of relay 19, so that a steady drain on battery 16 is maintained regardless of which of the contacts 17 and 18 the armature of relay 11 engages. The flow of current through the substitute resistors 122 and 123 has no present effect other than to maintain a steady potential difference across battery 16 regardless of whether the receiving relay 11 is responding to a marking or spacing condition. The interruption of the circuit of the operating winding of relay 19 and resulting cessation of current through resistor 21 reduces to or near zero the potential difference across this resistor. Accordingly, the full potential of the battery is applied through springs 128 and 116 of key 118 and through half wave rectifier 113 and retardation coil 112 to condenser 111. Condenser 111 thus becomes charged, the charging current returning to ground through resistor 109, and the positive potential is applied to the control grid 106 of the cathode ray tube 43 through condenser 107 to increase the intensity of the electron beam to a value which will render its point of impingement upon the screen of the tube visible. The relative values of the retardation coil 112, condenser 111 and resistor 109 are so chosen that the circuit is very nearly critically damped. The potential therefore rises very rapidly, becomes nearly constant for a short interval and falls to zero with rapidity almost equal to the rise, thus producing a sharply defined spot on the screen. This pulse is in the direction in which the half wave rectifier 113 is connected to accommodate a flow of current and hence the rectifier presents low impedance to the charging current for the condenser 111.

When the receiving relay 11 again responds to a marking impulse and moves its armature into engagement with contact 17, current flows through the operating winding of relay 19 and through resistor 21, and the potential applied to the upper terminal of the half wave rectifier 113, drops to the former value only slightly above ground. The potential across condenser 111 at this instant is considerably in excess of the potential applied to the upper terminal of the half wave rectifier and accordingly the condenser seeks to discharge. The discharging current is in the reverse direction and therefore a negative potential is again applied to the control grid 106 of the cathode ray tube 43 to render the point of impingement of the electron beam upon the screen of the tube invisible. The half wave rectifier 113 offers high impedance to the flow of the discharge current in the opposite direction and therefore the flow of discharging current is prolonged over an extended interval as compared with the interval during which condenser 111 became charged. The prolongation of the discharging interval prevents chattering of the contacts of polarized relay 11, which might occur incident to movement of the armature into engagement with the contact 17, from recharging condenser 111 during the discharging interval and thus prevents the production of unwanted visible spots upon the screen of the cathode ray tube. From the foregoing it will be apparent that with key 118 operated, a visible spot will appear on the screen of the cathode ray tube 43 in response to each transition from marking to spacing condition as the electron beam traces its invisible spiral path and that no visible spot will be produced in response to transitions from spacing to marking condition.

When it is desired to observe transitions from spacing to marking condition, key 118 is restored to unoperated condition and key 117 is operated, thus bringing its movable spring 119 into engagement with its stationary spring 114 to connect the right-hand end of resistor 122, the left-hand end of which is connected to contact 18 to the upper terminal of the half wave rectifier 113. Upon the restoration of key 118 to normal, the upper end of resistor 123 is connected to the right-hand end of resistor 122 through springs 126 and 127. With this circuit arrangement, when the armature of relay 11 moves from contact 17 to contact 18, and interrupts the energizing circuit of the operating winding of relay 19, it completes the circuit through resistors 123 and 122 whereby current flows through those resistors and since the resistance value of resistor 122 is a small fraction of that of resistor 123, the potential applied to the upper terminal of the half wave rectifier 113 through springs 119 and 114 of key 117 is only slightly above ground and the charging current for condenser 111 is insufficient to raise the potential of control grid 106 of the cathode ray tube to a value which will render the electron beam visible upon the screen. However, when a spacing signal causes the armature of relay 11 to move out of engagement with contact 18 and into engagement with contact 17, current will cease to flow through resistors 123 and 122 and the potential applied to the upper terminal of the half wave rectifier will be that of the positive end of battery 16 since there is no potential difference across resistor 123. Charging current for condenser 111 will therefore flow and the potential of control grid 106 will be raised to cause the point of impingement of the electron beam upon the screen of the tube to become visible. When, in response to the next spacing signal, the armature of relay 11 again engages contact 18, the potential of the upper terminal of the half wave rectifier will be reduced to a value near ground potential and condenser 111 will discharge slowly to reduce the potential of control grid 106 and render the beam invisible upon the screen of tube 34 regardless of subsequent chattering of the armature of relay 11 on contact 18.

It is possible to observe transitions from marking to spacing condition and from spacing to marking condition by placing both of the keys 117 and 118 in the operated condition. With this circuit arrangement the operating winding of polarized relay 19 and its companion resistor 122 are both connected to the upper terminal of the half wave rectifier 113, the former through the springs 116 and 128 of key 118 and the latter through springs 114 and 119 of key 117. Under these circumstances upon movement of the armature of relay 11 out of engagement with contact 17, the full potential of battery 16 is applied to the half wave rectifier through resistance 21. Charging current flows through condenser 111 and the potential of control grid 106 is momentarily raised to cause a visible spot on the screen of the tube. As soon as the armature of relay 11 engages contact 18, a circuit is completed from grounded battery 16 through battery conductor 14, resistor 21, springs 128 and 116 of key 118, springs 114 and 119 of key 117, resistor 122, armature of relay 11 to ground. From this it will be apparent that the charging of condenser 111 takes place only during the transition of the armature of relay 11 from contact 17 to contact 18 and that as soon as the armature engages contact 18, the upper terminal of the half wave rectifier is brought substantially to ground potential over the conductive path from grounded armature of relay 11 through resistor 122 and springs 119 and 114 of key 117.

The armature of relay 11, now being in engagement with contact 18, will be moved to engage contact 17 in response to the next marking impulse. As the armature leaves contact 18, current ceases to flow through resistor 122 and the full potential of battery 16 is again applied to the upper terminal of the half wave rectifier 113 through resistor 21 and through springs 128 and 116 of key 118. Condenser 111 again becomes charged and the control grid 106 of the cathode ray tube is momentarily rendered positive to cause a visible spot to appear on the screen of the tube. When armature of relay 11 engages contact 17, the energizing circuit for the operating winding of relay 19 is completed and the potential on the upper terminal of the half wave rectifier 113 applied through springs 128 and 116 of key 118 is reduced due to the flow of current through resistor 21 and the operating winding of relay 19. As in the case of the transition from marking to spacing, the charging of condenser 111 occurs only during the transit time of the armature, and during the reception of the impulse which caused the transit of the armature the condenser 111 discharges.

Due to the decrement of the oscillatory circuit, the electron beam enters the screen of the tube approximately half way through the start pulse. Thereafter each positive impulse on the intensity control electrode causes a spot of light to become visible on the screen of the cathode ray tube, the spot being simultaneous with a transition of the relay 11. If the signals are without bias or distortion, the visible spots representing transitions of the relay 11 will appear at the same relative point in each convolution of the sweep circuit spiral and the visible points will be aligned radially of the spiral at the point of zero bias or distortion. The alignment will be radial because the sweep circuit is so adjusted that the electron beam describes exactly one convolution of the spiral for each impulse of the code combination. The dots 146, 147, 148, 149 and 151 in Fig. 4 represent the transitions of an unbiased and undistorted signal having the characteristics of the signal shown in Fig. 3 and observed for transitions from marking to spacing and spacing to marking. It will be observed that there is no visible point between the points 148 and 149 to represent a transition to the fourth impulse of the code combination, since there is no transition in the code combination shown in Fig. 3, the third and fourth impulses being of marking nature.

Bias or distortion suffered by telegraph signals usually results from adverse line conditions and is evidenced by lengthening or shortening of certain or all of the impulses of a code combination. Lengthening of marking impulses is accompanied by shortening of spacing impulses and conversely lengthening of spacing impulses is accompanied by shortening of marking impulses of a code combination. Any such distortion of telegraph signals will cause the visible point representing a transition from one type of impulse to the other to deviate from a radial line on the screen of the cathode ray tube. If all marking impulses of a signal combination are equally distorted as in biased signals, the transitions from marking to spacing will be aligned along one radius and the transitions from spacing to marking will be aligned along another radius. If only one impulse of a code combination is distorted, a visible point representing its transition will be out of radial alignment with points representing the transitions of the remainder of the signal.

The 360 degrees of angle from the zero position represents the extent to which an impulse may be distorted before it disappears altogether and therefore represents a range of distortion from zero to 100 per cent. A screen of transparent material such as Celluloid having one hundred equally spaced radial lines may be placed in front of the screen of the cathode ray tube and the appearance of visible points on the tube observed in terms of percentage of distortion.

During the reception of telegraph signaling impulses affected by fortuitous distortion, the spots appear to jump or wander over substantial areas of the screen of the cathode ray tube. As an aid in observing maximum deviation or displacement of a spot from the reference position, a semicircular mask may be put over the screen in such manner that it obscures substantially all of the spots. The mask may then be adjusted so that only the spot having the farthest deviation from the reference point is visible at its edge. This enables the deviation of this particular spot to be readily observed on the scale.

In Fig. 3 the reference line 166 indicates the interval relative to the start-stop permutation code signal represented in Fig. 3 during which the armature of polarized relay 19 is held in engagement with the front contact 24, due to the application to the biasing winding of that relay of direct ground connection through the armature and contact 73 of polarized relay 67, rather than through the resistor 22. Reference line 167 indicates the interval during which the armature of relay 19 engages the back contact 23 and in this interval the relay 19 is responsive to control by the receiving relay 11.

In Fig. 4 the portion 168 of the broken line representing the trace of the electron beam of the cathode ray tube 34 indicates the path of the beam returning to normal or initial position following the reengagement of the armature of relay 19 with its left-hand contact 23, which occurs during but not in response to reception of the stop impulse at the end of the signal combination. In Fig. 2 the sharply rising solid line at the right of that figure and descending broken line represent the voltages applied to the vertical and horizontal deflecting plates, respectively of the cathode ray tube which cause the beam to trace the portion 168 at the end of its spiral path.

Instead of providing for travel of the beam in a path as indicated in Fig. 4, with the beginning of the path outside the limits of the screen and the terminus of the path near the center of the screen of the tube, the beginning of the path may be brought inside the screen by reducing the gain of the triodes comprising the tube 38 and the pitch of the spiral may be reduced to zero by so adjusting the potentiometer arm 81 as to increase the feedback obtained from the tube 86 through transformer 29. Then the path of the beam will be circular and the visible points produced by undistorted signals will appear at a single point rather than along a radius of the screen.

If the frequency of the oscillatory circuit is so adjusted that the electron beam makes two revolutions during each received impulse, the 360 degrees of the screen will represent 50 per cent of a pulse length. In this manner, by causing the beam to rotate two or more times during each received impulse, the scale representing small values of distortion may be greatly magnified.

Although a specific embodiment of the invention has been disclosed in the drawings and described in the foregoing specification, it is to be understood that the invention is not limited to such specific embodiment but is capable of modification, rearrangement and substitution of parts and elements without departing from the spirit of the invention and within the scope of the appended claims.

What is claimed is:

1. A start-stop telegraph signal distortion indicator having in combination a source of start-stop permutation code signals composed of im-

pulse transitions, means for receiving said signals, a cathode ray tube, oscillator means activated once per received permutation code combination of signals for causing the ray of said tube to travel in an arcuate path, means for normally maintaining the intensity of said ray at a level to render it invisible on the screen of said tube, and means for transiently increasing the intensity of said ray in response to the reception of an impulse transition to render said ray visible on the screen of the tube.

2. A start-stop telegraph signal distortion indicator having in combination a source of start-stop permutation code signals composed of impulse transitions, means for receiving said signals, a cathode ray tube, means activated once per received code combination of signals for causing the ray of said tube to travel unidirectionally in an arcuate path, means operable independently of received signals for terminating the travel of said ray at the end of a received signal combination, means for normally maintaining the intensity of said ray at a level to render it invisible on the screen of the tube, and means for transiently increasing the intensity of said ray in response to the reception of an impulse transition to render said ray visible on the screen of the tube.

3. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube, an oscillator circuit for applying to said cathode ray tube electron beam deflecting voltages of equal magnitude and in quadrature, means for connecting across said oscillator circuit a source of steady potential to produce a predetermined initial deflection of said electron beam, means controlled by said signal receiving means for disconnecting said source of potential from said oscillator circuit to permit said circuit to oscillate and apply decreasing oscillatory voltages to said cathode ray tube whereby to deflect said electron beam in a spiral path, and means controlled by said signal receiving means for increasing the intensity of said electron beam in response to signaling current transitions.

4. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube, a damped oscillatory circuit for applying to said tube diminishing voltages in quadrature and equal in magnitude for causing the electron beam in said tube to be deflected in a spiral path, means controlled by said signal receiving means for initiating oscillation of said oscillatory circuit, and means also controlled by the signal receiving means for increasing the intensity of said electron beam in response to signaling current transitions.

5. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube, a damped oscillatory circuit connected to said tube for applying thereto diminishing oscillatory voltages in quadrature and equal in magnitude for causing the electron beam in said tube to be deflected in a spiral path, means controlled by said signal receiving means for initiating oscillation of said oscillatory circuit, means operable independently of said signal receiving means for determining the interval during which oscillation continues, means for normally maintaining the intensity of the electron beam of said tube at a level to render it invisible on the screen of said tube, and means controlled by said signal receiving means for increasing the intensity of said beam in response to signaling current transitions to render said beam visible on said screen.

6. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube, a damped oscillatory circuit connected to said tube for applying thereto diminishing oscillatory voltages in quadrature and equal in magnitude at the rate of an integral number of cycles per normal telegraph signal impulse interval for causing the electron beam in said tube to be deflected in a spiral path, means controlled by said signal receiving means for initiating oscillation of said circuit, means operable independently of said signal receiving means for limiting oscillation of said circuit to an interval equal to that allotted to a telegraph signal code combination, means for normally maintaining the intensity of the electron beam of said tube at a level to render it invisible on the screen of said tube, and means controlled by said signal receiving means for transiently increasing the intensity of said beam in response to signaling current transitions to render said beam visible on said screen.

7. In a telegraph signal distortion indicator, means for receiving equal length permutation code telegraph signals composed of current transitions, a cathode ray tube, a damped oscillatory circuit connected to said tube for applying thereto diminishing oscillatory voltages in quadrature and equal in magnitude at the rate of one cycle per normal impulse of said code for causing the electron beam in said tube to be deflected in a spiral path, means controlled by said signal receiving means for initiating oscillation of said circuit, means operable during reception of a code combination but independently of said signal receiving means for limiting oscillation of said circuit to an interval equal to that allotted to a permutation code signal, means for normally maintaining the intensity of the electron beam at a level to render its point of impingement on the screen of the tube invisible, and means controlled by said signal receiving means for transiently increasing the intensity of said beam in response to signaling current transitions to render points of impingement of said beam with said screen visible at corresponding points in the convolutions of said spiral path for undistorted signaling impulses.

8. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube including electrical potential responsive means for controlling the intensity of the electron beam of said tube, means for normally applying a predetermined potential to said intensity controlling means, means controlled by said signal responsive means for increasing the potential applied to said intensity controlling means, and means connected between said potential increasing means and said intensity controlling means for nullifying the effect upon said intensity controlling means of chattering of said signal responsive means.

9. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube including electrical potential responsive means for controlling the intensity of the electron beam of said tube, means for normally applying a predetermined potential to said intensity controlling means, means controlled by said signal responsive means for increasing the potential applied to said intensity controlling means, and means offering

low resistance to the flow of electrical current in one direction and high resistance to the flow of electrical current in the opposite direction connected between said potential increasing means and said intensity controlling means for nullifying the effect upon said intensity controlling means of chattering of said signal responsive means.

10. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube including electrical potential responsive means for controlling the intensity of the electron beam of said tube, means for normally applying a predetermined potential to said intensity controlling means, means including electrical energy storing means controlled by said signal responsive means for increasing the potential applied to said intensity controlling means in response to signaling current transitions, and means associated with said electrical energy storing means for retarding the discharging of energy by said storing means to nullify the effect upon said intensity controlling means of chattering of said signal responsive means.

11. In a telegraph signal distortion indicator, means for receiving telegraph signals composed of current transitions, a cathode ray tube including electrical potential responsive means for controlling the intensity of the electron beam of said tube, means for normally applying a predetermined potential to said intensity controlling means, means including electrical energy storing means controlled by said signal responsive means for increasing the potential applied to said intensity controlling means, and half wave rectifier means connected in series with said electrical energy storing means for readily accommodating the flow of current to charge said energy storing means and for retarding the flow of current to discharge said energy storing means to nullify the effect upon said intensity controlling means of chattering of said signal responsive means.

12. In a telegraph signal distortion indicator, means for receiving signals composed of current transitions, including an element movable between two positions in response to current transitions, a cathode ray tube including electrical potential responsive means for controlling the intensity of the electron beam of said tube, means for normally applying a predetermined potential to said intensity controlling means, means for applying an increased potential to said intensity controlling means, means for causing said increased potential to be applied to said intensity controlling means upon movement of said element from one position to the other, and means for causing said increased potential to be applied to said intensity controlling means upon movement of said element from said other position to said one position.

13. In a telegraph signal distortion indicator, means including an element movable between two positions for receiving telegraph signals composed of current transitions, a cathode ray tube having means for controlling the intensity of the electron beam of said tube, a circuit for controlling said intensity controlling means, means controlled by said element for energizing said circuit, selectively operable means for causing said circuit to be energized from said energizing means upon transition of said element in one direction and to be deenergized upon the next transition of said element, and selectively operable means for causing said circuit to be energized from said energizing means upon transition of said element in the other direction and to be deenergized upon the next transition of said element.

14. In a telegraph signal distortion indicator, means for receiving permutation code telegraph signals composed of impulse transitions, a cathode ray tube, means for imparting to the ray of said tube a predetermined initial deflection, means activated once per received code combination of signals for causing the ray of said tube to travel unidirectionally in an arcuate path, means operable independently of received signals for terminating the travel of said ray at the end of a received signal combination, and means for critically damping said travel causing means to energization, whereby to cause said ray to be restored to said initial position in an interval equal to a small fraction of the interval of reception of a code combination.

15. In a telegraph signal distortion indicator, means for receiving permutation code telegraph signals composed of impulse transitions, a cathode ray tube, means for causing the ray of said tube to be deflected to a predetermined initial position, oscillator means activated once per received code combination of signals for causing the ray of said tube to travel unidirectionally in an arcuate path, means operable independently of received signals for terminating the travel of said ray at the end of received signal combination, and means for critically damping said oscillator means to energization, whereby to cause said ray to be restored to said initial position in an interval less than an impulse interval of a permutation code combination.

16. In a telegraph signal distortion indicator, means for receiving permutation code telegraph signals composed of impulse transitions, a cathode ray tube, means for causing the ray of said tube to be deflected to a predetermined initial position, oscillator means activated on per received code combination of signals for causing the ray of said tube to travel unidirectionally in an arcuate path, means operable independently of received signals for terminating the travel of said ray at the end of a received signal combination, and a resistor included in the energizing circuit of said oscillator means proportioned to damp said oscillator means critically to energization, whereby to cause said ray to be restored to said initial position in an interval less than an impulse interval of a permutation code signal combination.

17. In a telegraph signal distortion indicator, means for receiving permutation code telegraph signals composed of impulse transitions, a cathode ray tube, oscillator means activated once per received code combination of signals for causing the ray of said tube to travel unidirectionally in an arcuate path, means for damping said oscillator means critically to energizing current whereby to bring said ray to an initial position in an interval less than an impulse interval of a permutation code combination, means for prolonging the discharging of said oscillatory means for an interval longer than the interval occupied by a permutation code signal combination, and means for terminating the travel of said ray at the end of a received signal combination.

18. In a device for receiving equal length permutation code signals, a signal responsive relay, a second relay responsive to operation of said signal responsive relay, normally inactive oscillator means set in operation by said second relay and adjusted to oscillate at an integral number of

cycles per impulse interval of said signals, means controlled jointly by said signal responsive relay and said oscillator means for displaying signaling impulse transitions, a third relay operable under the control of said second relay for rendering said second relay unresponsive to said signal responsive relay, and means for limiting the operation of said third relay substantially to a permutation code signal interval.

19. In a device for receiving equal length permutation code signals, a signal responsive relay, a second relay responsive to operation of said signal responsive relay, normally inactive oscillator means set in operation by said second relay and adjusted to oscillate at an integral number of cycles per impulse interval of said signals, means controlled jointly by said signal responsive relay and said oscillator means for displaying signaling impulse transitions, a third relay operable under the control of said second relay for rendering said second relay unresponsive to said signal responsive relay, and means including a condenser to be charged by energizing current for said third relay for limiting the operation of said third relay substantially to a permutation code signal interval.

20. In a telegraph signal receiving device, a signal responsive relay, a second relay operable by said signal responsive relay, a third relay operable by said second relay for maintaining said second relay operated independently of control by said signal responsive relay, a normally inactive oscillator rendered active by said second relay, means associated with said third relay for predeterminedly limiting the interval during which said third relay remains operated, and a cathode ray tube controlled jointly by said oscillator and said signal responsive relay for registering signal responsive operation of said signal responsive relay.

21. In a telegraph signal receiving device, a signal responsive relay, a second relay operable by said signal responsive relay, a third relay operable by said second relay for maintaining said second relay operated independently of control by said signal responsive relay, said third relay having alternative energizing paths one of which normally short-circuits the other, means operated by said third relay for interrupting said one path whereby said other path becomes effective, means contained in said other path for predeterminedly limiting the interval during which said other path remains effective to maintain said third relay operated, and a cathode ray tube controlled jointly by said second relay and said signal responsive relay for registering signal responsive operation of said signal responsive relay.

22. In a telegraph signal receiving device, a signal responsive relay, a second relay operable by said signal responsive relay, a third relay operable by said second relay for maintaining said second relay operated independently of control by said signal responsive relay, said third relay having alternative energizing paths one of which normally short-circuits the other, means operated by said third relay for interrupting said one path whereby said other path becomes effective to maintain said third relay operated, a condenser contained in said other path for prolonging the operation of said third relay for a predetermined interval following the interruption of said one path, and a cathode ray tube controlled jointly by said second relay and said signal responsive relay for registering signal responsive operation of said signal responsive relay.

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