Aug. 18, 1936. P. T. FARNSWORTH 2,051,372

SCANNING AND SYNCHRONIZING SYSTEM

Original Filed July 14, 1931

Fig. 1.

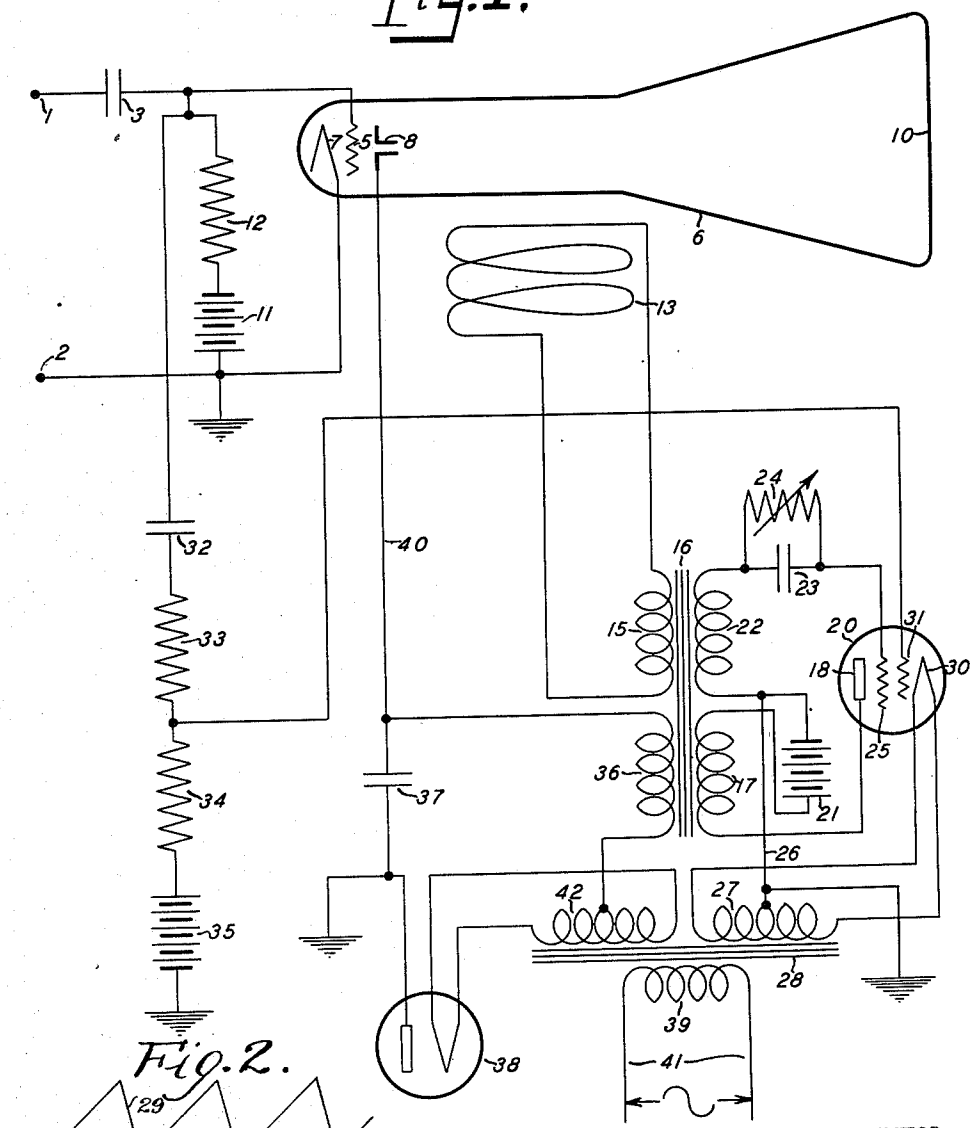
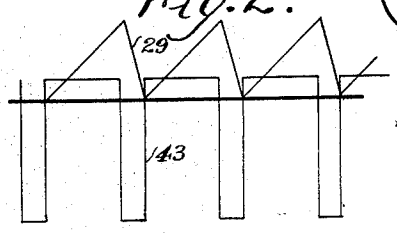


Fig. 2.



INVENTOR.
PHILO T. FARNSWORTH.
BY Donald K. Lippincott
ATTORNEY.

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SCANNING AND SYNCHRONIZING SYSTEM

Philo T. Farnsworth, San Francisco, Calif., assignor to Television Laboratories, Ltd., San Francisco, Calif., a corporation of California

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Renewed February 11, 1935

15 Claims. (Cl. 178—6)

My invention relates to systems for the electrical transmission of pictures, such as television, facsimile transmission, and the like, and particularly to such systems as use cathode ray apparatus for transmitting or receiving the picture or both.

Among the objects of my invention are: To provide an oscillator which will produce currents of saw-tooth wave form for deflecting a cathode ray beam in order to scan the picture; to provide a means of synchronizing an oscillator of the type described with a component of the received picture current; to provide a method of neutralizing or suppressing the effect upon the oscillator of picture current components having less than a predetermined magnitude, to prevent the tendency of the oscillator to fall into step with parts of the picture other than the predetermined scanning impulses, thus preventing distortion of the picture field; to provide a means of neutralizing the reaction between the oscillator and the picture circuit, which would cause distortion of the picture due to the locally generated oscillation; to provide a source of high voltage current for the cathode ray apparatus itself; and to provide such a source having no frequency components other than those of the transmitted picture, and which is readily filtered to produce a smooth, uniform current flow.

Referring to the drawing, Fig. 1 is a schematic diagram of the scanning and synchronizing system of this invention as applied to a receiving system such as is described in my copending applications, Serial Nos. 449,984, 500,092, and others.

Figure 2 comprises graphs showing the forms of the current and voltage waves supplied by the scanning oscillator.

In receiving apparatus of the type mentioned, for television images and the like, the reproducer comprises preferably an oscillight or cathode ray receiving tube having a control element or grid as well as the usual cathode and perforated anode for generating the beam of cathode rays, which impinges upon a fluorescent screen to trace the picture. The beam of cathode rays is deflected across the fluorescent screen by a suitable coil system, which is supplied with deflecting or scanning current by an oscillator, preferably an oscillator supplying a current having a saw-tooth wave form. This oscillator is held in step with the picture frequency by means of impulses impressed upon the grid or control element of the oscillight, to which the oscillator is connected by a suitable coupling system.

The system thus outlined has two weaknesses which may, under certain circumstances, cause difficulties. The first of these is a slight tendency for the locally generated oscillation to react upon the control electrodes, exerting thereon an undesired control which causes some distortion of the picture. The second, and more severe limitation, is a tendency of the oscillator to pull into step with powerful components of the picture current other than the impulses with which it is desired to synchronize. Furthermore, in order to obtain an oscillator capable of being synchronized in this manner, without rendering the above mentioned reaction upon the control electrode unduly great, it has in the past been necessary to provide an oscillating system comprising a plurality of tubes. In the system of the present invention, these difficulties are overcome.

Broadly considered, the invention comprises the combination with a cathode ray television apparatus, of an oscillator adapted to produce the saw-tooth current wave described above. This oscillator includes a tube having an additional or auxiliary control electrode, coupled to the grid of the oscillight tube, for impressing the synchronizing impulses upon the oscillator to hold the latter in step. Means are provided whereby impulses of normal picture amplitude, applied to the auxiliary electrode, are suppressed or neutralized, so that they have no effect upon the frequency of oscillation. Impulses exceeding a predetermined value, however, have a large effect, and serve to hold the oscillator in step with the synchronizing impulses of the picture current. The oscillator is provided with an additional winding which is connected to a rectifier circuit, charging a condenser. The current waves comprising the output of the oscillator have a rapid rate of change in one direction, and a slow rate of change in the other, and the corresponding voltages are alternately high and low. The rectifier is so arranged as to charge the condenser to the high voltage value. The condenser is connected with the anode of the oscillight so that the condenser discharge furnishes anode current for the tube. The synchronizing pulses applied to the grid of the oscillight are negative, and any reaction of the oscillator upon the oscillight is also negative. Any failure of the condenser completely to filter the discontinuous pulses from the oscillator results in increases in charge occurring simultaneously with the negative reaction upon the oscillight grid, and the result is a tendency to compensate for this reaction. Furthermore, since the pulses of scanning frequency are much more rapid than the ordinary

frequencies of commercial supply, the resultant rectified waves are much easier to filter and include no frequencies other than picture frequencies. For this reason distortions due to imperfect filtering are almost entirely eliminated, this being particularly noticeable in the absence of an appearance of waves on the picture field, and an increased steadiness of the picture. Moreover, the load of the rectifier circuit upon the oscillator offers a means of absorbing the energy stored in the oscillator coils during the positive portion of the oscillator cycle, and facilitates the production of the steep negative wave front, at the same time providing a source which delivers the anode current at the requisite high potential, while the reverse potential is low. This reduces the duty upon the rectifier.

The type of oscillator used for producing saw-tooth current waves preferably comprises a circuit which, in form, resembles the well known "Hartley" oscillator circuit. It differs from this circuit as ordinarily used, however, in several respects. The usual tuning condenser is omitted and the coupled grid and plate coils preferably comprise the windings of an iron core transformer having a step-up ratio between the plate coil and the grid coil, which therefore have different natural frequencies of oscillation. In series with the grid coil and the control electrode of the tube, is a condenser, bridged by a high resistance. The impedance of this combination is low in comparison with frequency of oscillation desired. The control electrode is operated without the normal bias. The inductance of the plate coil is so high that the impedance of the entire plate circuit, including the space path within the tube, is predominantly reactive. As a result, current flow through the tube is governed by the inductance of the transformer, and builds up only gradually. During this build-up period a positive potential is induced upon the control electrode, which accordingly draws electrons from the filament. Due to the low impedance of the condenser and bridging resistor, this has little effect on the grid potential until the grid and plate approach the same voltage, when the grid starts to rob current from the plate, decreasing the rate-of-change of current in the plate coil and suddenly throwing the grid highly negative and blocking current flow, after which the cycle repeats, to produce a current wave of the desired saw-tooth form.

The embodiment of my invention shown in the drawing is a modification of a portion of the device illustrated in my copending application, Serial No. 449,984, filed May 5, 1930, above mentioned. In Fig. 1, reference characters 1 and 2 indicate the output terminals of a suitable amplifier of television signals, these signals including powerful negative pulses of scanning frequency, as described in the application mentioned. Terminal 1 connects through a condenser 3 to the control electrode 5 of an oscillight or cathode ray receiver tube 6. Terminal 2 connects to the filament 7 of the oscillight. The anode 8, which is perforated to permit passage of a stream of electrons, is supplied with a high positive potential by means to be described later, and attracts electrons from the cathode. A portion of the electrons thus attracted pass through the opening in the anode, and are focused by means not shown to form a spot of light upon the fluorescent screen 10 of the oscillight. The intensity of this spot is controlled by the grid or control electrode 5, the latter being biased, in accordance with usual vacuum tube practice, by means of a battery or other source 11 through a grid leak or high resistance 12.

In order to cause the spot on the screen 10 to trace the picture thereon, the cathode ray beam is deflected magnetically by current, preferably of saw-tooth wave form, flowing in coils suitably disposed about the oscillight. Two sets of such coils are used to deflect the rays in two dimensions and at different frequencies, but in order to simplify the drawing only a single coil 13 is shown, the low or "picture frequency" scanning system being omitted. Coil 13 is supplied by the output or secondary winding 15 of an iron core transformer, which is indicated by the general reference characters 16. The transformer carries two windings which comprise the oscillator windings proper. Of these windings one is a plate coil 17, one terminal of which connects with the plate 18 of a vacuum tube 20. The other terminal of the plate coil connects, through a plate potential source 21, to the termiual of the grid coil 22 of the transformer, the other end of the grid coil being connected through a condenser 23, bridged by a resistor 24, with a grid or control electrode 25 of the tube. The low potential end of the grid coil connects through a lead 26 with the center tap on the winding 27 of a transformer 28 which supplies current for heating the filament 30 of the tube 20.

It will be seen that in the circuit diagram of the oscillator as thus described, there is a close resemblance to the well known Hartley oscillator circuit. The action of the circuit, however, differs markedly from that of the Hartley oscillator, and the circuit itself differentiates over the Hartley circuit in several important details. First, the usual tuning condenser, bridging both the plate and grid coils, is absent. Second, the windings 17 and 22 of the transformer are so proportioned that there is a material set-up ratio between the plate and grid coils, so that the potential on the grid coil is higher than the potential impressed across the plate coil. This difference in potential will, of course, vary with the amplification constant of the tube 20, but for a tube having an amplification constant of 4, a suitable step-up ratio is 1 to 2. Third, the condenser 23 and the variable grid leak 24 have very low impedance at the frequency of oscillation desired. Thus, in an oscillator operating at from 2,000 to 3,000 cycles per second, I have found that a suitable value of condenser is one-tenth microfarad while the adjustable grid leak 24 is variable from 2,500 to 10,000 ohms.

At the frequency mentioned, the reactance of the plate coil 17 is high in comparison with the resistance of the tube, and since there is a step-up ratio between the plate and the grid, the natural periods of oscillation of the two coils are entirely different.

The action of the oscillator is as follows: The circuit being closed, the potential of the plate battery 21 is impressed upon the plate circuit and current starts to flow. Since the plate circuit is largely inductive, this current increases only gradually, and the increasing current induces a positive charge upon the grid 25. This makes the effective resistance of the tube still smaller, so that the inductance of the plate coil is the predominating factor in determining the current flow, and the current continues to increase at a substantially uniform rate. The grid being positive, it attracts electrons from the space current of the tube, but owing to the large value

of the condenser 23 and the relatively low resistance 24, this current has a very small effect upon the bias of the tube, leaking off almost as fast as it reaches the grid. Practically the entire electron output of the filament is utilized toward the end of this phase of the oscillation.

As the current approaches saturation, the resistance of the winding 17 begins to cause a decrease in plate potential, and eventually the grid 25 and plate 18 approach the same potential. When this occurs, a sudden diversion of current takes place from the plate to the grid, which therefore begins to accumulate an effective negative bias. This causes a decrease in the rate of change of plate current, reducing the positive charge induced on the grid by the coil 22, which still further reduces the grid potential. The result is a rapidly cumulative effect which swings the grid highly negative in an extremely short interval of time, resulting in almost instant blocking of the plate current.

As soon as plate current has ceased to flow, the charge accumulated by the grid leaks off, the grid starts to swing positive again, and the cycle repeats. The oscillation thus comprises a gradual building up of currents in almost a straight line form, followed by a practically instantaneous stoppage of current, again in an almost straight line wave form. The period of oscillation, unlike that of the Hartley oscillator, which produces practically sinusoidal waves, is determined not by the natural frequency of the plate and grid coils, but by the potential of the battery 21, the inductance of the plate coil 17, and, primarily, by the resistance of the leak 24. Roughly, as long as the current leaks off as fast as it is received the current in the plate circuit continues to build up, but as soon as the flow to the grid materially exceeds the flow away therefrom the negative portion of the cycle starts. A low grid leak value therefore corresponds to a low frequency. As will be seen by the values given, for best operation, the impedance of the leak is not more than one order of magnitude greater than that of the condenser 23 at the fundamental frequency of the oscillator. Oscillation will occur if the condenser 23 be made smaller, but the wave form produced is less desirable, and the operation of the oscillator is much less stable. The form of the current wave generated by the oscillator is approximately as shown by curve 29 in Figure 2.

The tube 20 is preferably provided with an auxilliary control electrode 31, with control upon the space current of the same general character as that of the grid 25, but less complete. The electrode 31 is connected with the grid circuit of the oscillight through a large blocking condenser 32 and a resistor 33. The control electrode 31 is biased to a positive potential, through a resistor 34 by a battery or other source 35. In practice a battery of about 20 volts potential is used, and the resistances 33 and 34 are of about the same value, usually about 50,000 ohms.

It will be seen that since the grid 31 is positive it will draw current from the filament 30. This current, flowing through the resistor 34, causes a voltage drop, thus reducing the effective potential upon the auxiliary grid 31, so that in practice it may be of the order of +2 volts.

Although the grid 31 exercises the same type of control as the grid 25, it is preferably of much smaller dimension, and the magnitude of its control is much less than that of the main grid. Hence, as long as the auxiliary grid is positive, its effect upon the oscillation of the tube may be neglected.

During the cycle of increasing oscillator current the auxiliary grid is receiving picture impulses, which may be either positive or negative, through the condenser 32 and resistor 33. The effect of positive impulses is merely to increase slightly the positive charge on the grid 31, this increased positive charge being quickly neutralized by additional grid current, it being noted that as long as the grid 31 is positive the effective impedance of the tube to these impulses is relatively low. Negative impulses also have little effect, due to the low effective impedance of the tube, unless they are applied very suddenly and exceed the potential of the biasing battery 35. Under the latter conditions, the grid 31 becomes negative. The effective impedance of the circuit between grid 31 and filament 30 then suddenly becomes practicaly infinite, and the full effect of the negative charge impressed upon the picture circuit becomes active upon the grid. The result of this is to reduce the plate current flow in the oscillator tube, which starts the negative phase of the oscillator cycle. The oscillator thus stabilizes itself at a frequency corresponding to the negative synchronizing pulses in the picture currents, but is not affected by picture impulses of normal magnitude.

The action of the oscillator during the positive-grid phase, is to build up current gradually, storing magnetic energy in the inductive circuits, including the plate circuit of the oscillator and the deflecting circuit comprising the transformer coil 15 and deflecting coil 13. When the current flow is suddenly interrupted by the action of the grid, the energy stored in these circuits must find an outlet in some manner. This is provided for by an additional circuit comprising a winding 36 on the transformer 16, across which is connected a condenser 37 in series with a rectifier tube 38. The rectifier tube is connected to permit the passage of current during the fraction of the cycle corresponding to the interruption of current in the oscillator plate circuit. The steep wave front portion of the cycle corresponds to a short pulse of extremely high voltage, and the condenser 37, which is of relatively large capacity, charges to this high voltage. Discharge occurs through the lead 40, the anode 8 of the oscillight tube, the filament 7 of the tube, and the ground, back to the grounded side of the condenser 37. Since the anode current of the oscillight is very small it does not appreciably effect the charge of the condenser between the charging pulses, and the oscillator thus provides a substantially steady, unidirectional current, at high potential, for the oscillight. Moreover, the voltage pulses in the opposite direction are low, and the rectifier 38 need therefore handle only a relatively small inverse potential, which simplifies the problem of its insulation and tends toward long life for the rectifier tube.

The form of the voltage wave supplied to the rectifier, with its alternate short, high voltage pulses, and longer low voltage pulses, is shown in curve 43 of Figure 2.

Such light changes as do occur in the output potential of the condenser 37 are exactly opposite in phase with the reaction upon the grid of the oscillight tube received through the resistor 33 and condenser 32 from the oscillator. The result is a compensating effect as between the plate and grid potentials of the oscillight. Moreover, the reaction due to imperfect filtering of the anode

current is at picture frequency, and for this reason does not produce "waves" in the picture field which occur when an improperly filtered 60-cycle supply is used. This type of interference gives the picture field the appearance of a waving flag, and is one of the most difficult types of distortion to overcome in picture transmission.

Current for heating the cathodes of the oscillator tube 20 and the rectifier tube 38 is preferably derived from the usual power sources, which are represented in the present case by an alternating current line 41 feeding the primary 39 of the transformer 28. Besides the winding 27 which supplies the filament 30 of the oscillator tube, this transformer is preferably provided with a highly insulated winding 42, to the center of which the coil 36 is connected. A separate source of supply for the filament of the tube 38 may, of course, be provided if desired.

The circuits shown and described comprise the high frequency scanning system. Low frequency scanning may be accomplished by a similar oscillator, the grid condenser and leak whereof have a longer time constant, connected to the oscillight grid in a similar manner. Similarly, the same type of oscillator may be utilized to provide scanning and anode currents for a cathode ray transmitter tube, the method of this application being obvious from the present disclosure in connection with my copending application Serial No. 449,984 before referred to.

It should be noted also that as long as the scanning oscillator is in operation, the luminous spot is in continuous motion across the screen. This allows exceptionally heavy beam currents to be used, currents giving rise to a spot which if stationary would burn or destroy the screen material. As the anode supply for the cathode ray tube also comes from the oscillator, it is seen that the anode supply will fail when the scanning currents fail. Thus it is never possible to harm the screen material. It is also obvious that the scanning currents and anode excitation will continue regardless of interruption of the received signals, the oscillator falling into step with the scanning impulses when signals are resumed. The luminous screen is completely protected, and spots of extreme brilliancy can be safely employed.

I claim:

1. The combination with an apparatus for reproducing electrically transmitted pictures and a circuit for applying picture impulses to said apparatus, of an oscillator for generating scanning currents for said apparatus and comprising a vacuum tube having a control electrode, means for connecting said electrode with said picture circuit to synchronize said oscillator with a component of the picture frequency, and means for applying a positive bias of predetermined magnitude to said control electrode to suppress the effect on said oscillator of negative picture impulses of less absolute magnitude than the biasing potential.

2. The combination with an apparatus for reproducing electrically transmitted pictures and a circuit for applying picture impulses to said apparatus, of an oscillator for generating scanning currents for said apparatus and comprising a vacuum tube having a control electrode, a circuit including a high resistance connecting said control electrode with said picture circuit for synchronizing said oscillator with a component of said picture frequency, and means connected with said electrode for suppressing the effect on said oscillator of picture impulses having less than a predetermined magnitude.

3. The combination with an apparatus for reproducing electrically transmitted pictures and a circuit for applying picture impulses to said apparatus, of an oscillator for generating scanning currents of said apparatus and comprising a vacuum tube having a control electrode, a circuit including a high resistance connecting said control electrode with said picture circuit for synchronizing said oscillator with a component of said picture frequency, means for applying a positive bias to said control electrode, and a resistor in series with said biasing means for limiting the current flow in the biasing circuit.

4. The combination with an apparatus for reproducing electrically transmitted pictures and a circuit for applying picture impulses to said apparatus, of an oscillator for generating scanning frequencies comprising a vacuum tube having a main control electrode connected in an oscillating circuit and an auxiliary control electrode, coupling means linking said auxiliary electrode with said picture circuit for sychronizing said oscillator with a picture frequency component, and means connected with said auxiliary electrode for neutralizing the controlling effect on said oscillator of picture impulses of less than a predetermined magnitude.

5. The combination with an apparatus for reproducing electrically transmitted pictures and a circuit for applying picture impulses to said apparatus, of an oscillator for generating scanning frequencies comprising a vacuum tube having a main control electrode connected in an oscillating circuit and an auxiliary control electrode, a high resistance connecting said picture circuit and said auxiliary electrode, and a high resistance biasing circuit including means for maintaining a positive bias on said auxiliary electrode.

6. The combination with a cathode ray reproducer of electrically transmitted pictures and a circuit for applying picture impulses thereto, of an oscillator for producing scanning currents for said reproducer, means for synchronizing said oscillator with a component of said picture impulses, and a rectifier circuit coupled to said oscillator and deriving energy therefrom for supplying unidirectional potential to said reproducer.

7. The method of providing anode current for television reproducing apparatus and the like which includes the steps of generating a scanning current of saw-tooth wave form, rectifying a portion of said current, and utilizing said rectified current to supply the anode of said apparatus.

8. The method of providing anode current for television reproducing apparatus and the like which includes the steps of generating a scanning current of saw-tooth wave form, rectifying a portion of the half-cycle of said scanning current having the greater rate of increase to provide said anode current at high potential.

9. The combination with a cathode ray reproducer of electrically transmitted pictures or the like, of a deflecting coil, an oscillator for producing saw-tooth current waves in said coil, a winding coupled to said oscillator, a rectifier in series with said winding, a condenser connected across said winding to be charged by the impulses passed by said rectifier, and means for supplying current from said condenser to energize the anode of said reproducer.

10. A scanning and synchronizing system comprising a cathode ray tube for television pictures or the like, a deflecting coil associated with said tube to cause the cathode rays to scan the picture field, and an oscillator provided with a plurality of output circuits, one of said circuits including said deflecting coil and another including means for energizing the anode of said tube, whereby such irregularities as may occur in the energization of said tube are in consonance with the scanning frequency.

11. The method of operating a cathode ray image reproducer including an anode which comprises generating a current of saw-tooth waveform, rectifying a portion of the half cycle of said scanning current having the greater rate of increase to provide current at high potential for said anode, and utilizing the remainder of said current to deflect the cathode ray beam.

12. The method of operating a cathode ray reproducer which comprises generating an alternating current, utilizing a portion of the current to move the cathode ray beam, rectifying a portion of the current cycle, and utilizing the rectified current to energize the anode of said reproducer at high potential.

13. The method of operating a cathode ray reproducer which comprises generating an asymmetrical alternating current, utilizing a portion of the current to move the cathode ray beam, rectifying and filtering a portion of the current cycle, and utilizing the rectified current to energize the anode of said reproducer at a constant high potential.

14. The method of actuating a cathode ray image reproducer which comprises moving the beam thereof by the influence of an inductive circuit, building up a current gradually in said circuit to store magnetic energy therein, suddenly interrupting said current and utilizing the magnetic energy released by said interruption to energize the anode of said reproducer.

15. In combination with a cathode ray reproducer of electrically transmitted pictures and a circuit for applying picture impulses thereto, of an oscillator for generating scanning frequencies comprising a thermionic tube having a space current control circuit and a power circuit connected thereto, means for coupling said circuits to produce sustained oscillation of said tube, means for withdrawing a scanning current for said reproducer from said coupled circuits, means for additionally controlling the space current of said tube in accordance with a picture frequency component, and means for neutralizing the controlling effect created by picture impulses having less than a predetermined magnitude.

PHILO T. FARNSWORTH.