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FACSIMILE RECORDING APPARATUS

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FIG. 1

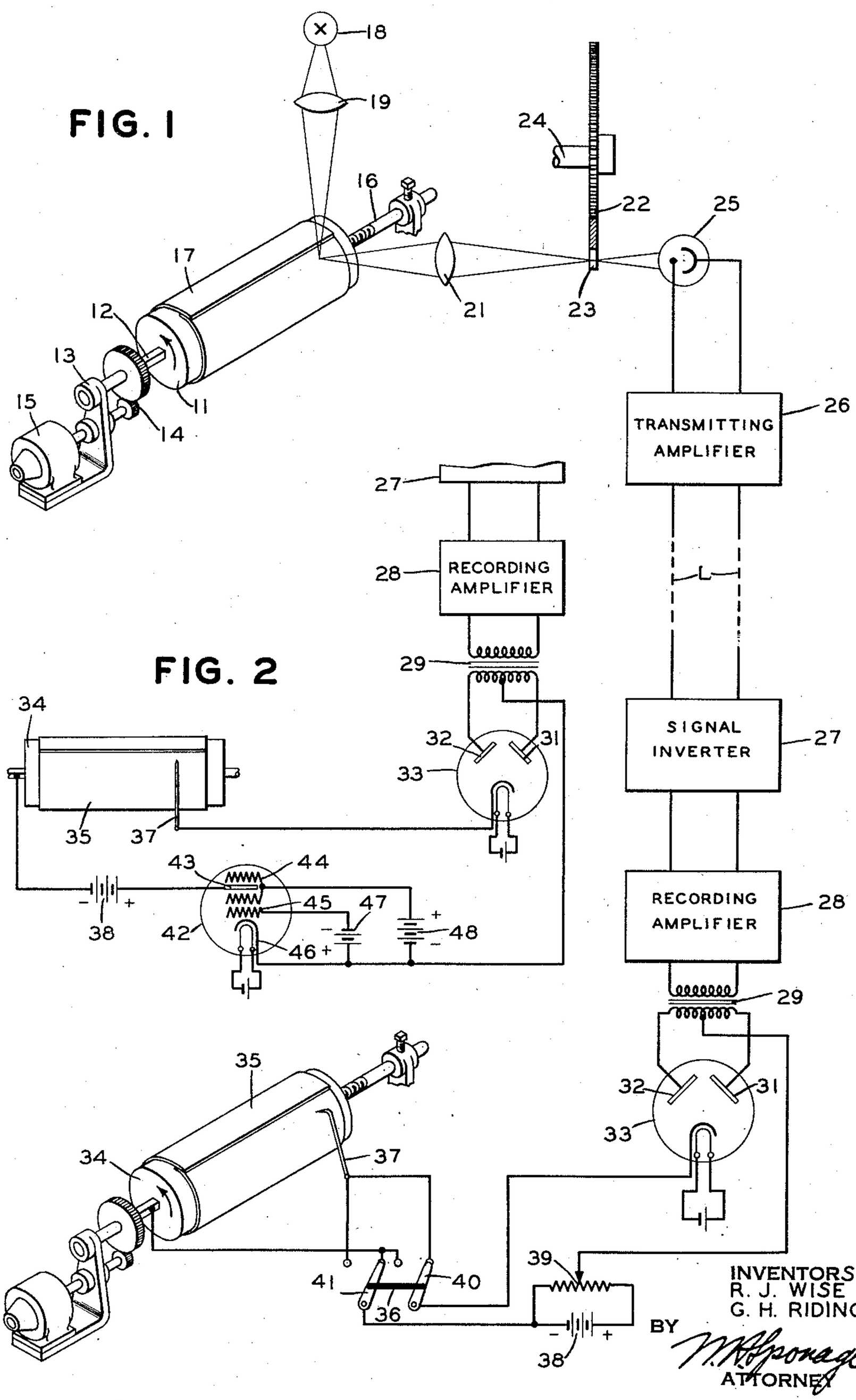

FIG. 2

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FACSIMILE RECORDING APPARATUS

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This invention relates to facsimile telegraph recording systems and has particular reference to systems employing recording instrumentalities having non-linear response characteristics.

In order to make accurate reproductions of pictures or other subject matter having tonal densities varying from white to black, it is first necessary to generate signals representative of the entire range of tonal densities. The present day systems are equipped to generate such signals but they necessarily vary between rather wide limits. However, most facsimile recording systems are not equipped to make accurate reproductions from such signals for the reason that they include one or more instrumentalities which are non-linear in their responses to signals covering a substantially wide range. These instrumentalities are capable of responding in a substantially linear manner to signals covering a somewhat narrower band. The signals which lie beyond the limits of this band are not translated into marks on the recording medium in strict accordance with the signals, thereby resulting in reproductions which are not accurate at the extreme parts of the band of tonal densities of the original picture or other subject matter. Consequently, the usual practice is to contract the signal band to the point where it will lie within the range of linear response of the recording medium. The result of such practice is a loss in the fine distinction between tonal densities differing very slightly from one another but which are essential for the accurate reproduction of the original subject matter.

The dry recording media in common use require that a substantial potential be impressed across the surfaces of the media before a mark is produced. Consequently, when the facsimile signals alone are applied to the recording medium, some part of all of the signals is employed to produce the initial striking voltage. Hence, weak signals which are generated to represent comparatively light elemental areas of the subject matter being transmitted are frequently ineffective to mark the recording medium. Obviously, such a condition results in an inaccurate reproduction of the subject matter.

It is therefore a major object of the instant invention to provide improved recording means whereby a picture or other subject matter may be more accurately reproduced by electrical recording apparatus.

Another object of the invention is to provide means for utilizing substantially the entire signal range for purposes of marking the recording medium.

Still another object of the invention is to provide means for expanding the marking range of a recording medium having a non-linear response characteristic in order to utilize a wide band of signals.

A further object of the invention is to provide a bias for the recording apparatus to compensate for inherent impedance characteristics of the recording medium.

Still another object of the present invention is to provide a variable impedance to compensate for the non-linear impedance characteristic of the recording medium employed in apparatus for electrically reproducing pictures or other subject matter.

Another object of the invention is to provide an impedance variable in one sense under the control of the facsimile signals to compensate for the impedance of a recording medium which varies with the strength of the facsimile signals in the opposite sense whereby the total impedance of the recording circuit is at all times maintained at a constant value.

The invention is disclosed in two forms and will be described in connection with the accompanying drawing, of which:

Fig. 1 illustrates schematically the circuit arrangements whereby a fixed bias is employed in the recording apparatus; and

Fig. 2 is a modification showing an arrangement for varying the value of an impedance used in conjunction with a bias in the recording circuit under the control of the facsimile signals.

In its preferred form the invention is embodied in a system in which the received signals representing pictures or other subject matter are applied to the anodes of a rectifier which, together with its cathode, are connected in circuit with a dry recording medium and a cooperating scanning electrode. A biasing potential is also included in this circuit and in one form of the invention is fixed at some predetermined value and in the other form illustrated is used in series with a variable impedance which may be an electronic device separately biased to provide the desired impedance variation under the control of the received signals.

Having reference first to Fig. 1 of the drawing, there is shown a facsimile transmitter employing means for optically scanning a picture and for generating facsimile signals representative thereof. This apparatus comprises a rotatable copyholder or cylinder 11 slidably supported

by a driving shaft 12 which is journaled in a suitable manner in a bearing 13 forming a part of the transmitter framework and driven through a set of reduction gears 14 by a motor 15. The cylinder 11 is adapted to move axially along a threaded shaft 16 as it is rotated by the shaft 12. The picture or subject matter 17 to be scanned is mounted in a suitable manner upon the cylinder 11. Scanning of the subject matter is accomplished by means of a light spot which is derived from a source of light 18. Light rays emanating from the source are condensed by means of a lens 19 so that a small scanning spot is incident upon the surface of the subject matter to be scanned. The light reflected from the surface of the sheet 17 varies in intensity in accordance with the tonal densities of the picture. The reflected light is focused by means of a condensing lens 21 so that the rays converge at a point in the plane of a rotatable shutter or light chopper 22. The light chopper may take any one of a variety of forms such as the one illustrated herein which is a disc having formed in the periphery thereof a series of notches 23 whereby, upon rotation of the disc by means of a suitably driven shaft 24, the light beam is alternately intercepted and allowed to fall upon the light sensitive electrode of a photoelectric cell 25. In this manner alternating current signals having variable amplitudes in accordance with the tonal densities of elemental areas of the scanned subject matter are generated. Obviously other methods of generating amplitude modulated alternating current signals may be employed and, since the transmitter forms no part of the present invention, it is not contemplated that the invention be limited to use with any particular type of transmitter such as that illustrated.

The facsimile signals generated in a manner such as that described are amplified by a transmitting amplifier 26 and transmitted over the line conductors L to a receiving station. Inasmuch as the signals generated in the manner described, if applied directly to electrical recording apparatus, will produce a negative copy of the scanned subject matter, it is necessary to invert the signals by means of a signal inverter 27, if a positive copy is desired. After inversion, the signals are amplified by a recording amplifier 28, the output circuit of which is connected to the primary winding of a transformer 29.

The inverted and amplified facsimile signals impressed upon the primary winding of a transformer 29 are reproduced by induction in the secondary winding thereof. The terminals of the secondary winding are connected to the anodes 31 and 32 of a full wave rectifier tube 33. The midpoint of the secondary winding of the transformer 29 and the cathode of the rectifier tube 33 are connected to recording apparatus similar in construction and operation to that employed at the transmitting station and described hereinbefore. The chief difference between the transmitting and recording machines is that at the recorder a scanning electrode or stylus is used instead of the optical scanning system of the transmitter. The rotatable cylinder 34 serves to support a sheet 35 of electro-sensitive recording material capable of color changes by the passage therethrough of electrical currents.

The recording apparatus includes a double-pole double-throw switch 36 by means of which the polarity of the recording stylus 37 with respect to the cylinder 34 may be reversed for a purpose and in a manner which will be described later. The recording apparatus also includes a source of direct current potential 38 which is shunted by the resistance element of a potentiometer 39. The positive cathode of the rectifier tube 33 is connected through the switch blade 40 and its right hand contact to the stylus 37. The midpoint of the secondary winding of the transformer 29 is connected in series with a portion of the resistance element of the potentiometer 39 through the switch blade 41 and its right hand contact to the cylinder 34.

A suitable portion of the potential of the source 38 is applied by means of the potentiometer 39 across the anodes 31 and 32 of the rectifier tube 33 and the cylinder 34 of the recording apparatus. When no facsimile signals are being received, the recording circuit is influenced only by the fixed biasing voltage derived from the source 38. As soon as facsimile signals are transmitted from the transmitting apparatus, they are rectified by the rectifier tube 33, thereby producing unidirectional undulations corresponding to the modulated alternating current transmitted. The potentials of the unidirectional undulations are added to the biasing potential and are applied by means of the stylus 37 to the recording sheet 35. The value of the biasing potential is selected to be equal to or slightly less than the striking voltage required to produce a mark on the sheet 35. Thus, it is seen that, when the voltage impressed upon the recording sheet is increased slightly as by means of a weak facsimile signal, a mark is produced in response thereto and has a tonal density substantially equal to the tonal density of the elemental area of the picture 17 which is scanned at the transmitting station to generate the signal. Consequently, for recording purposes, the rectified facsimile signals produce marks of varying densities on the recording medium 35 which bear approximately the same ratio to one another within the working range as the ratio of the facsimile signals.

It has been found that with some types of recording media optimum results are obtained by applying the facsimile signals thereto in such a manner that the stylus is of a positive polarity with respect to the copyholder, while with other types of recording media optimum results are obtained with the stylus negative with respect to the copyholder. In the system just described the stylus 37 is at all times positive with respect to the copyholder 34. When it is desired to reverse this polarity the switch 36 is moved to the left. The recording circuit then may be traced from the secondary winding of the transformer 29 through the anode-to-cathode path of the rectifier 33, the switch blade 40 and its left hand contact, the copyholder 34, the recording medium 35, the stylus 37, the left hand contact and switch blade 41, and the potentiometer 39, returning to the transformer secondary winding. Thus, it may be seen that the stylus 37 is at a negative potential with respect to the copyholder 34.

In the system described, the biasing potential furnished by the source 38 is introduced into the recording circuit by means of the potentiometer 39 which has an impedance characteristic which is substantially constant for all values of the recording voltages Because of the nature of the medium used for recording, the response characteristic thereof deviates appreciably from a straight line for various values of recording potentials. In most of the dry recording media in use at the present time, the response character-

istic follows a curve which is generally concave downward when the densities of the marks produced are plotted as ordinates against the values of recording voltage as abscissae. The result of such a characteristic is that a saturation point is reached beyond which increases in the value of the recording potential produce substantially no increases in the densities of the marks made upon the recording medium. In systems using such a recording medium care must be taken to choose the working range well below the saturation point so that variations in strength of the recording signals produces approximate variations in the densities of the marks made. At best such systems will not produce accurate reproductions for the reason that the response characteristic below the saturation point is non-linear. The system disclosed in Fig. 2 is designed to improve the record produced upon such a recording medium. To this end there is included in the recording circuit an element having a response characteristic which is variable for variations in the recording signals in a sense opposite to the variable response characteristic of the recording medium. A suitable element of this character is an electronic device having a fixed grid-to-cathode potential and having the anode-to-cathode space discharge path connected in series with the circuit of the recording signals.

The recording circuit and as much of the receiving station apparatus as is necessary to correlate Fig. 2 with Fig. 1 is illustrated in the former figure, like reference characters designating similar apparatus in the two figures. The recording circuit includes an electronic device **42**, which is preferably a tetrode, having an anode **43**, a screen grid **44**, a control grid **45** and a cathode **46**. The anode to cathode space discharge path of the tube **42** is connected in series with the recording circuit, which also includes a source of biasing potential **38**. The positive electrode of this battery is connected to the anode **43** and thus serves to furnish a portion of the space current. A battery **47** is connected between the control grid **45** and the cathode **46** of the tube **42** in the manner shown. Another battery **48** is connected between the screen grid **44** and the cathode **46** of the tube.

By properly choosing the values of the batteries **38**, **47** and **48**, the tube **42** may be made to function with substantially any desired impedance characteristic. Thus, the impedance introduced into the recording circuit by means of the vacuum tube **42** may be caused to vary with the strength of the facsimile signals in the same ratio but in the opposite sense to the variations in the impedance of the recording medium **35**. The result of such an arrangement is a recording circuit having a substantially constant impedance throughout the entire arrangement of facsimile signals. Consequently, the recording current is at all times proportional to the potential of the facsimile signals appearing in the secondary winding of the transformer **29**. It is apparent then that the densities of the marks recorded upon the medium **35** are substantially proportional to the facsimile signals. Thus, within the marking range the facsimile signals are employed to make accurate reproductions in which the same relation between the shading of one part of the picture or other subject matter bears the same relation to the shading of another part as in the original picture.

Furthermore, the working range may be increased beyond the present limits by the use of the instant invention so that the saturation point, if any, occurs well beyond the signal range necessary to secure faithful reproductions of the pictures or other subject matter. It should be apparent that the modification of Fig. 2 may be arranged to produce the useful results of the apparatus of Fig. 1 in addition to those already described. To one skilled in the art it is a relatively simple matter to adjust the values of the various fixed sources of potential so that, in the absence of facsimile signals, the voltage impressed between the surfaces of the recording medium **35** is just under the potential necessary to mark the medium.

Also, the potential of the stylus **37** with respect to the copyholder **34** may be reversed by means of a switch similar to the switch **36** of Fig. 1, connected as shown in this figure, between the cathode of the rectifier tube **33** and the source of biasing potential **38**, and the recording apparatus.

The form of the invention illustrated in Fig. 2 shows the vacuum tube **42** as a tetrode. This type of tube is preferred for the reason that it is more susceptible to adjustments for the purpose described than a tube of the triode type. However, fairly satisfactory results may be obtained by the use of a triode so that it is not contemplated that the invention be limited to the use of the specific type of tube illustrated.

In addition to the more accurate reproductions which may be made, the invention makes it easier to design other parts of the recording apparatus. For example, the transformer **29** may be fabricated with precision and accurately matched in impedance to the remainder of the recording apparatus. Heretofore it has not been possible to effect this desirable result for the reason that the impedance of the recording circuit varied appreciably with variations in the signal strength.

The nature of the invention may be ascertained from the foregoing disclosure, the scope thereof being defined in the appended claims.

What is claimed is:

1. A facsimile telegraph system comprising, means for generating alternating current facsimile signals modulated in amplitude in accordance with the tonal densities of elemental areas of a picture, a communication channel over which said generated signals are transmitted, facsimile recording apparatus connected to said channel comprising, means for converting said alternating current signals into unidirectional undulations corresponding to said modulations, a recording medium capable of color changes by the application thereto of electrical potentials, said recording medium having a non-linear response characteristic due to its impedance varying with variations of the applied electrical potentials, a current controlling element having a non-linear current controlling characteristic due to its impedance varying oppositely to that of said recording medium with variations of applied electrical potentials, and means including said current controlling element for impressing upon said medium said unidirectional undulations modified sufficiently to neutralize the non-linear response characteristic of said medium.

2. In a facsimile telegraph recording system a source of amplitude modulated alternating current voltage representative of the tonal densities of elemental areas of a picture, a rectifier, means including said rectifier for converting said alternating current voltage into unidirectional un-

dulations corresponding to said modulations, a record sheet capable of color changes by the passage therethrough of electrical currents, said record sheet having a non-linear response characteristic due to its variable impedance, a scanning electrode cooperating with said record sheet, means including said electrode for impressing said unidirectional undulations upon said record sheet, a current limiting device having a non-linear current limiting characteristic due to its variable impedance, said latter impedance being variable oppositely to the variable impedance of said record sheet, and means including said current limiting element for modifying the unidirectional undulations sufficiently to counteract the non-linear response characteristic of said record sheet.

3. In a facsimile telegraph recording system, a source of amplitude modulated alternating current signals representative of elemental areas of a picture, a rectifier, means including said rectifier for translating said signals into unidirectional undulations corresponding to said modulations, a record sheet capable of color changes by the application thereto of electrical potentials in excess of a fixed minimum value, a source of direct current potential approximately equal to said minimum value, and means including a series connection of said rectifier, said recording medium and said source of biasing potential for recording said signals upon said medium.

4. In a facsimile telegraph recording system, a source of alternating current signals modulated in amplitude in accordance with elemental areas of a picture, a rectifier, means including said rectifier for converting said alternating current signals into unidirectional undulations, a record sheet capable of color changes by the passage therethrough of electrical currents, said sheet having a non-linear response characteristic due to the impedance thereof varying in one sense with variations of the applied voltage, a source of biasing potential, an impedance element variable in an opposite sense to that of said record sheet with variations of the voltage applied to the terminals of said impedance element, and means including said source of biasing potential and said variable impedance element for applying to said record sheet said undulations modified to produce a linear response by said record sheet.

5 In a facsimile telegraph recording system, a source of alternating current signals modulated in amplitude in accordance with elemental areas of a picture, a rectifier, means including said rectifier for converting said alternating current signals into unidirectional undulations, a record sheet capable of color changes by the passage therethrough of electrical currents, said sheet having a non-linear response characteristic due to the impedance thereof increasing with variations of the applied voltage, a source of biasing potential, an electronic device arranged to have an impedance decreasing with variations of the applied voltage, and means including said source of biasing potential and said electronic device for applying to said record sheet said undulations modified to produce a linear response by said record sheet.

6. In a facsimile telegraph recording system a source of alternating current signals modulated in amplitude in accordance with elemental areas of a picture, a rectifier, means including said rectifier for converting said alternating current signals into unidirectional undulations, a record sheet capable of color changes by the passage therethrough of electrical currents, said sheet having a non-linear response characteristic due to the impedance thereof varying in one sense with variations of the applied voltage, a source of biasing potential, an electronic device having a space discharge path and a control electrode, means to maintain a constant voltage on said control element suitable to impart to said space discharge path an impedance variable in an opposite sense to that of said record sheet with variations of the voltage applied to said space discharge path, and means including a series connection of said source of biasing potential and said variable impedance space discharge path for applying to said record sheet said undulations modified to produce a linear response by said record sheet.

7. In a facsimile recording system, a source of amplitude modulated alternating current signals representative of elemental areas of a picture, a rectifier, means including said rectifier for translating said signals into unidirectional undulations corresponding to said modulations, a recording device responsive to electrical potentials in excess of a fixed minimum value, a source of direct current potential approximately equal to said minimum value, and means including a series connection of said rectifier, said recording device and said source of biasing potential for operating said recording device in accordance with the picture signals.

8 In a facsimile recording system, a recording device responsive only to impressed voltages having a range substantially above zero, a rectifier, means including said rectifier for impressing upon said device a unidirectional voltage undulating in accordance with picture signals, said unidirectional voltage having at times a value less than the voltage necessary to produce a response by said recording device, and a source of constant voltage in series with said device and said rectifier for maintaining said device substantially at its lowest responsive voltage, said undulating unidirectional voltage being the sole electrical effect which produces a response by said recording device in accordance with received signals.

9. In a facsimile recording system, a source of unidirectional voltage undulating in accordance with the tonal densities of elemental areas of a picture, a recording device operable only in response to voltages having a range substantially above zero, a source of direct current voltage substantially equal to the lowest voltage to which said recording device is responsive, and means including a series connection of said source of direct current voltage, said recording device and said source of undulating unidirectional voltage for operating said recording device in accordance with said undulations.

10. In a facsimile system, a recording device responsive to current variations and having an impedance variable with variations of the applied voltage, a current controlling device having an impedance variable oppositely to the impedance of said recording device with variations of the applied voltage, said recording device and said current controlling device comprising a recording circuit having a substantially constant impedance throughout an appreciable range of voltage, and a source of voltage varying in accordance with tonal densities of a picture connected to said constant impedance recording circuit.

11. In a facsimile system, a recording device

responsive to undulating unidirectional currents and having an impedance variable with variations of the voltage applied thereto, a current limiting device having an impedance variable oppositely to the impedance of said recording device with variations of voltage applied thereto, said recording device and said current limiting device comprising a recording circuit having a substantially constant impedance throughout a wide range of voltage values, and a source of unidirectional voltage undulating in accordance with the tonal densities of a picture connected to said constant impedance recording circuit.

12. In a facsimile system, a record sheet capable of color changes by the passage therethrough of electrical currents and having an impedance variable with variations of a unidirectional voltage, a current limiting device having an impedance variable in the opposite sense to the impedance of said record sheet with variations of a unidirectional voltage, said record sheet and said current limiting device being connected in series to form a substantially constant impedance recording circuit, and a source of unidirectional voltage undulating in accordance with the tonal densities of elemental areas of a picture connected to the terminals of said constant impedance recording circuit.

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