Feb. 13, 1940. R. V. L. HARTLEY 2,189,898

SYSTEM OF COMMUNICATION

Original Filed Aug. 23, 1933 3 Sheets-Sheet 1

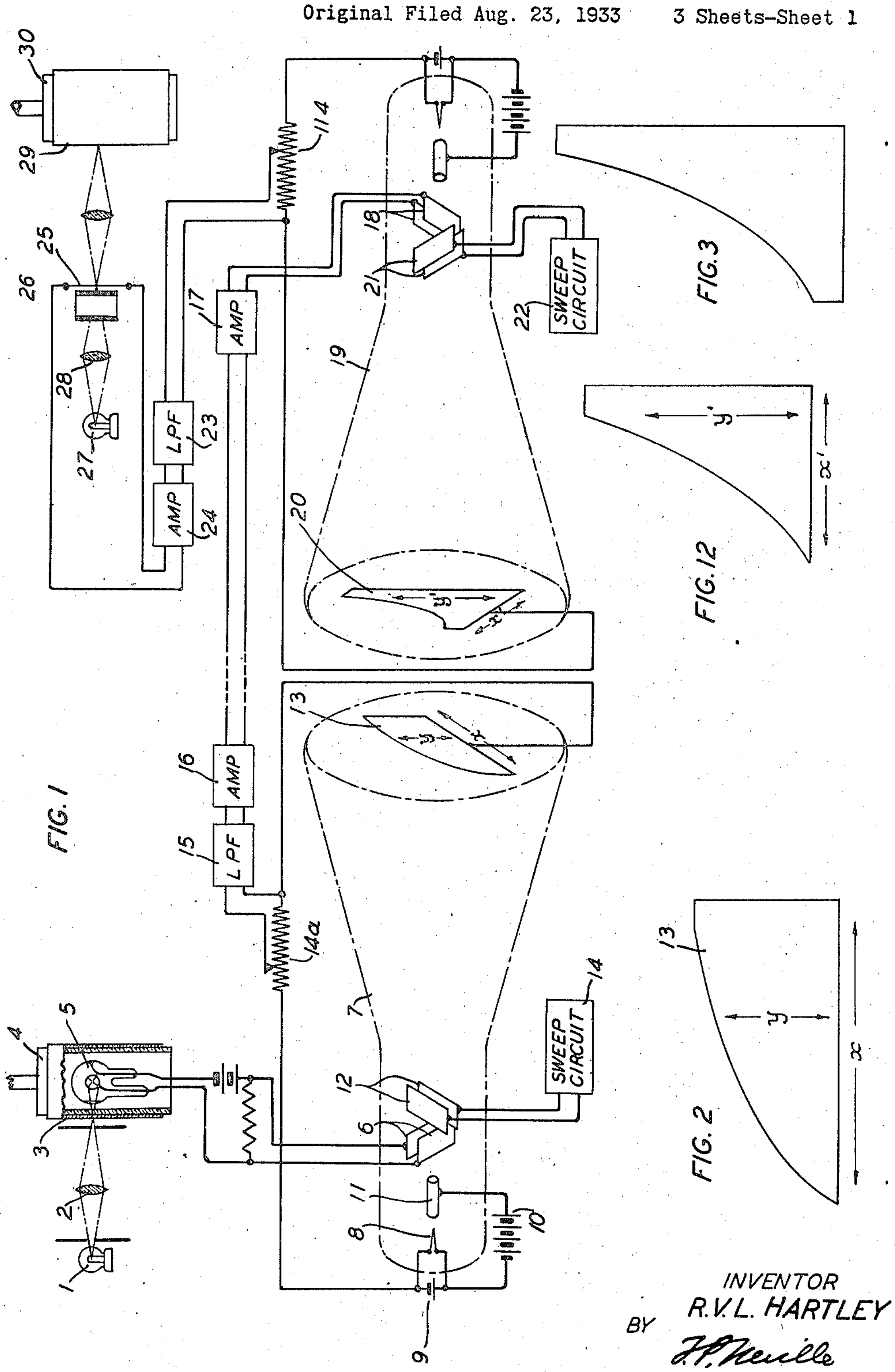

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FIG. 4

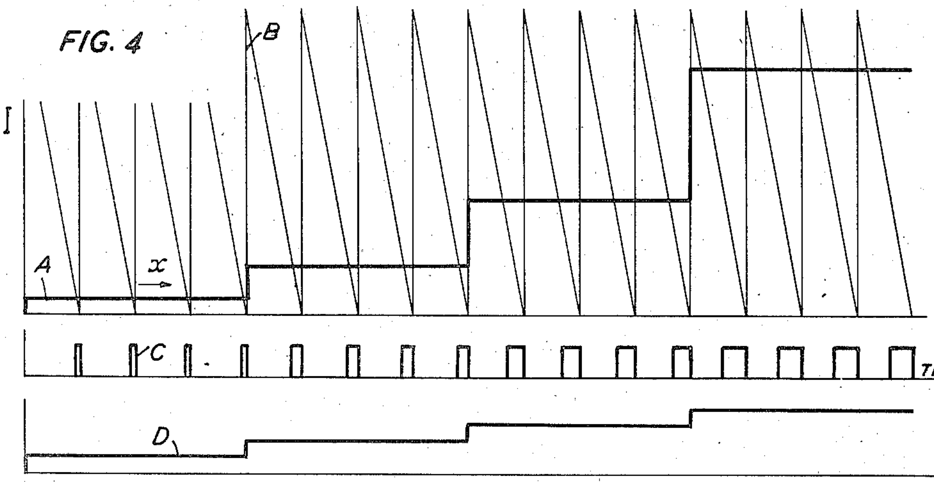


FIG. 6

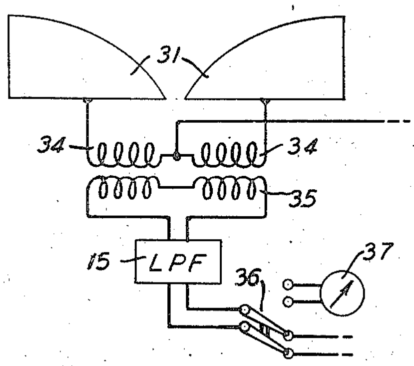


FIG. 7

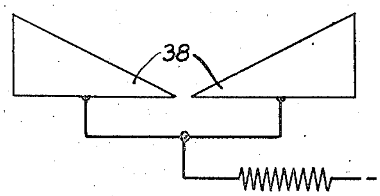


FIG. 8

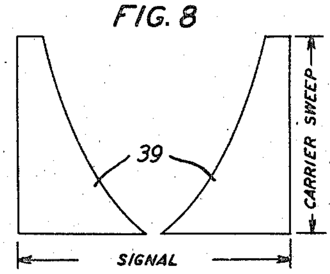


FIG. 5

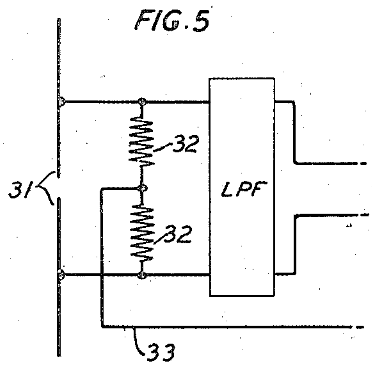
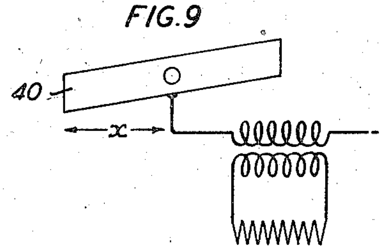


FIG. 9



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Feb. 13, 1940. R. V. L. HARTLEY 2,189,898

SYSTEM OF COMMUNICATION

Original Filed Aug. 23, 1933 3 Sheets-Sheet 3

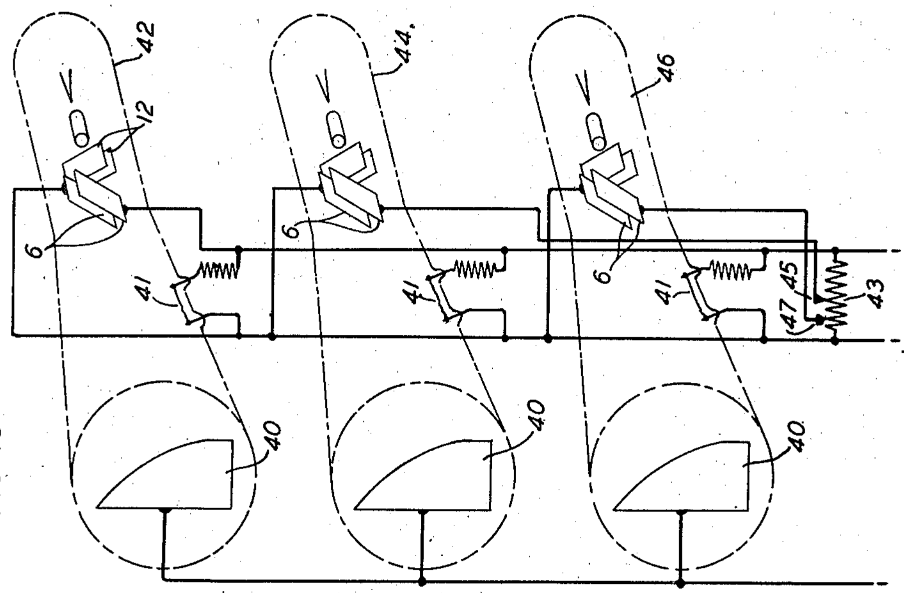

FIG. 10

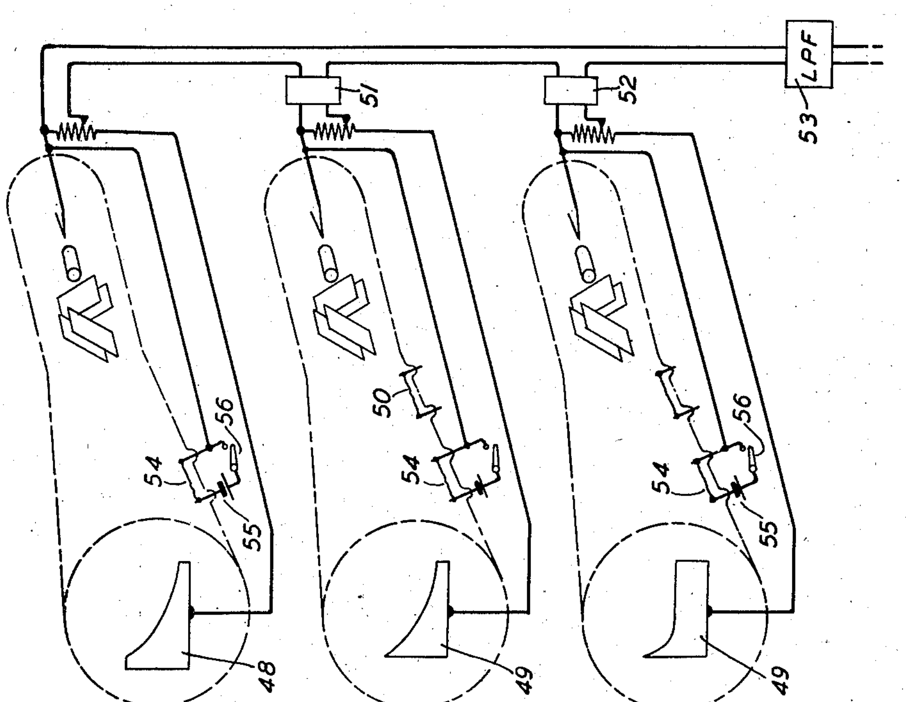

FIG. 11

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Patented Feb. 13, 1940

2,189,898

UNITED STATES PATENT OFFICE

2,189,898

SYSTEM OF COMMUNICATION

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Application August 23, 1933, Serial No. 686,348
Renewed May 3, 1939

29 Claims. (Cl. 178—7.7)

This invention relates to systems of communication and more particularly to a method of and means for effecting signal transmission at high efficiency and with a reduction in the effect of interfering currents.

It has heretofore been disclosed, in connection with systems for transmitting images, to provide electrical means for reducing the distorting effect of variations in the attenuation of a line. This disclosure also includes optical means for obtaining any desired functional relation between the instantaneous value of the current transmitted and the brightness of the corresponding elemental area of the subject scanned for transmission.

An object of the present invention is to provide electrical means for securing any desired functional relation between the instantaneous value of the current and light.

Another object is to provide a different type of electrical means from that disclosed in the above mentioned proposal which may be utilized to effect the result therein set forth as well as a variety of other desirable results.

In one embodiment of the invention, which may be used for transmitting pictures, image currents produced at the transmitting station are transformed into currents having instantaneous values which are logarithmically related to those of the image currents, by a cathode ray device provided with a conductive plate or anode connected to its cathode by an external path including a load circuit. The conductive plate or anode is so shaped that its vertical height varies as the logarithm of the horizontal distance across it. The image current is used to deflect the cathode beam horizontally across the plate, while a current supplied by a sweeping circuit, or a high frequency current, is used to deflect the cathode beam vertically across the plate to produce in the load circuit current impulses which are utilized to control the production of a current having instantaneous variations logarithmically related to those of the image currents.

The invention, in its aspect considered in the preceding paragraph, may be used by providing a plate or anode of the desired configuration, or any equivalent structure, to produce an output current having any desired non-linear relation with respect to the applied control voltage wave. Again by using a plurality of plates or anodes properly positioned with respect to the normal or rest position of the cathode beam and providing a corresponding number of the external load circuits connected together differentially, volume compression and expansion of speech or music may be secured, or a volume indicator may be provided. By connecting the external circuits directly together an alternating current wave may be rectified, with or without current transformation. Moreover, the apparatus may be designed so that separate currents may be combined to effect detection, or to cause the amplitude or phase of one current to be modulated in accordance with variations of the other current.

Other objects and aspects of the invention will be apparent from the following description.

A detail description of the invention follows and is illustrated in the attached drawings in which,

Fig. 1 diagrammatically illustrates a picture transmitting system which includes the invention;

Fig. 2 illustrates the plate used in the transmitting cathode ray tube of Fig. 1;

Fig. 3 illustrates the plate included in the receiving cathode ray tube of Fig. 1;

Fig. 4 illustrates curves which will be used to explain the operation of the system of Fig. 1;

Figs. 5 to 8 schematically show two plates for use in cathode ray tubes which may be used for a variety of purposes;

Fig. 9 illustrates the shape of a plate which may be used to effect modulation;

Figs. 10 and 11 illustrate schematically an arrangement which may be used when the range of signal voltage variations is wide; and

Fig. 12 shows a plate which may be used in the second and subsequent tubes of Fig. 11.

In picture transmission and television systems successive elemental areas of the picture or field of view are illuminated to cause the activation of light sensitive devices which produce an image current, the instantaneous values of which correspond to the varying tone values of successive elemental areas of the picture or field of view. When the light sensitive device is supplied with direct current, the current produced by its activation is unidirectional.

Fig. 1 diagrammatically illustrates a system for transmitting a picture or other representation. Light of constant intensity supplied by a source 1 is focussed by a lens 2 on a picture 3 mounted on a drum 4 which is given a motion of rotation and translation, in accordance with standard practice. Scanning of successive elemental areas of the picture is thereby effected in a manner disclosed, for example, in U. S. Patent 1,706,032, March 19, 1929, of M. B. Long, and the light passes through the picture to activate the light sensitive device, herein shown as a photoelectric cell 5, to cause the production of a picture current, the instantaneous value of which varies in accordance with the tone values of successive elemental areas of the picture.

The picture current is applied to one pair of deflecting plates 6 of a cathode ray tube 7. This tube comprises a cathode 8 adapted to be heated to emit electrons by a source 9 and connected by a circuit including a battery 10 to an anode 11, whereby a cathode ray beam is produced and is projected longitudinally of the tube, a second pair of deflecting plates 12, between which may be established an electric field at right angles to that produced between the plates 6 to which the picture current is applied, and a plate or anode 13 upon which the cathode beam is incident.

The plate or anode 13 is of conductive material and, as shown in Fig. 2, when viewed along the longitudinal axis of the tube, its vertical height y varies as the logarithm of the horizontal distance x across it. The picture current is applied to plates 6 to cause the cathode beam to move across the plate 13 in the direction indicated by the double headed arrow x and a current, supplied by a sweep circuit 14, causes the beam to traverse the plate 13 in a direction y, i. e., at right angles to the direction indicated by the arrow x. A suitable sweep circuit for the purposes of the invention is disclosed in U. S. Patent 1,613,954, January 11, 1927 of W. H. Knoop.

The plate 13 may occupy any position in a plane intersecting the longitudinal axis of the tube, provided the picture current causes the beam to move along a path parallel to its x edge and the current supplied by the sweep circuit causes the beam to move at right angles thereto and to be completely swept thereacross at a constant and relatively high rate compared with the rate of traversal produced by the picture current.

The cathode 8 and plate 13 are connected by a load circuit externally of the tube which includes a resistance 14a adapted to be connected to the input terminals of a low-pass filter 15 having a cut-off which is below the frequency of the deflections caused by the sweeping current. The output current supplied by the filter comprises a continuous wave, the instantaneous values of which are proportional to the logarithm of the voltage of the picture current applied to the plates 6. The sweep circuit may be replaced by a source supplying a current of frequency which is high compared with the highest frequency component of the picture current. If sinusoidal in form, the amplitude of the high frequency current should be such that the cathode ray beam is only in contact with the plate 13 during straight portions of the successive cycles of the high frequency sweep current.

The action of the apparatus so far described may be explained by reference to Fig. 4 in which the ordinates represent current and the abscissae represent time. To simplify the exposition, the following explanation will be based on the special case in which the subject or field of view to be transmitted varies in tone value between definite limits, for example, from black to white, and in which the difference in tone values of the elemental areas corresponds to the minimum difference in light intensity, used to illuminate the subject or field, that the eye is able to recognize.

Since the eye responds to illumination in accordance with Weber's law, i. e., the sensation varies as the logarithm of the stimulus, the minimum difference in light intensity which the eye is able to recognize increases with the intensity of the light.

In reproducing an individual elementary area into which the picture or scene is resolved, we are interested in the number of different light intensities which can be correctly distinguished from each other. We are also interested in the range of variation of intensity, which may be measured by the ratio of the currents corresponding to the maximum and minimum light intensities which we wish to reproduce. The choice of a value of this ratio, which we shall call K, is somewhat arbitrary. If we select a size of elemental area, a value of ratio K and a number of distinguishable steps, we prescribe the degree of fidelity of reproduction. Let it be assumed that the number of distinguishable steps is the same for all areas. Call a_1 the amount of current (or light) corresponding to the least brightness. Since the apparent brightness varies as the logarithm of the illumination, the currents corresponding to successive steps of equal increase of brightness will increase in geometric progression. Thus the currents corresponding to the various steps are

$$a_1,\ ra_1,\ r^2a_1\ \ldots\ r^{(s_1-1)}a_1 \qquad (1)$$

where s_1 is the total number of distinguishable steps. The ratio of the currents which correspond to maximum and minimum brightness is

$$K=\frac{r^{(s_1-1)}a_1}{a_1}=r^{(s_1-1)} \qquad (2)$$

In Fig. 4 curve A represents the currents produced by a photoelectric cell or other light sensitive device activated by light controlled by elemental areas successively varying in tone values as described above. When the current indicated by curve A is applied to the pair of deflecting plates 6, and current supplied by the sweep circuit, represented by curve B, is applied to the pair of deflecting plates 12, the cathode ray beam will simultaneously move with respect to the plate 13 in a direction along the x axis for the duration of the signal impulse and in a direction at right angles thereto a number of times determined by the frequency of the current supplied by the sweep circuit, which should be high compared with the time period of the signal impulses. If successive signal impulses are of the same value, the beam will remain deflected in the direction x during successive signal impulse time periods. For the sake of clarity in illustrating the operation of the apparatus, the frequency of the sweep circuit current is so chosen that the cathode ray beam makes four excursions during the interval required to scan each elemental area. Preferably, the frequency of the sweep current should be much higher than that indicated in Fig. 4.

Current only flows through the load circuit while the cathode ray beam is in contact with the plate, and the period of such engagement is determined by, among other factors, the joint action of the picture current and the sweeping current and the varying dimensions of the plate. Since the intensity of the beam remains constant, the load circuit will be supplied with current impulses of the same amplitude, but, as the amplitudes of the photoelectric currents corresponding to the successive elemental areas progressively increase, the cathode ray beam will engage the plate for correspondingly longer periods and hence the duration of the current impulses supplied to the load circuit will progressively increase.

As indicated by curve C, there will be four current impulses supplied to the load circuit for the photoelectric current corresponding to each elemental area. The duration of the impulses in the period corresponding to any particular element is proportional to the logarithm of the value of the photoelectric current during that period. The four impulses will be supplied to the low-pass filter which operates to suppress the high frequency current components introduced by the sweep circuit and to integrate the low frequency energy of these impulses, whereby there is produced a single impulse having the same time period as the corresponding photoelectric current impulse, but having a value which is logarithmically related thereto, as indicated by curve D. With respect to curve C, it is pointed out that a given disturbing current has the same effect in causing confusion between adjacent steps of brightness, regardless of the actual degree of brightness, whereas with curve D the low brightnesses are affected the most. The values of the successive current variations of curve D increase arithmetically.

As described above, the cathode ray tube 7 operates, due to the modulation of the current of sweeping frequency by the picture current, to produce a modulated wave having a flat topped envelope as indicated by curve A and to transform this wave into current impulses which are of equal amplitude but vary in their time duration as indicated by curve C.

Referring now to Fig. 1, the current variations of curve D are amplified by the device 16 and are transmitted over a communicating channel to a receiving station, where they are amplified by the device 17 and applied to one pair of deflecting plates 18 of a cathode ray tube 19, similar to tube 7 at the transmitter, but including a conductive plate 20 the height y' of which varies as the anti-logarithm of the distance x' across it. A plate of this type is shown in Fig. 3. The other pair of deflecting plates 21 is supplied from a sweep circuit 22, with current similar to that supplied by sweep circuit 14 at the transmitter, whereby the cathode ray beam is swept across the plate 20 to cause the production of current impulses similar to those illustrated at C in Fig. 4, but obviously of different relative durations. These impulses are applied, via the resistance 114 to a low-pass filter 23, i. e., a filter having a cut-off low compared with the frequency of the sweep circuit current. This filter operates to suppress the high frequency components and to transform the low frequency energy into a current of the character indicated by curve A in Fig 4. This current may, if desired, be amplified by the device 24 and applied to the ribbon 25 of a light valve 26, adapted to control light of constant intensity supplied by a source 27, which is focussed by a lens 28 on a light sensitive element 29 carried by a drum 30, which is given a motion of rotation and translation in synchronism and in phase with the drum 4 at the transmitter. Thus the unidirectional picture current produced at the transmitter is compressed, transmitted over a communicating channel, and expanded to its original value at a receiving station to control the light applied to a light sensitive element in accordance with the tone values of the picture, whereby the latter is reproduced.

While the operation of the system has been described for a special case, its operation is not limited to such use, since it may be used in the manner described above to effect a like result when any unidirectional current having varying instantaneous values is applied to the plates 6.

The transmission circuit is herein indicated as a pair of conductors, but it should preferably include means for combining the current represented by curve D, i. e., the signal current, with a wave of carrier frequency to produce modulation products which may be transmitted over one channel of a line or radio system. Any suitable apparatus may be used for this purpose, such as, for example, that disclosed in U. S. Patent 1,537,535, May 12, 1925, of Kranz, which, in addition to producing modulation products per se, permits a controllable amount of unmodulated current of carrier frequency to be supplied to the channel. Use of this apparatus is desirable, because it permits the transmission of a selected amount of carrier bias for combination at the receiver with the incoming modulation products to reproduce the signal current, including its direct current component. Since the average tone value of the received picture corresponds to the value of the unmodulated carrier, its value should be controlled by the picture current. Any suitable means actuated by the picture current may be used to adjust contact 19 of the potentiometer 18, shown in the above mentioned Kranz patent, to determine the amplitude of the unmodulated carrier current supplied to the transmission channel.

In case the picture scanning beam is interrupted at carrier frequency, as has frequently been proposed, the apparatus shown in Fig. 5 may be used. This figure diagrammatically illustrates that the cathode ray tube 7 is provided with two plates 31 in place of the single plate 13, to take care of both half waves of the picture modulated current applied to plates 6. Plates 31 should be of the same design as plate 13, and they should be mounted symmetrically of the normal position of the cathode ray beam, that is, the position occupied by the beam when no picture current, which tends to deflect the cathode beam in the direction of the arrow x, is applied to the plates 6.

Sweep current being supplied to the plates 12 and picture controlled current being applied to plates 6, positively directed components of the latter will deflect the cathode beam onto one of the plates 31 and negative components will cause it to engage the other plate 31, while it is being swept across the plate with which it engages by the field produced by the sweep current.

Current impulses resulting from the engagement of the cathode beam with one of the plates 31 will flow through one resistance 32 and over conductor 33 to the cathode 8, while those produced when the cathode beam engages the other plate 31 will traverse the second resistance 32 and conductor 33 to cathode 8. These impulses, occurring alternately in the respective branches, including the resistances 32, will be applied to the filter 15, which passes substantially without attenuation, an alternating current of carrier (sweep) frequency, the amplitude of which varies as indicated by curve D in Fig. 4. This current is transmitted and utilized in the receiver apparatus of Fig. 1 to control the production of the picture.

The apparatus of Fig. 6 will operate in a manner similar to that of Fig. 5, provided the current supplied to plates 6 does not include a direct current component. It, therefore, may be used to effect volume compression of a current representing speech or music. Current impulses, produced by the incidence of the cathode ray beam with the respective plates 31 of the tube, flow in opposite directions through the primary windings 34 of the transformer and serve to induce in the single secondary winding 35 currents that are applied to the low-pass filter 15, which, as previously described, suppresses the high frequency currents and accumulates the low frequency energy to produce a current, the instantaneous values of which are logarithmically related to those of the current applied to plates 6. The compressed current may be transmitted over a channel to a receiving station where it is applied to an apparatus of the type shown in Fig. 1 which operates to produce a current having instantaneous values corresponding to those of the current applied to the plates 6. Alternatively the compressed current band may be supplied through a switch 36 to a meter 37, the deflection of which will be proportional to the level of the energy transmitted through the filter. This apparatus may be used as a volume indicator.

If the tube 7 is provided with a pair of plates 38, having straight edges and connected directly together as shown in Fig. 7, the apparatus may be used in the manner described above to rectify an alternating current. By properly shaping the plates, any desired degree of current transformation as well as rectification may be produced.

The invention may also be used to effect modulation and detection. By superposing the signal current and a carrier frequency wave, or a signal modulated carrier wave and an unmodulated carrier wave, upon the deflecting plates 6 and 12, respectively, of the cathode ray tube, which is provided with properly shaped conductive plates that are engaged by the cathode beam, the signal current and carrier wave may be combined to produce a signal modulated carrier wave, or the unmodulated and modulated waves may be combined to yield the signal current. Again by giving the conductive plate the desired configuration, any desired non-linear relation between the voltage applied to the plates 6 and the current in the load circuit may be obtained.

By providing the tube 7 with a pair of conductive plates 39, as shown in Fig. 8, in which the height of each plate increases as the cube of the distance from the center of the tube and differentially connecting these plates to the output circuit, as shown in Fig. 6, third order modulation may be effected.

Phase modulation may be produced by providing a conductive plate 40 passing through the rest or normal position of the cathode ray beam and inclined to the direction indicated by the double headed arrow x as shown in Fig. 9. The signal current is applied to the deflecting plates 6, and a carrier frequency current of sinusoidal wave form or of the form supplied by a sweep circuit is applied to the deflecting plates 12. If the current applied to the deflecting plates 12 is such that the load current due to the upward sweep of the cathode ray beam is negligible, compared with that due to the downward excursion, i. e., if the upward sweep occurs very rapidly and the downward sweep occurs slowly, there will be a component in the load circuit of carrier frequency, the phase of which is determined by the point in the downward sweep where the beam crosses the plate 40. This will be determined by the deflection of the beam in the direction of arrow x and will be controlled by the signal current.

One difficulty with cathode ray tubes is that, in order to maintain the desired relations over a wide range of variation in signal voltage, the conductive plate must be prohibitively large or the diameter of the beam prohibitively small. In the case of picture and television transmission, the requirements in this respect are much more lenient than in speech and music. For example, the ratio of maximum to minimum currents that need be preserved is of the order of 10 to 1, hence it should be possible to cover the range with a practically operative tube.

In case it is desired to translate a current having a range of variation wider than 10 to 1, this may be effected by using a plurality of tubes. Such a system will now be described in terms of the logarithmic relation described for picture transmission. Let the tube which handles the lowest part of the intensity range be as shown in Fig. 1. If a is the minimum signal voltage, the rest position is so chosen that the cathode ray beam just reaches the plate for that voltage. For voltages up to $10a$ the current supplied to the load circuit increases logarithmically, and beyond that this value is made constant by providing the plate with a short section, the height of which is uniform and equal to $10a$. If V_1 is the signal voltage, the current

$$i_1=\log_b\frac{V_1}{a}$$

where b is a constant which depends on the dimensions of the plate and the constants of the system.

For

$$V_1 \overline{\overline{<}} a \text{ the current } i_1=o$$

and for

$$V_1 \overline{\overline{>}} 10a, \text{ the current } i_1=\log_b 10$$

Let the tube which handles the next range be identical with the first except that the voltage applied to its deflecting plates

$$V_2=\frac{V_1}{10}$$

Let its load current i_2 be added to that of the first tube. For V_1 less than $10a$, i_2 is zero and only the first tube functions. For values from $10a$ to $100a$.

$$i_2=\log_b\frac{V_2}{a}=\log_b\frac{V_1}{a}-\log_b 10$$

From the above expressions for i_1 and i_2 the total current

$$i=i_1+i_2$$
$$=\log_b\frac{V_1}{a}$$

In other words, the current added by the second tube to the constant current produced by the first tube serves to extend the desired relation over the second decade. This process may be further continued by adding more tubes, the voltage applied to the deflecting plates being reduced by a factor of ten for each successive tube.

A decade system operating in accordance with the foregoing theory and comprising three cathode ray tubes which are identical, is shown in Fig. 10. These tubes differ from that included in the system of Fig. 1, in that each includes a conductive plate 40, which is extended at constant height beyond the upper end of its operating range, and each is provided with an electrode 41 which is energized to limit the deflection of the beam, produced by abnormal voltages, so that it does not move off the extended portion of the plate.

The purpose of extending the plate 40 beyond the operating limit $10a$, $100a$ or $1000a$ is to provide a target for the cathode beam when the voltage applied to the deflecting plates of each tube exceeds its prescribed operating range, whereby the load circuit will be supplied with current corresponding to the nominal maximum value for the respective tubes and will not fall to zero, as would be the case if the cathode beam were deflected past the upper margin of the plate.

Electrode **41** may comprise a fine wire parallel to the height of the plate **40** and located at one side of the normal path of the cathode beam between the deflecting plates **6** and the conductive plate **40**. Signal current or current from a separate source may be applied to electrode **41** to produce a field sufficiently strong to prevent the beam from moving beyond the right-hand end of the extension.

Current from a sweep circuit is supplied to the deflecting plates **12** and signal current is applied to the deflecting plates **6** of the tube **42** through a resistance **43**, to the deflecting plates **6** of tube **44** through a connection **45** adapted to supply a voltage corresponding to one-tenth ($\frac{1}{10}$) the signal voltage, and to the deflecting plates **6** of tube **46** by means of a contact **47** engaging the resistance **43** at a point having a voltage equal to one-hundredth ($\frac{1}{100}$) of the signal voltage. In case the applied signal does not include a direct current component, transformers having ratios of 10 to 1 and 100 to 1, respectively, may be used in place of the connections **45** and **47**.

The plates **40** of the respective tubes are connected in parallel and through a potentiometer resistance to the corresponding cathodes, to supply energy to a low-pass filter in a manner similar to and for the purpose described above in connection with Fig. 1.

The receiver for use with the arrangement of Fig. 10 includes a group of three tubes as shown in Fig. 11. These tubes are similar, but the first tube is provided with a conductive plate **48** having the exponential form shown in Fig. 3, and which is extended at constant height beyond the upper end of its operating range, for the purpose described above in connection with plates **40** of the tubes at the transmitter. Let the rest position of the cathode beam be at the left edge of the plate, for which the current i_1' is a'. The other two tubes are each provided with a plate **49** similar to that shown in Fig. 3, from the bottom of which a strip of height a' has been cut off.

For the first tube, if a voltage V_1' is supplied from the line to the deflecting plates **6**, the resulting load current is

$$i_1' = a'c^{V_1'}$$

Since the received voltage is proportional to the sending current, it follows from the expression for i at the transmitter, that

$$V_1' = K \log_b \frac{V_1}{a}$$

where the constant K can be controlled by adjusting the gain of the receiving apparatus. If we make

$$K = \frac{1}{\log_b c}$$

then

$$V_1' = \log_c \frac{V_1}{a}$$

and from this expression taken with the expression for i_1' we find that

$$i_1' = \frac{a'}{a} V_1$$

Thus the received current is made proportional to the original signal voltage. If some other adjustment of the receiver gain is used, the current will vary as some power of the original signal voltage other than the first.

For decade steps at the receiver, the maximum height of the plate should be ten times the minimum. The second tube is provided with an electrode **50** to which is applied a polarizing voltage equal to $\log_c 10$. Hence the cathode beam only reaches the left-hand edge of the plate **49** of the second tube when the voltage, supplied to the deflecting plates **6** of this tube from the line, is the same as that applied to the first tube to cause the current supplied by it to the load circuit to reach that corresponding to an original signal voltage of $10a$. This is also the value at which the current in the first tube reaches its maximum and becomes constant. For greater values it is evident that the current in the second tube is given by

$$i_2' = a'c^{\left(\log_c \frac{V_1}{a} - \log_c 10\right)} - a'$$
$$= a'\left(\frac{V_1}{10a} - 1\right)$$

If this current is amplified ten times and added to that of the first tube we get

$$i' = i_1' + 10i_2' = \frac{a'}{a} V_1$$

which is the desired relation. This process may be extended by increasing the polarizing voltage by a constant amount for each additional tube and increasing the amplification by a constant multiple.

To effect the desired amplification the potentiometers in the load circuits of the second and succeeding tubes are respectively connected to amplifiers **51**, **52**, etc. The amplifying factor of the amplifier **51** is ten, that of **52** is 100 and that of the succeeding amplifiers is increased by multiples of ten. The output circuits of the amplifiers **51**, **52**, etc. are connected in multiple to a low-pass filter **53**, which operates in a manner similar to filter **23** of Fig. 1. The tubes are each provided with an electrode **54** to which is applied a polarizing voltage, that may be derived from the incoming signal or supplied by a separate source, to prevent the cathode beam moving off the extended portions of constant height of the plates **48** and **49**, when voltages abnormal for the respective tubes are applied to their deflecting plates **6**. Battery **55** may be used to supply polarizing voltage to the electrode **54** by closing switch **56**.

When multiple stages are used for alternating currents, a pair of conductive plates, similar to **48** and **49**, may be used in the manner just described. However, for stages after the first, separate tubes should be used for receiving the positive and negative half waves. This is made necessary by the fact that the two half waves call for the use of polarizing voltages of opposite sign, i. e., the polarization for preventing the beam from contacting with the plate at the lower end of the operating range and for limiting its deflection at the upper end of the operating range would be of one sign for the positive half wave and of the opposite sign for the negative half wave.

In a picture transmission system, operating under the conditions assumed above, namely that a_1 is the current (or light) corresponding to the least brightness and that the apparent brightness varies as the logarithm of the illumination, the currents corresponding to successive steps of equal increase in brightness will increase, as noted above, in geometric progression. Referring to Equation 1, the currents corresponding to the various steps are

$$a_1, ra_1, r^2a_1 \ldots r^{(s_1-1)}a_1$$

where s_1 is the total number of distinguishable steps. In accordance with Equation 2, the ratio of the currents which correspond to maximum and minimum brightness is

$$K=\frac{r^{(s_1-1)}a_1}{a_1}=r^{(s_1-1)}$$

The present invention, therefore, provides a system in which the instantaneous values of transmitted current are proportional to the logarithm of the picture current, and hence permits the effect of interference to be distributed more evenly over the range of current employed to transmit the picture.

What is claimed:

1. A signal system comprising a cathode ray discharge device including a conductive plate of negligible resistance, a circuit connecting said plate to the cathode of said device, means controlled by signal currents and high frequency currents applied to deflecting means individual thereto for deflecting the cathode beam of said device with respect to said plate, which operates to control the production in said circuit of a current non-linearly related to the signal current.

2. A signal system comprising means for producing signal currents, a cathode ray discharge device including electrodes energized to produce a cathode ray beam, deflecting means therefor and a conductive plate of negligible resistance, a circuit connecting said plate to an electrode of said discharge device, and means for applying signal current and high frequency current to deflecting means individual thereto for effecting deflection of said cathode beam with respect to said plate, to thereby control the production of currents having instantaneous values non-linearly related to the instantaneous values of said signal currents.

3. A wave changer comprising a cathode ray discharge device including a cathode, a conductive element of a predetermined shape and having a cathode ray beam extending between said cathode and element, a circuit connected between said cathode and said element, means for deflecting said beam in one direction and means supplied with an electric wave to cause said cathode ray beam to sweep across said element transversely to said first-mentioned deflection whereby current impulses are produced in said circuit, and means supplied with said impulses for converting them into a wave having instantaneous values the relationship of which to the instantaneous values of the applied wave is determined by the shape of said element.

4. A wave changer comprising a cathode ray discharge device including a cathode and anode energized to produce a cathode ray beam and a conductive element having a logarithmic curvature, a circuit connecting said cathode and said element, means for deflecting said cathode ray beam in one direction and means supplied with a wave for effecting a second deflection of said beam, whereby current impulses controlled by said element are produced in said circuit, and means supplied with said impulses for converting them into a current wave having instantaneous values bearing a logarithmic relation to the instantaneous values of the applied wave.

5. A signal system comprising a cathode ray discharge device including a cathode and anode supplied with energy to produce a cathode ray beam, a conductive member of predetermined shape and means for deflecting said cathode beam in two directions with respect to said member, and means for supplying a signal wave to one of said deflecting means to cause the production of a wave having instantaneous values determined by the shape of said member and nonlinearly related to those of the signal wave, means for transmitting the modified wave, and means controlled by the modified wave for reproducing the signal wave.

6. A signal system comprising a cathode ray discharge device including a cathode and anode supplied with energy to produce a cathode ray beam, a conductive member of predetermined shape and means for deflecting said cathode beam in two directions with respect to said member, and means for supplying a signal wave to one of said deflecting means to cause the production of a wave having instantaneous values determined by the shape of said member and non-linearly related to those of the signal wave, means for transmitting the modified wave, and means including a cathode ray discharge device actuated by the modified wave for controlling the production of the signal wave.

7. An electrical system comprising a cathode ray discharge device including pairs of deflecting plates and low resistance conductive plates, a circuit connecting said conductive plates to the cathode of said device, means for supplying an electric wave to one pair of deflecting plates and current of frequency high compared to that of the electric wave to the other pair of deflecting plates to deflect the cathode beam of said device with respect to said conductive plates which operate to cause current flow in said circuit, and means utilizing said current for controlling the production of electrical energy having a characteristic determined by said electric wave.

8. A system as described in claim 7 in which the conductive plates are directly connected together and are included in the circuit connection to the cathode to control the production of rectified current corresponding to the electric wave.

9. A system as described in claim 7 in which the conductive plates are differentially connected in the circuit to the cathode and current flow therein controls the production of energy having a characteristic determined by said electric wave.

10. A picture transmission or television system in which the transmitted image wave has instantaneous values corresponding to the logarithm of the light tone value of the elemental area being scanned at that instant including a cathode ray discharge device, a cathode and a conductive plate in said device between which an electron beam extends, means to move said beam across said plate in accordance with the varying tone values of successively scanned elemental areas, means to sweep said beam across said plate at right angles to said first mentioned movement at high speed and constant distance of travel, said plate having one edge so shaped that the perpendicular distance of any point along said edge from a line parallel to the path of said beam as traced by said first movement alone is proportional to the logarithm of the distance traveled by said beam from its zero position when executing said first movement alone

to a line through said point perpendicular to said path, and means associated with a conductive circuit connecting said cathode and plate to produce image currents having instantaneous values bearing a logarithmic relation to the instantaneous values of the light tone values of the elemental areas.

11. A signaling system comprising means to produce a signaling wave varying in amplitude with time, means to produce from said wave another wave consisting of a series of electric impulses of equal amplitude and time spacing but of duration corresponding to the logarithm of the amplitude of the signaling wave, and a low pass filter upon which said wave is impressed for suppressing frequencies corresponding to the time spacing of said impulses and higher frequencies.

12. A cathode ray discharge device comprising a cathode, a conductive plate having one edge which is non-linear, a load circuit connected between said plate and cathode, means to deflect a beam of electrons emitted from said cathode towards said plate transversely of said plate in accordance with signaling current, and means to also deflect said beam across said plate in substantially straight lines at a frequency higher than any essential frequency of the signaling current so that the beam passes off of said plate intermittently.

13. A signal system comprising a cathode ray discharge device including a plate of negligible resistance and selected contour, means for producing a cathode ray beam extending to said plate and deflecting means therefor, and means for supplying signal current and high frequency current to deflecting means individual thereto for effecting deflection of said cathode beam with respect to said plate for controlling the production of a current of desired amplitude relation, determined by the contour of the plate, with respect to the signal current.

14. A signal system including the use of a signal wave having a series of components extending over a frequency band, a cathode ray discharge device including a cathode and a conductive plate between which an electron beam extends, means for moving said beam across said plate in accordance with the different components of said signal wave, means to sweep said beam across said plate at right angles to said first movement and at constant speed which is high compared with the current component of maximum frequency of said signal current, said plate having one edge of a predetermined shape, and means associated with a conductive circuit connecting said cathode and said plate to control the production of a current having a definite relation, determined by the shape of the said edge of said plate, to said signal current.

15. A wave changer comprising a cathode ray discharge device including an electron emitter and a conductive plate between which an electron beam extends and means for deflecting said beam, a circuit connected between said emitter and said plate, means for simultaneously applying a signal current extending over a definite frequency range and a current of high frequency, with respect to said signal current, to respectively different cooperating elements of said deflecting means, said deflecting means thereby causing said beam to be deflected in two directions with respect to said plate, the contour of said plate being such as to control the production in said circuit, connecting the emitter and said plate, of a current having values mathematically related to and in the same frequency range as said applied signal current.

16. An apparatus for effecting translation of a signal wave having a series of components extending over a frequency band comprising a cathode ray discharge device including a cathode and a conductive plate between which a cathode beam extends, means for moving said beam with respect to said plate in one direction by the components of said signal wave and in a second direction by high frequency current, said plate being of selected contour for controlling the production of a current including components mathematically related to those of and in a frequency range determined by said signal current.

17. An apparatus for effecting translation of a signal wave having a series of components extending over a frequency band comprising a cathode ray discharge device including a cathode and a conductive plate between which a cathode beam extends, means for moving said beam with respect to said plate in one direction by the components of said signal wave and in a second direction by high frequency current, said plate being of selected contour for controlling the production of a current including components logarithmically related to those of the signal current.

18. An apparatus for effecting translation of a signal wave having a series of components extending over a frequency band comprising a cathode ray discharge device including a cathode and a conductive plate between which a cathode beam extends, means for moving said beam with respect to said plate in one direction by the components of said signal wave and in a second direction by high frequency current, said plate being of selected contour for controlling the production of a current including components logarithmically related to those of and in a frequency range determined by the signal current.

19. A signal system comprising a cathode ray discharge device including an electron emitter and a plate of negligible resistance and selected contour between which an electron beam extends and deflecting means for said beam, and means for applying a signal current in which successive signals are represented by geometrically progressive amplitude changes and a high frequency current to deflecting means individual thereto for deflecting the cathode beam of said device with respect to said plate, to thereby control the production of a current in which said successive signals are represented by arithmetically progressive amplitude changes.

20. A signal system comprising a cathode ray discharge device including a cathode and a plate of negligible resistance and selected contour between which a cathode ray beam extends and deflecting means for said beam, and means for supplying signal current and high frequency current to deflecting means individual thereto for effecting deflection of said cathode beam with respect to said plate, the contour of which serves to control the production of a current logarithmically related to the signal current.

21. A signal device comprising a plurality of cathode ray discharge devices respectively responsive to different portions of a signal current and each including means for producing an electron beam extending from an emitter to a target and pair of deflecting means therefor, and means for connecting the deflecting means of said devices in parallel to a control circuit.

22. In combination, a plurality of cathode ray

discharge devices, respectively responsive to different portions of a signal current and each including means for producing an electron beam extending from a electron emitter to a target and pairs of deflecting means therefor, and a signal circuit connected in parallel to deflecting means of the respective devices.

23. A signal device comprising a plurality of cathode ray discharge devices respectively responsive to portions of a signal current, each portion occupying a different intensity range and each including means for producing an electron beam extending from an emitter to a target and pairs of deflecting means therefor, and means for connecting the deflecting means of said devices in parallel to a control circuit.

24. In combination, a plurality of cathode ray discharge devices respectively responsive to portions of a signal current, each portion occupying a different intensity range, and each including means for producing an electron beam extending to a target and pairs of deflecting means therefor, and a signal circuit connected in parallel to deflecting means of the respective tubes.

25. An electrical wave generator comprising an electric discharge tube having means for producing a beam of electrons, a signal plate of electrically conducting material shaped in accordance with the desired wave shape of the electrical wave to be generated, means for deflecting said electron beam at a comparatively high frequency in a certain plane whereby said electrons strike said signal plate along a line, means for deflecting said electron beam periodically at a comparatively low frequency and substantially at right angles to said line, whereby the number of electrons striking said plate is varied, and means including a filter for taking the resulting signal from said plate, said filter having a time constant which is larger than a period of said high frequency deflection.

26. An electrical wave generator comprising an electric discharge tube having means for producing a beam of electrons, means for deflecting said beam in a certain plane at a comparatively high frequency, means including a screen structure so positioned in the path of said beam that said deflection causes said beam to trace a line thereon for generating in response to deflection of said beam at right angles to said certain plane a signal voltage having a wave shape determined by the outline of said screen structure, means for deflecting said beam at right angles to said certain plane at a comparatively low frequency, an output circuit including a filter having a time constant which is larger than the period of one of said high frequency oscillations, and means for supplying said signal voltage to said output circuit.

27. An electrical wave generator comprising means for generating a beam of electrons, a target upon which said beam impinges, beam deflecting means adjacent the path of said beam, a source of high frequency waves, a source of low frequency waves, means for simultaneously applying waves from both said sources to said deflecting means, said beam deflecting means causing said waves from said high frequency source to tend to deflect said beam in one plane only and waves from said low frequency source to tend to deflect said beam in another plane only which is transverse to said first plane whereby said beam intersects any plane near said target and generally perpendicular to the paths of said beam in a series of points forming a zig-zag line, and means including said target for generating a pulse of electromotive force under control of said beam during a portion only of the period of each of the waves from said high frequency source, said portions being different for different periods of the high frequency waves.

28. The combination with the elements recited in claim 27, of means for converting said train of pulses into a continuous wave of varying amplitude corresponding to the varying duration of said pulses.

29. A signal transmission system comprising at a transmitting station an electric wave generator having means for generating a beam of electrons, a target upon which said beam impinges, beam deflecting means adjacent the path of said beam, a source of high frequency waves, a source of low frequency signal waves, means for simultaneously applying waves from both said sources to said deflecting means, said beam deflecting means causing said waves from said high frequency source to tend to deflect said beam in one plane only and waves from said low frequency source to tend to deflect said beam in another plane only which is transverse to said first plane whereby said beam intersects any plane near said target and generally perpendicular to the paths of said beam in a series of points forming a zigzag line, means including said target for generating a pulse of electromotive force under control of said beam during a portion only of the period of each of the waves from said high frequency source, the duration of said pulses changing with changes in the amplitude of said signal waves but at a lesser rate, means for transforming said pulses into signal voltage variations of amplitude proportional to the duration of said pulses, said signal voltage variations corresponding to said first-mentioned signal waves but with a compressed amplitude range, means for transmitting said signal variations to a receiving station, an electric wave generator at said receiving station comprising means for generating a beam of electrons, a target upon which said beam impinges, beam deflecting means adjacent the path of said beam, a source of high frequency waves, means for simultaneously applying waves from said last-mentioned high frequency source and the signal variations received from said transmitting station to said deflecting means, said beam deflecting means causing said waves from said high frequency source to tend to deflect said beam in one plane only and waves from said low frequency source to tend to deflect said beam in another plane only which is transverse to said first plane whereby said beam intersects any plane near said target and generally perpendicular to the paths of said beam in a series of points forming a zigzag line, and means including said target for generating a pulse of electromotive force under control of said beam during a portion only of the period of each of the waves from said high frequency source at said receiving station, the duration of said pulses corresponding to the amplitude of said first-mentioned signal waves, and means for transforming said pulses into voltage variations of amplitude corresponding to the duration of said pulses to produce a wave corresponding to said original signal waves.

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