March 7, 1944. M. W. BALDWIN, JR 2,343,634

NOISE REDUCTION SIGNALING SYSTEM

Filed Nov. 1, 1940

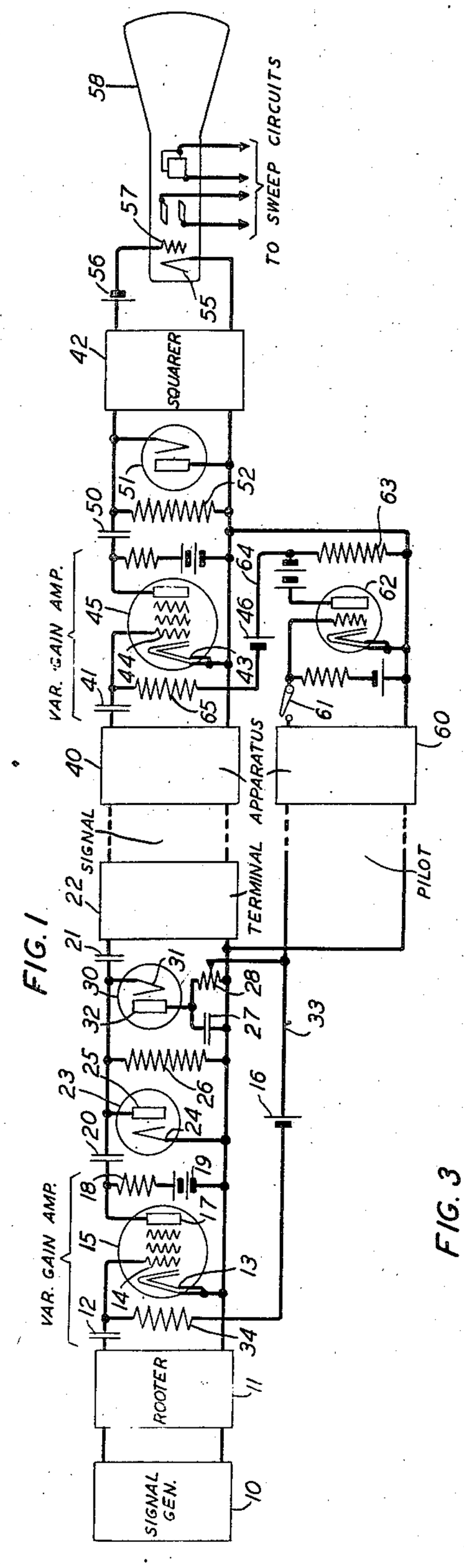

FIG. 1

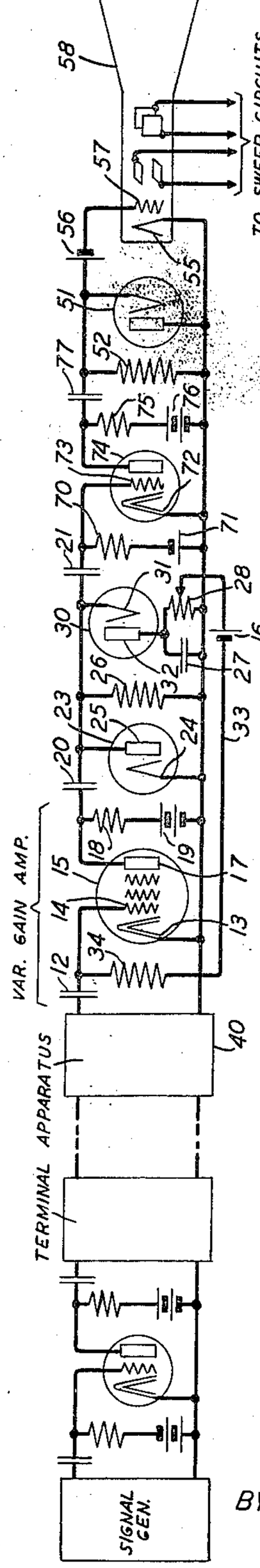

FIG. 3

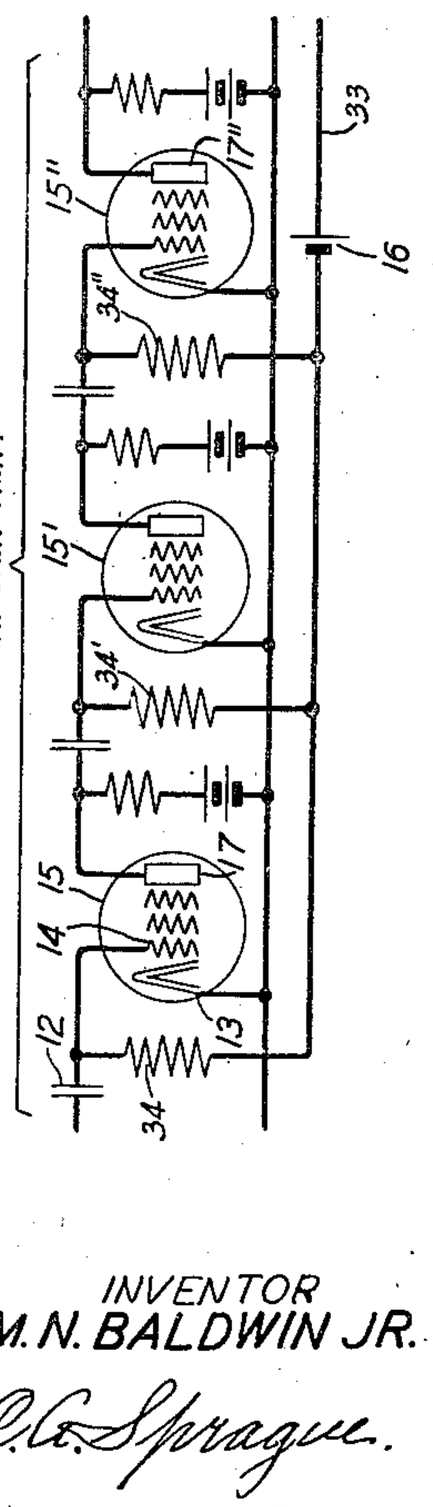

FIG. 2

INVENTOR
M. N. BALDWIN JR.
BY O. C. Sprague.
ATTORNEY

Patented Mar. 7, 1944 2,343,634

UNITED STATES PATENT OFFICE

2,343,634

NOISE REDUCTION SIGNALING SYSTEM

Millard W. Baldwin, Jr., Glen Ridge, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application November 1, 1940, Serial No. 363,813

8 Claims. (Cl. 178—6.8)

This invention relates to electric signaling, and particularly to the transmission of signals of the type usually encountered in the arts of telephotography and television.

A principal object of the invention is to improve the ratio of wanted image signal to unwanted interference signal or noise. To this end the original signal is predistorted in amplitude in a particular fashion prior to transmission. This distorted signal may then be restored to its original form at the receiver by a complementary transformation under control of the amount of distortion introduced at the transmitter. In accordance with the invention the distortion is such that the signal peaks corresponding to the maximum highlights of the field of view or copy to be transmitted are brought to a common high level. In other words, the signal peaks representing the maximum highlights of dark pictures (pictures in which the maximum highlights are relatively low) are brought up to the same level as those of bright pictures (pictures in which the maximum highlights are relatively high), and the signal peaks of intermediate value in proportion. This common level is low enough to be adequately handled by the usual transmission apparatus, yet much higher than the level which the low brightness peaks would attain in the absence of the alteration. As a result, the general level of the dark picture signals is above the threshold at which unwanted interference signals, which are commonly of a level comparable with that of the unmodified bright picture signals, can seriously degrade the quality of the image as ultimately reconstituted. Thus a feature of the invention is the full utilization of the available amplitude range of the signal transmission channel.

This alteration of signal level may be effected in accordance with the invention by varying the gain of some component, for example an amplifier, of the transmitter apparatus in inverse relation to the amplitude of the maximum signal peaks occurring in the course of a single frame. A device for delivering a control voltage (or current) in response to the peak amplitude of the image signal may be employed in the combination of the invention, the resulting control voltage being utilized to control the amplifier gain. If desired, it may be transmitted over a pilot channel to control complementary gain variations of a receiver amplifier.

In the absence of special provisions for carrying direct currents, the image signals which appear in the circuits of the usual television signal amplifiers contain no direct current components. In consequence of this, zero signal corresponds neither to black in the field of view nor to a highlight, but to some intermediate value, so that the peak amplitude-responsive device measures the excursion from this mean brightness value to the highlight and controls the amplifier gain accordingly. This gives partial improvement in the signal-noise ratio. In order to gain the full benefits of the invention, however, it is preferable to control the amplifier gain by the full excursion from black to maximum highlight, and it is among the objects of the invention to provide such control. Accordingly, a feature of the invention is a novel combination of a plurality of independent peak amplitude-responsive devices, one responsive to positive signal peaks and the other to negative signal peaks, and means for deriving from the combination a control voltage which is a measure of the peak-to-peak amplitude of the original signal. A particular feature of the invention is to be found in a novel combination of two storage devices, each having a unidirectional conducting device associated therewith, the storage devices being so connected with one another and with the signal carrying circuit that together they record the full black-to-highlight excursion.

The time constants of the storage circuits of the invention may be of any desired order. It is preferred, however, that they be of an order of magnitude such that maximum highlight peaks are equalized from each frame to the next but not within a single frame.

When the signal as it appears in the amplifier circuits does contain a direct current component representative of the average picture brightness the full advantages of the invention may be secured by the use of a single storage device which in this case can provide amplifier gain control in terms of the full black-to-highlight excursion of the signal.

The advantages afforded by the invention in the form of improvement of signal-noise ratio are of the same character, generally speaking, as those afforded by systems for the instantaneous compression and expansion of signal range per se, and accordingly a further feature of the invention comprises the combination of an instantaneous range compressor with the highlight accentuator of the invention at the transmitter and the inclusion of a corresponding range expander at the receiver.

The invention will be more fully understood from the following detailed description of pre-

ferred illustrative embodiments thereof, taken in connection with the appended drawing, in which:

Fig. 1 is a circuit diagram, partly schematic, showing a transmission system in accordance with the invention and including both transmitter and receiver;

Fig. 2 shows the details of a variable gain amplifier of Fig. 1; and

Fig. 3 is a diagram of an alternative arrangement, showing a receiver in accordance with the invention and a conventional transmitter.

Referring to Fig. 1, a block 10 indicates a generator of image signals. This device may be of any desired type and is indicated symbolically in order to emphasize its unrestricted character. For example, it may be any device in which an optical image of a field of view to be transmitted is projected onto a suitable photosensitive surface which is then repeatedly scanned by an electron beam or the equivalent to produce image signals at the output terminals of the device.

The output terminals of the image signal generator 10 are connected to a range compressing device indicated by a block 11. This range compressing device may be of any desired type, for example, a "rooter" which operates instantaneously and whose property it is that its output signals are proportional to the square root of the input signals thereto. As above stated, the range compressing device may assist in improving the signal-noise ratio and it is therefore believed preferable to employ it in connection with the invention. However, devices of this kind are well known per se and their mode of operation is different from that of the invention. It is, therefore, in no way essential and may be dispensed with without departing from the spirit of the invention.

The output terminals of this compressor 11, or, if no compressor is employed, the output terminals of the signal generator 10 itself or of any intermediate amplification stages that may be desired, are connected in accordance with the invention, through a condenser 12 to the input terminals of a variable gain amplifier, for example, the cathode 13 and control grid 14 of a pentode 15. This amplifier preferably comprises a plurality of stages, and three such stages are shown in Fig. 2. To avoid undue complexity in Fig. 1 only a single stage is there shown. Except in the matters of amplification and sensitivity, a single stage is equivalent to an odd number of stages. As many stages may be employed as may be found desirable, and it is to be understood in the following description that the single stage is taken for the sake of simplification and by way of example only.

Returning, then, to Fig. 1 and bearing the above in mind, the pentode 15 is preferably of the so-called "variable mu" type, characterized by a wide variation of gain with control grid bias. The control grid 14 of this pentode is not returned to the cathode 13 but is connected through a battery 16, which provides an average bias, to another point in the circuit later to be described. The cathode 13 and anode 17 of this pentode 15, constituting the output terminals of the variable gain amplifier are connected through two condensers 20, 21 in series to the final output stages of the transmitter system. These output stages may include amplification stages, a carrier signal generator, means for modulating the signal onto the carrier, means for transmitting signals, either carrier-modulated or not, and such other apparatus as may be desired. Apparatus of this kind is well known per se and since the detailed construction thereof forms no part of the invention it has been grouped together and indicated symbolically by a block 22.

Connected to the line from the pentode 15 to the output stages 22 is a novel circuit arrangement forming a part of the invention. The components of this circuit arrangement are, in order, starting at the anode 17 of the pentode, the condenser 20 first above named which is in series; a unidirectional conducting device, for example, a diode 23 bridged across the output line with its cathode 24 connected to the pentode-cathode side of the line; a resistor 26 shunting the diode; and an arrangement of a condenser 27 and a resistor 28 in parallel, both in series with a second unidirectional conducting device 30, of which the cathode 31 is connected to the anode 25 of the device 23. An adjustable tap on the resistor 28 is connected through a conductor 33 and a resistor 34 to the pentode control grid 14.

In what follows a unidirectional conducting device, for example either of the diodes 23, 30 will be briefly designated by the term "valve"; and the combination with such a valve of a storage device, for example a condenser and a resistor will be designated by the term "rectifier." Thus it will be noted that the circuit arrangement connected between the variable gain amplifier and the output stages 22 comprises two separate rectifiers, each of which in turn comprises a condenser, a resistor and a valve, the valves being oppositely poled in relation to the signal. The resistance and capacitance values of the elements 27, 28 are preferably chosen to give the rectifier 27, 28, 30 a time constant of the order of a few times the frame scanning time; for example, in the case of a television system, about one-tenth second. The time constant of the rectifier 20, 23, 26 may be determined in accordance with well-known considerations and may be, for example, of the order of 0.03 second.

The operation of this portion of the invention will now be understood. Neglecting for the time being the function of the condenser 20, the valve 23 and the resistor 26, assume that due to the character of the signal generator and the number of phase reversals that take place in the associated amplifying and other apparatus ahead of the pentode 15, a highlight of the original field of view is represented by a rise in the potential of the pentode control grid 14 with respect to the cathode 13, and therefore by a fall of anode potential and a voltage drop from the lower end of the anode resistor 18 to its upper end, due to anode current supplied by the battery 19. These conditions are repeated in like phase relation in the third stage of the variable gain amplifier of Fig. 2. In this event the potential of the anode 32 of the tube 30 will be raised with respect to its cathode 31 and current will flow through the condenser 27 to charge the latter to a potential depending on the brightness of the particular highlight signal. This condenser 27 will be slowly discharged through the resistor 28 at a rate such that its potential is maintained comparatively near to its initial value over the period occupied by a single scan of the field of view, but falls to a much lower value over the period occupied by a number of such scans. A fraction of the potential of this condenser, adjustable at will by means of the movable tap on the resistor 28, is then applied through the conductor 33 to the control grid 14 of the pentode 15 to bias the

latter to a lower potential at which the amplification factor of the pentode and likewise that of the variable gain amplifier as a whole is reduced. As a result the signals from the generator 10 are delivered to the transmitting apparatus 22 at a reduced level, as compared with the level they would attain without modification by the circuit arrangement above described. Evidently, since the control valve 30 is poled to conduct on highlight peaks and to be non-conductive on black peaks of the signal, the greater the brightness of the brightest highlight in the field of view, the higher will be the potential to which the condenser 27 is charged, and the greater the grid bias of the pentode 15 and the resulting decrease of the gain of the amplifier. Therefore, as the signals reach the transmitting apparatus the portions, representing the brightest highlight of each complete scan, are brought to a fairly uniform level.

Certain types of image signal generators are incapable of delivering signals of the steady or very low frequency values corresponding to the steady or slowly changing average brightness of the field of view being transmitted. Even when a generator which is capable of delivering the average brightness signal is employed, this signal cannot usually pass through the associated apparatus, since it is extremely difficult to construct broad band amplifiers capable of passing a band of frequencies extending all the way to zero. Thus, in the normal case, for whatever the reason, the signal reaching the input terminals of the pentode 15 will usually contain no steady or slowly varying component corresponding to the average brightness of the field of view. This condition is indicated on the drawing by the presence of the coupling condenser 12 in the grid circuit of the pentode 15 which, as is well known, operates as a stop to direct current. Under these conditions, disregarding the steady potential of the anode battery 19, the signal appearing in the anode load resistor 18 of the pentode 15 will have peaks of one polarity corresponding to bright portions of the scene and peaks of the opposite polarity corresponding to some intermediate value of scene brightness. The absolute value of the scene brightness to which zero signal corresponds will depend on the brightness of the highlight. That is, if the contrast range of the field of view extends from black to full white, zero signal will correspond to a certain value of gray; whereas, if the field contrast extends from black to gray with the same geometrical configuration, zero signal will correspond to a much darker gray value. As a result, the potential supplied to the pentode control grid from the control condenser 27, which measures the potential difference between zero signal and maximum brightness peaks, controls the amplifier gain in terms of the contrast between maximum scene highlight and some intermediate gray value which varies widely. In other words, the control depends not only on the black-to-highlight range, but also on the average brightness of the field.

To avoid this condition and secure control of the amplification factor in terms only of the full contrast between the black of each scene and its maximum highlight value, a further combination of condenser, resistor and valve may be included in accordance with the invention. Thus in Fig. 1, a valve 23 is connected across the output terminals of the variable gain amplifier ahead of the control circuit above described and is shunted by a resistor 26, while a condenser 20 is connected in series with the anode 17 of the pentode 15. As above pointed out, this valve is poled in a sense opposite to that of the polarity of the control valve 30 with respect to the image signal. That is, since the control valve is poled so as to conduct on highlight peaks, for example signal peaks which are of positive polarity at the input terminals of the variable gain amplifier, the auxiliary valve 23 is poled so as to conduct on negative peaks corresponding to black. Thus this auxiliary circuit will have no effect on highlight peaks since the auxiliary valve 23 is then in effect removed from the circuit; but upon the arrival of a negative peak corresponding to black, the auxiliary valve 23 conducts, substantially short-circuiting the resistor 26 and charging the condenser 20 to a potential depending on the magnitude of the black peak. This condenser 20 thereupon proceeds to discharge slowly through the resistor 26 at a rate which is preferably the same as the discharge rate of the control circuit condenser 27. While its charge is sustained it modifies the low frequency component of the potential across the control circuit and thus provides, so to say, a threshold upon which the latter operates, so that the control circuit may now exert on the variable gain amplifier a control which is based solely on the contrast range of the field of view and is independent of its average brightness value. Even when the field of view proper contains no black at all, the signal representing it does contain "black" or "blanking" portions which are not reproduced at the receiver as such but occur during the flyback time intervals of the scanning device, which intervals may be utilized for transmission of synchronizing information. Therefore the circuit arrangement of the invention will exert the proper amount of control even in the case of a field of view whose contrast extends, for example, from dull gray to light gray or white, containing no true black at all. If desired, other means may be employed for interposing an artificial "black" or "blacker than black" signal.

In the absence of the highlight peak control of the invention the effect of the compressor, as is well known, is to produce a signal peak variation which is less than the highlight peak variation. Consequently, a less degree of the control of the invention is required to bring the resulting highlight peaks to a uniform high level when the compressor is employed than without it. For example in the case of the rooter shown, the gain control variation need only be the square root of the variation which would be necessary without the rooter.

Turning now to the right-hand portion of Fig. 1, the signal, transmitted by carrier modulation or otherwise, is received at the input terminals of a receiver, demodulated if necessary, amplified if desired, and modified in such way as may be appropriate in a particular case. Apparatus for this purpose, which forms no part of the invention and is well known per se, is symbolically indicated by the block 40. The output terminals of this input apparatus 40 are connected to the input terminals of a variable gain amplifier represented by a pentode 45. It may contain as many stages as desired and its gain versus grid bias characteristic preferably matches that of the corresponding amplifier at the transmitter. As in the case of the transmitter amplifier, a stopping condenser 41 is included to indicate that the receiver amplifier need not be capable of passing direct current, and the control grid 44

of the pentode 45 is not returned to its cathode 43 but is connected, through a battery 46 which supplies an average bias, to a control circuit to be described. The output terminals of the pentode 45 are connected through a condenser 50 to a range expander, for example, an instantaneous squaring device 42, whose output terminals are in turn connected to the input terminals of a reconstituting device, for example, to the cathode 55 and, through a bias battery 56, to the control grid 57 of a cathode ray tube 58. Since the latter may be of any desired type, it is indicated in the drawing with no emphasis on detail. Apparatus for providing horizontal and vertical scanning voltages for application to the deflecting elements of the tube, focusing electrodes and synchronizing apparatus are all omitted from the drawing since they form no part of the invention and are well known per se.

A rectifier circuit including the condenser 50, a valve 51 and a resistor 52 is included in the circuit ahead of the range expander 42. This arrangement operates in the well-known manner to bring the black portions of the received image to a common level and hence permit reconstitution of the average brightness of the field as well as it contrasts. Such black signal restoration may also be accomplished by any suitable means.

The range expander 42 may have a characteristic complementary to that of the range compressor 11 employed in the transmitter or, if desired, an expander having a different characteristic may be employed. Indeed, either of these devices may be employed without the other. But since these two devices, operating together, add to the effectiveness of the invention, it is recommended that both be employed.

The control voltage applied from the control condenser 27 to the control grid 14 of the transmitter pentode 15 is also transmitted, along with but separate from the main image signal to the receiver station. This transmission may be carried out by a separate line, a separate carrier, or, when a sound signal is transmitted in addition to the vision signal, the control voltage may conveniently be transmitted in combination therewith. Amplifying, transmitting, modulating, demodulating and other apparatus of this character for bringing the control voltage from transmitter to receiver are well known per se and may be of any desired type. In the interests of simplicity they have therefore been omitted from the drawing.

The control voltage as received at the receiving station first enters receiver terminal apparatus symbolically indicated by a block 60, and then passes through a switch 61 to the input terminals of a triode 62 to produce a voltage drop in the triode load resistor 63 which varies in magnitude with the control signal but in opposite phase thereto. This triode load resistor 63 is connected through conductor 64, resistor 65 and bias battery 46 to the control grid of the pentode 45 so that, as the control voltage increases in magnitude (and in the negative direction proper to increase the negative bias of the transmitter amplifier) the anode voltage of the auxiliary triode 62 increases so that the negative bias of the receiver pentode 45 is reduced or the control grid potential raised to increase the amplifier gain. Thus as the transmitter gain is reduced the receiver gain is increased and vice versa so that the received signals, modified at the transmitter by the circuit of the invention, are restored to their original amplitude range for correct reproduction and reconstitution as a visible image.

Provision of the switch 61 enables the user of the receiving apparatus to operate with or without compensatory receiver gain control at will.

Circumstances may arise in which the problem of noise is not serious and in which, at the same time, it may be desirable to equalize the highlight peaks in the reproduced image. In such case the equalization may be effected by the inclusion of the circuit arrangements of the invention at the receiver instead of the transmitter. Fig. 2 shows in schematic form such a receiver which is intended to receive and reproduce ordinary image signals derived from a conventional transmitter, the signal peaks which correspond to highlights in the field varying between wide limits, and to bring the highlights of the reproduced image to a common level. This receiver comprises, in order, input terminal apparatus 40, a variable gain amplifier 12—19, a peak-to-peak signal responsive device 20—32, and means 33, 34 for feeding back an auxiliary signal derived from the peak-responsive device to control the amplifier gain. These portions of the circuit arrangement may be similar to those of Fig. 1 and operate in the same way. Following these portions are a conventional triode amplifier stage 70—71, an average brightness signal restoring stage 51, 52 and a reproducer stage 55—58. The triode amplifier stage is included to insure that the signal phase relations shall be correct for positive reproduction. The average brightness restorer and the reproducer may be similar to those in the receiver of Fig. 1 and operate in the same manner. No rooter or squarer or the like is included in the drawing, though it is to be understood that such a component may, if desired, be employed in accordance with the principles outlined hereinabove.

This arrangement serves as an automatic operator to relieve the observer of the necessity of frequent readjustment of the receiver controls to maintain uniform highlight brightness level in the reproduced image, whether such adjustment is called for by changes in the picture content or by changes in the transmission loss from transmitter to receiver.

It is, of course, within the scope of the invention so to proportion the circuit components that the time constant of the peak responsive circuit has any desired value. However, it is believed preferable to keep it considerably longer than a line time for the following reasons. When compensatory receiver control is employed, the control voltage being transmitted over a pilot channel, a long time constant for the peak-responsive circuit has the effect that the pilot channel need only carry information of a low order of complexity as represented, for example, by 30 cycles per second. This in itself constitutes a substantial advantage—while a readjustment of the noise level occupying one-thirtieth second is not noticeably inferior to a readjustment which takes place much more rapidly.

Whereas in the case of each of the modifications above described the control circuit has been shown for the sake of illustration as a simple arrangement of a condenser, a valve and a discharging resistor, any other suitable arrangement, storage device or otherwise, which delivers a steady or slowly varying control voltage (or current) in proportion to peaks of the image

signal which correspond to maximum highlights in the field of view may be employed.

Again, in the case of each of the transmitter modifications, the control voltage has been fed back to vary the bias of a control device connected ahead of the control source point, thus providing regressive control. It will be understood by those skilled in the art that progressive control, in which the control voltage modifies the gain of apparatus which follows the control source point, may equally well be employed.

The use of the pilot channel for the control voltage, the frequency space requirements for which are very light, permits substantially complete treatment of the original signal in accordance with the invention, and thus permits the realization of its advantages in maximum amount. However, if desired the pilot channel may be dispensed with and the control information transmitted to the receiver in implicit form. There, any suitable self-actuating circuit may be employed to restore the image signals to their original form, for example, a circuit similar to the transmitter of Fig. 1, with the exception that the polarities of the component parts should be so arranged that decrease of signal peak amplitude operates to reduce the corresponding brightness of the reconstituted image still further, and vice versa.

As above stated a signal in which the positive signal peaks on the grid of the first stage pentode 15 of the variable gain amplifier correspond to highlights was selected for the purpose of illustration and explanation. The invention is of course equally applicable to a system in which negative signal peaks correspond to highlights, it being necessary only that appropriate reversals be made in the control circuit connections.

In the pictures, scenes and copy usually encountered in practice, the average brightness is much closer to the background light value than to the light value corresponding to the more detailed portions of the picture. That is, in the usual picture, the average signal lies in the dark region and the highlight peaks are generally of substantially greater amplitude than the black peaks. Therefore control by maximum highlight peaks alone, as by the use of a single rectifier, secures, on the average, more than half the benefits of the invention, and as between this single peak control form of the invention and its opposite in which control is effected by, and equalization applied to maximum dark peaks, the former is preferred.

The invention has been described in connection with examples in which the more detailed portions of the picture subject-matter appeared as highlights and the background as dark. It is to be understood that these examples are by way of illustration only, and that the invention is equally applicable, with appropriate modifications of a type which should be obvious, to systems in which the details are dark and the background light. Such, for example, are documents, printing, maps and the like and also negative images of natural fields of view.

Still other modifications will occur to those skilled in the art which depart in form from the particular arrangements shown but not in spirit from the invention illustrated thereby.

What is claimed is:

1. In an image signal transmission system, means for producing an image signal varying in accordance with light and shade values of successive areas of a field of view, means for amplifying said signal, means responsive to maximum peaks of said signal corresponding to maximum highlights of a stipulated number of said successive areas and insensitive to the occurrence of lesser peaks corresponding to medium brightness areas among said stipulated number, and adapted to deliver an auxiliary voltage related to said peaks, means for varying the amplification of said image signal inversely in accordance with said auxiliary voltage to produce a modified image signal, means for transmitting said image signal as modified and said auxiliary voltage to a receiver station, and at said receiver station, means including an amplifier for reconstituting an image from said signal, and means for varying the gain of said receiver amplifier under control of said auxiliary voltage.

2. In image signal transmitter apparatus, means for producing an image signal, an amplifier having output terminals connected to said means, a condenser in series with one of said output terminals, a valve connected between the terminal of said condenser remote from said amplifier and the other terminal of said amplifier, a passive resistor having two terminals conductively connected, respectively, to terminals of said valve, a circuit arrangement shunting said resistor comprising a condenser and a resistor in parallel, both in series with a second valve, said two valves being oppositely poled in relation to said signal, and means for varying the gain of said amplifier inversely in accordance with the potential of said second-named condenser.

3. In an image signal transmission system, means for producing an image signal varying in accordance with light and shade values of successive areas of a field of view, means for instantaneously compressing the amplitude range of said signal, means for amplifying said signal, means responsive to maximum peaks of said signal occurring within a stipulated period and insensitive to the occurrence of lesser peaks corresponding to medium brightness areas occurring within said period, and adapted to deliver an auxiliary voltage related to said peaks, means for varying the amplification of said range-compressed signal in accordance with said auxiliary voltage to produce a modified image signal, means for transmitting said image signal as modified and said auxiliary voltage to a receiver station, and at said receiver station, means, including an amplifier, for reconstituting an image from said signal, means for varying the gain of said receiver amplifier under control of said auxiliary voltage, and means for instantaneously expanding the amplitude range of said signal in a manner complementary to the manner in which the original signal was compressed.

4. In the art of picture transmission, the method which comprises producing at a transmitter station a signal current varying in accordance with light and shade values of successive areas of a field of view, instantaneously compressing the amplitude range of said signal current, amplifying said compressed signal current in amounts varying inversely in accordance solely with the maximum peak amplitudes thereof occurring within a stipulated period, transmitting said compressed and variously amplified signal current to a receiver station, and at said receiver station, amplifying the received signal current in amounts related in complementary

fashion to the amplification step at the transmitter station, instantaneously expanding the amplitude range of said variously amplified received signal current in complementary fashion to the compression step at the transmitter and reconstituting said resulting signal current as an image.

5. In the art of picture transmission, the method which comprises producing at a transmitter station a signal current varying in accordance with light and shade values of successive areas of a field of view, amplifying said signal current in amounts varying inversely in accordance solely with the maximum peak amplitudes thereof occurring within a stipulated period, transmitting said variously amplified signal current to a receiver station, and at said receiver station amplifying the same in amounts related in complementary fashion to the amplification step at the transmitter station, and reconstituting said resulting signal current as an image.

6. In an image signal transmission system, means for scanning an image line by line throughout a frame to produce first order image signals varying in amplitude in accordance with the light and shade values of successive elemental areas of said image frame and having a maximum peak-to-peak amplitude proportional to the maximum dark-to-highlight tone difference of said frame, means for similarly scanning succeeding frames, a network having a characteristic such that its output is proportional to a fractional power of its input, means including said network for converting said first order image signals into second order image signals in which low amplitudes have been increased and higher amplitudes have been reduced as compared with said first order signals, said second order signals having a maximum peak-to-peak amplitude corresponding to the maximum dark-to-highlight tone difference for each frame but no longer proportional thereto, a variable gain amplifier, means for deriving an auxiliary control voltage in response to said maximum peak-to-peak amplitude of said second order signals occurring within the space of a single frame, means for varying the gain of said amplifier under control of said auxiliary voltage to convert said second order signals into third order signals in which the maximum peak-to-peak amplitudes of successive frames are brought substantially to a common level and other amplitudes increased and reduced in proportion, means for transmitting said third order signals and said control voltage to a receiver station, and at said receiver station, means including a variable gain amplifier controlled by said auxiliary voltage for reconverting said received signals into second order signals, a circuit arrangement having a characteristic inverse to that of said fractional power device for reconverting said second order signals into first order signals, and means for reconstituting an image from said first order signals.

7. In the art of signal transmission, means for producing a varying signal current having peaks of maximum amplitude interspersed with a relatively great number of variations of smaller amplitudes, there being periods during which said peaks of maximum amplitude are all reduced in amplitude but are still of greater amplitude than the variations therebetween, means for amplifying said signal current in amounts varying inversely in accordance with the maximum peak amplitudes of said signal current whereby during said periods of lower maximum peak amplitudes the signal variations are all amplified more than during said periods of higher maximum peak amplitudes, said last-mentioned means comprising an amplifying element, a unilaterally conducting means in series with a timing circuit having a condenser and a resistance element in parallel with each other, means for impressing said signal on said series circuit, whereby said condenser is charged in one direction only, the time constant of said timing circuit being of such value that maximum peak variations of said signal alone contribute to the charging of said condenser, a second unilaterally conducting means upon which said signals are impressed in parallel with said first unilaterally conducting means, said second unilaterally conducting means being poled oppositely from said first unilaterally conducting means with respect to the signal, a second resistance element upon which said signal is impressed in parallel with said second unilaterally conducting means, means which is non-conducting for direct current and conducting for alternating current through which said signal is impressed upon said second unilaterally conducting means, and means controlled by the charge on said condenser for controlling the gain of said amplifier element, means for transmitting said variously amplified current to a receiving station, means at said receiving station for amplifying said received current in amounts related in complementary fashion to the amplification produced by said first-mentioned amplifying means, and means for utilizing said amplified current to produce an indication of the kind which said original signal current would be able to produce directly.

8. In the art of signal transmission, means for producing a varying alternating signal having peaks of maximum amplitude interspersed with a relatively great number of variations of smaller amplitudes, there being periods during which said peaks of maximum amplitude are all reduced in amplitude but are still of greater amplitude than the variations therebetween, a rectifier in series with a timing circuit having a condenser and a resistance element in parallel with each other, means for impressing said signal on said series circuit, whereby said condenser is charged in one direction only, the time constant of said timing circuit being of such value that maximum peak variations of said signal alone contribute to the charging of said condenser, a second rectifier upon which said signals are impressed in parallel with said series circuit containing said first rectifier, said second rectifier being poled oppositely from said first rectifier with respect to the signal, a second resistance element upon which said signal is impressed in parallel with said second rectifier, means which is non-conducting for direct current and conducting for alternating current through which said signal is impressed upon said second rectifier, a space discharge repeating device having an input circuit and an output circuit, and means for applying a varying potential difference generated in said timing circuit to said input circuit.

MILLARD W. BALDWIN, JR.