

July 11, 1950

V. PAGLIARULO
LIGHT MODULATING SYSTEM

2,515,054

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2 Sheets-Sheet 1

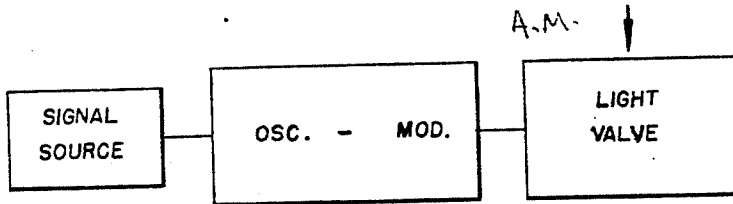


FIG. 1

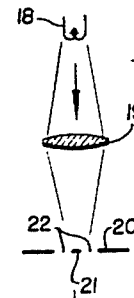
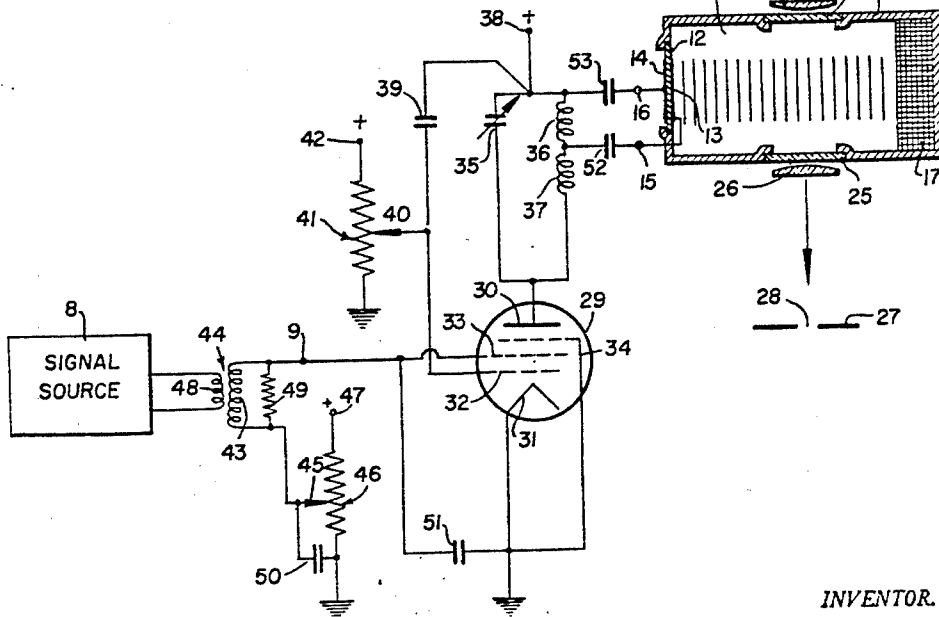


FIG. 2



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2 Sheets-Sheet 2

FIG. 3

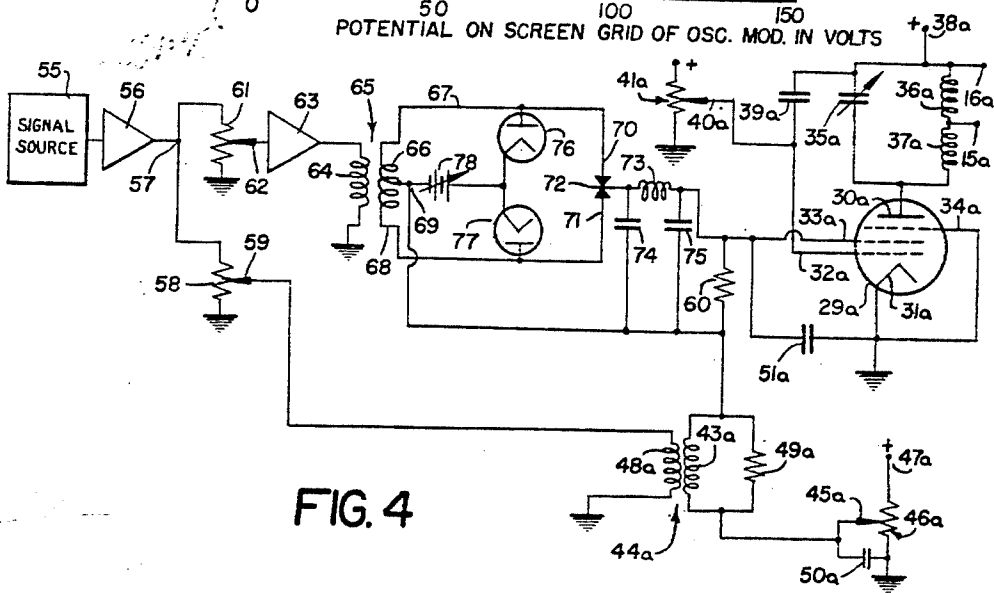
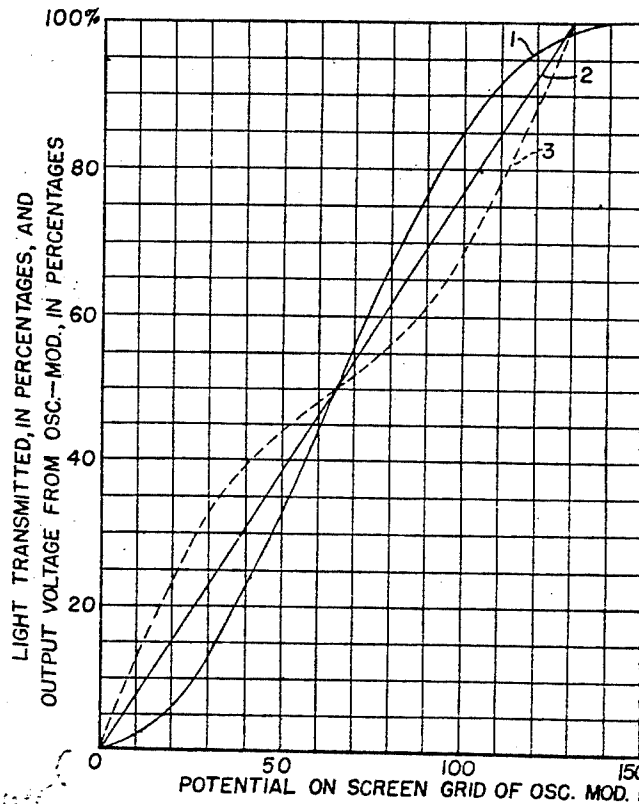


FIG. 4

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2,515,054

LIGHT MODULATING SYSTEM

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7 Claims. (Cl. 179-100.3)

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The present invention relates to apparatus and a method for modulating light.

The invention is particularly applicable to light-modulating systems of the type employing an ultrasonic light valve. For a general description of ultrasonic light valves reference may be made to Patent 2,287,587 granted June 23, 1942, to G. W. Willard.

One difficulty frequently encountered in ultrasonic light valves is that while they provide a light-transmission versus signal-voltage characteristic which is approximately linear over a certain range of signal amplitudes, this characteristic is non-linear at signal amplitudes outside this range. Thus at signal amplitudes higher than this range, the rate of change of light transmission with respect to signal voltage is less than it is within this range. In Patent 2,287,587, Willard discloses an ultrasonic light valve featuring piezoelectric driving means of special design for increasing the linear portion of the characteristic of the light valve. The present invention represents a new and particularly advantageous approach to this problem of obtaining linearity over a wide range.

An object of the invention is to improve the operating characteristics of light-modulating systems.

Another object is to provide a light-modulating system having a generally linear light-transmission versus signal-voltage characteristic over a wide range of signal voltage amplitudes. A feature of the invention is the provision, in a light-modulating system of the type employing a light valve having a non-linear characteristic, of circuit means for driving the light valve, such as a modulator or combined oscillator-modulator, having a non-linear characteristic of such shape as to compensate for the non-linearities of the light valve, thereby providing a linear over-all characteristic for the system. Another feature of the invention is the provision, in combination with a light modulating system having a modulator of the aforementioned type, of special noise reduction circuit means to reduce the unwanted film noise issuing from a sound-on-film record during reproduction.

The above-mentioned, as well as other objects, together with the many advantages obtainable by the practice of the present invention, will be readily comprehended by persons skilled in the art by reference to the following detailed description taken in connection with the annexed drawings which respectively describe and illustrate a

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preferred embodiment of the invention, and wherein

Fig. 1 is a diagrammatic view of a light-modulating system.

Fig. 2 is a more detailed diagrammatic representation of a light modulating system showing in plan view an ultrasonic light valve, and showing circuit details of one embodiment of an oscillator-modulator adapted to provide, with the light valve, a linear overall characteristic.

Fig. 3 is a graph including curves which will be referred to in explaining the present invention.

Fig. 4 is a diagram of an alternative circuit which may be used instead of the circuit of Fig. 2 to drive a piezoelectric crystal of an ultrasonic light valve. This circuit has a noise reduction feature, applicable to sound-recording on film, in addition to having features similar to those of the oscillator-modulator of Fig. 2.

In one embodiment of the invention, there is provided, in a light-modulating system including an ultrasonic light valve having a non-linear characteristic, a combined oscillator-modulator comprising, for example, a pentode having an oscillatory anode circuit coupled to its control grid, for providing a carrier voltage of ultrasonic frequency. A signal voltage, for modulating the output voltage of the oscillator-modulator, is applied to the screen grid of the pentode in series with a positive bias voltage. The bias on the control grid is adjusted to such a value that the output voltage versus screen-voltage characteristic of the oscillator-modulator is shaped so as to compensate for the non-linearities of the characteristic of the light valve. As a result, the overall characteristic of the system, that is, the amount of light transmitted by the light valve as a function of the signal voltage, is made linear as desired.

In Fig. 1, there is shown, very diagrammatically, a light-modulating system, such as might be used, for example, in recording sound on film, or in television, or in any application in which it is desired to vary an amount of light transmitted, in accordance with a control signal. The system of Fig. 1 comprises a light valve, an oscillator-modulator for controlling same by the application of an amplitude-modulated voltage of ultrasonic frequency thereto, and a signal source for applying a signal voltage to the oscillator-modulator for modulating same. In a system for recording sound on film, this signal source would correspond to a microphone.

The light valve may be assumed to be of a known type comprising a piezoelectric crystal

adapted to generate, in response to an applied alternating voltage of ultrasonic frequency, a compressional wave of like frequency in a liquid or other translucent elastic medium such as water, and means for directing a beam of light through the medium perpendicular to the direction of propagation of the compressional wave, that is, parallel to its wave fronts. Means are provided for absorbing the compressional wave at a point after it has passed through a beam of light, to prevent reflections. By known principles, the compressional wave tends to diffract the light beam very much as would a diffraction grating. By passing the light beam through suitable optical means, such as slotted shields, as well as through the field of sound waves in the translucent medium, the amount of the resulting light transmitted is related to the amplitude of the compressional wave generated by the crystal, and hence is related to the amplitude of the alternating voltage applied to the crystal.

If an alternating voltage of constant amplitude were applied to the crystal, the effect of the valve would be to transmit a constant amount of light. Since, however, the alternating voltage applied to the crystal is amplitude-modulated, the amount of light transmitted by the valve is also modulated. Within a certain range of amplitudes, the relationship between light transmitted by the valve and the modulation envelope of the voltage applied to the crystal is approximately linear, but outside this range, it tends to be non-linear. In the system of the present invention, there are non-linearities in the oscillator-modulator compensatory to non-linearities of the light wave, so as to provide an approximately linear overall characteristic for the composite system, as will be more fully described.

While in the present description it is assumed that the light valve is driven by a combined oscillator-modulator, it will be understood that it would be possible to separate the oscillator and modulator functions, so that they are performed by separate tubes. Thus the light valve might be driven by a modulator, which in turn is driven by an oscillator of ultrasonic frequency and a source of a modulating signal of audio or video frequency.

Fig. 2 shows a typical ultrasonic light valve, having non-linearities to be described, driven by an oscillator-modulator adapted to compensate for these non-linearities. Also shown is a signal source 8, for example, a microphone. The oscillator-modulator is provided with an input circuit including a point 9 to which point there is applied the signal from the source 8, along with a positive bias voltage. The oscillator-modulator is adapted to apply to the light valve a voltage of ultrasonic frequency, amplitude-modulated in accordance with the signal from the source 8, which would be at audio frequency if this source is a microphone.

The light valve itself comprises a vessel 10 filled with a suitable liquid or other translucent elastic substance, such as water or m-xylol, indicated by the numeral 11. A piezoelectric driver element for setting up compressional waves in the liquid is provided at one end of the vessel. This driver element comprises preferably an X-cut crystal 12 of quartz or other piezoelectric material, set into an opening in the end of the vessel, and sealed to the vessel, as by suitable gaskets, not shown, to prevent liquid from leaking out of the vessel. The crystal is provided

with an inner electrode 13 and an outer electrode 14. These electrodes are connected to a pair of terminals 15 and 16, respectively. At the end of the vessel opposite the crystal there is provided means such as a layer 17 of fine aluminum wire packed into a pad adapted to absorb the compressional waves, to prevent reflections. In the illustrated embodiment it may be assumed that the inner surface of this absorbent material is vertical, that is, perpendicular to the direction of propagation of the compressional waves. In some embodiments, if necessary in order to absorb the compressional waves effectively, this surface may be slanted upwardly at an angle of 45°, and the waves may be thus deflected toward the upper surface of the water. In the region of the upper surface of the water, an additional layer of absorbent material may be provided, for more completely suppressing reflections.

There is provided a source of light, schematically indicated at 18, and light from this source is caused to pass through a condensing lens 19 and a shield 20 having a central bar 21 and a pair of adjacent slits 22. The light thereafter passes through a lens 23, a glass window 24 closing an opening in the side of the tank 10, through the field of compressional waves in the tank, out through a window 25, through a lens 26 and toward a shield 27 provided with a slit 28. It may be seen that the arrangement of the shields 20 and 27 is that known as the bar-slit arrangement. In a manner which is well known in the art, the light emerging through the slit 28 is related to the amplitude of a voltage applied at the terminals 15 and 16. This light may be directed onto a moving film, for exposing same with varying light intensity in case the system is employed to record sound on film.

As a portion of the oscillator-modulator there is provided an electron discharge device such as a pentode vacuum tube 29, having an anode 30, a cathode 31, a control grid 32, a screen grid 33, and a suppressor grid 34. The pentode 29 may, for example, be a Western Electric 294A tube. Its cathode is, as shown, grounded and the anode is connected, through an oscillatory circuit including a variable capacitor 35 in parallel with inductive impedance means comprising windings 36 and 37 in series, to a terminal 38 comprising a source of B-supply potential, which may conveniently be of the order of approximately 250 volts. It may be assumed that, as is the case in actual practice with any such source, the source of potential available at the terminal 38 has some internal impedance, so that the potential appearing at the terminal 38 is to some extent dependent upon the current drawn from the source.

The control grid 32 is connected to the upper end of the oscillatory circuit through a capacitor 39. This capacitor 39 provides the necessary impedance and the proper phase relations between the alternating voltage on the anode and the alternating voltage on the control grid to cause undamped oscillations to be maintained in the oscillatory circuit.

The control grid 32 is biased to a strongly positive potential with respect to the cathode. For example, in the illustrative circuit it is, for good operation, biased to a potential of preferably approximately 45 volts, being connected to a slider 40 of a potentiometer 41, one end of the potentiometer being grounded and the other end being connected to a source of positive potential of, for example, 250 volts at a terminal 42. The effective resistance level at the slider 40, in the

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above-described circuit, should for best operation be preferably approximately 25,000 ohms. By an "effective resistance" of 25,000 ohms it is meant that the potentiometer and its associated impedance source could theoretically be replaced by connecting between the slider 40 and ground a resistor of 25,000 ohms, in series with an impedance-free source of bias potential of, say, 45 volts. The adjustment of the control grid bias by means of the slider 40 will be described in further detail at a later point. Means are provided for manually setting this slider to a proper value.

The suppressor grid 34 is connected to the cathode.

The screen grid 33 is connected through the secondary winding 43 of a transformer 44 to a slider 45 of a potentiometer 46, this potentiometer being connected between ground and a source of positive potential of, for example, 250 volts at a terminal 47. The primary winding 48 of the transformer 44 is connected to the output terminals of the signal source. A resistor 49 is connected in parallel with the secondary winding 43 of the transformer. Between the slider 45 and ground there is connected a large capacitor 50 adapted to bypass to ground alternating voltage components, of the frequencies of the signals from the source 8, and higher. The slider 45 is adjusted to bias the screen grid 33 to a positive voltage of, for example, 64 volts. A bypass capacitor 51 is connected between the screen grid 33 and the cathode, of such a value as effectively to bypass ultrasonic-frequency components but not to bypass signal-frequency components.

The output signal from the oscillator-modulator is derived across the winding 36, the ends of which are coupled through coupling capacitors 52 and 53 to the terminals 15 and 16, and thence to the electrodes of the crystal which drives the light valve.

The pentode with its oscillatory plate circuit operates as a tuned plate oscillator. The tuning capacitor 35 is adjusted so that the frequency of the oscillator is at approximately the resonant frequency of the crystal 12.

It will be understood that the output voltage at the terminals 15 and 16 will be in the nature of a carrier voltage of superperson frequency, having an amplitude modulation envelope related to the potential at the point 9, which varies at the frequency of the signal from the source 8. The relationship between the modulation envelope of the signal at the terminals 15, 16 and the signal from the source 8 will now be explained.

Reference is made to Fig. 3. S-shaped curve 1 represents, for a typical ultrasonic light valve driven by a linear oscillator-modulator, a plot of light transmitted by the valve as a function of a control voltage applied to the linear oscillator-modulator. More particularly, if the oscillator-modulator of Fig. 2 were linear, that is, if it were adapted to produce at the terminals 15, 16 an ultrasonic frequency voltage having an amplitude related by a linear function to an input potential at a point such as 9, the curve 1 of Fig. 3 would represent the relationship between the light transmitted by the valve and the potential applied at terminal 9. The non-linearity of curve 1 results from the non-linearity of the light valve. For this curve, light transmitted by the valve is plotted along the vertical axis, and the vertical scale is in terms of percentage of a maximum value of light transmitted. The horizontal scale

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represents the potential at point 9 with respect to the cathode, which is grounded.

Curve 2, a straight line, represents the desired relationship between light transmitted by the light valve and the potential at the terminal 9, with respect to the grounded cathode. The actual characteristic of the system is very nearly, although not exactly, the same as this desired characteristic.

Reverse S-shaped curve 3 represents the actual relationship between the amplitude of the output voltage of the oscillator-modulator, and the potential at the terminal 9 with respect to the grounded cathode. The output voltage at the terminals 15 and 16 is plotted along the vertical axis, in terms of percentage of a maximum value corresponding to the previously-mentioned maximum value of light transmitted by the valve. The potential at the terminal 9 is, as in the case of curves 1 and 2, plotted along the horizontal axis. It has been found that a linear characteristic which approximates that shown in curve 2, is obtained for the composite system of an oscillator-modulator having the characteristic shown in curve 3, used in connection with an ordinary non-linear light valve of the type which would produce a composite characteristic like that of curve 1 when driven by a linear oscillator-modulator. The significance of the various curves may be summarized by stating that curve 1 represents the unsatisfactory composite characteristic of an ultrasonic light valve and an oscillator-modulator which would be obtained if the light valve were used with an ordinary linear oscillator-modulator; curve 2 represents the desired composite characteristic; and curve 3 represents the actual characteristic of the oscillator-modulator of Fig. 2 alone. An approximately linear system is provided by using this non-linear oscillator-modulator in connection with the non-linear light valve shown.

The arrangement of the circuit of Fig. 2 which was found to give approximately the characteristic desired, has been described. It may now be stated, somewhat more generally than has been previously stated, that the bias on the control grid of the pentode of Fig. 2 should be adjusted to provide, for the oscillator-modulator, a characteristic having non-linearities compensatory to the non-linearities of the light valve. Thus since a system would have a generally S-shaped characteristic like that of curve 1 if used in connection with a linear oscillator-modulator, the oscillator-modulator of Fig. 2 is adjusted by means of the slider 40 which sets the bias on its control grid, so that the characteristic of the oscillator-modulator itself has a reverse S-shape, like that of curve 3, of such configuration that the overall characteristic of the system is substantially linear. It has been found in one circuit that if the slider 40 of Fig. 2 is open or disengaged from the potentiometer 41, a sinusoidal signal applied to the screen grid of sufficient amplitude to fully modulate the output signal of the oscillator-modulator will produce in the output signal 13% third harmonic, 3% second and 1% fifth. When the slider 40 is engaged and adjusted as herein described, the harmonics decrease to 1.5% second harmonic, 1.5% third, and a negligible amount of fifth harmonic.

It will be understood that the oscillator-modulator of the present invention is not limited to any one specific tube. Thus instead of employing a 294A pentode in Fig. 2, one may employ any pentode tube capable of an output power of

about 2 watts, at carrier or radio frequency with anode voltage about or below 180 volts. With such a tube, for which rated screen grid and anode potentials are about 135 volts optimum linearity of the system is obtained by using an effective impedance level of approximately 17,500 ohms at the slider 40. This bias on the control grid should, for good ultimate linearity, be preferably approximately 45 volts positive with respect to the cathode, as in the previous illustration.

Reference may now be made to Fig. 4. There is shown a signal source 55 and an oscillator-modulator generally similar to that of Fig. 2 except that there is additionally provided in Fig. 4 a noise reduction circuit applicable to reduce the objectionable film noise heard in reproduction from a sound record recorded on film. For a general discussion of the purposes of such noise reduction, reference may be made to an article "Noiseless Recording Western Electric System," *Journal of the Society of Motion Picture Engineers*, vol. XVIII, May 1932, by H. C. Silent and J. G. Frayne.

Components of the circuit of Fig. 4 similar to corresponding components in Fig. 2 are designated by like reference numerals, modified by the addition of the letter "a." The output voltage from the terminals 15a and 16a of the circuit of Fig. 4 is a non-linear function of the signal voltage from the source 55, generally of the type represented in curve 3 of Fig. 3 and described in connection with the oscillator-modulator of Fig. 2. Hence the terminals 15a and 16a of Fig. 4 may be connected to a light valve of the type shown in Fig. 2, and there will be obtained approximately linear overall performance.

The signal from the source 55 is applied to an amplifier 56, and the output voltage from this amplifier, at a terminal 57, is applied to the screen grid 33a of the oscillator-modulator via two paths.

In a first of these paths, voltage from the terminal 57 is applied to one end of a potentiometer 58, the other end of which is grounded, having a slider 59 connected to a primary 44a of a transformer 44a, the other end of this primary being grounded.

The secondary winding 43a of this transformer is provided with a parallel resistor 49a. One terminal of the secondary winding 43a is connected to a slider 45a of a potentiometer 46a, having one terminal grounded, and the other terminal connected to a source of positive potential of, for example, 250 volts at a terminal 47a. Connected in series with the secondary winding 43a of the transformer 44a and with the screen grid 33a, is a resistor 60. Hence the voltage at the screen grid 33a is the algebraic sum of the bias voltage at the slider 45a, the signal voltage across the secondary winding 43a, and a noise reduction voltage across the resistor 60, derived in a manner now to be described.

In a second path connecting the terminal 57 to the screen grid circuit, there is provided a potentiometer 61 between the point 57 and ground, having a slider 62 connected to an amplifier 63, the output terminal of which is connected to one terminal of a primary winding 64 of a transformer 65. The other terminal of this primary winding is grounded. The transformer 65 is provided with a secondary winding 66 having a terminal 67, a terminal 68 and a center-tap terminal 69.

Connected between the terminals 67 and 68 in a back-to-back arrangement are a pair of rec-

tifiers of the copper oxide type, for example. The remote electrodes of these rectifiers may be designated by the numerals 70 and 71, and the adjacent electrodes may be considered, for the sake of the present circuit diagram, as a single electrode 72. The arrangement of the rectifiers is such that electrons may flow from the electrode 72 to either of the electrodes 70 and 71 provided the electrode 72 is at a lower potential than the electrode 70 or 71 in question. Electrons may not, however, flow from the electrodes 70 or 71 to the electrode 72. The electrode 72 and the center-tap terminal 69 of the winding 66 are, through a π -type filter comprising a series inductor 73 and shunt capacitors 74 and 75, connected to the terminals of the resistor 60. It may thus be seen that there are provided a full wave rectifier and a filter, adapted to produce across the resistor 60 a unidirectional voltage of such polarity that the terminal of this resistor which is connected to the screen grid 33a is driven positive with respect to the other terminal of this resistor.

There is additionally provided as a part of the noise reduction circuit, means for limiting the voltage which may appear across the resistor 60. For this purpose, there is provided a pair of diodes 76 and 77, having their anodes connected to the terminals 67 and 68, respectively, and having their cathodes connected together. Connected between the cathodes of these diodes and the center-tap terminal 69 of the winding 66 is an adjustable source 78 of bias potential, adapted to maintain the cathodes of the tubes 76 and 77 at a positive potential of, for example, 50 volts with respect to the center-tap terminal 69.

The operation of the circuit shown in Fig. 4 may now be described. The tuning capacitor 35a will be adjusted so that the oscillator-modulator oscillates at the desired carrier frequency, which may, for example, be 5.6 megacycles per second. The signal from source 55 will be applied through the amplifier 56 and the path including the potentiometer 58 and the transformer 44a to the screen grid circuit. Hence there will appear across the terminals 15a and 16a a carrier signal modulated by the signal from the source 55. The signal from the source 55 will also be applied through the amplifier 56 and the path including the amplifier 63 to the transformer 65. There will, as a result of the rectifying action previously mentioned, be produced a direct-current voltage across the resistor 60 in a direction to increase the positive bias potential on the screen grid 33a. For maximum values of the signal source, this potential across the resistor 60 will be at the maximum limit allowed by the limiter portion of the circuit, including the diodes 76 and 77 and the bias and potential source 78. For example, this maximum direct-current voltage across the resistor 60 might be approximately 50 volts. The bias voltage at the slider 45a might, for example, be approximately 16 volts, and the signal across the winding 43a might range between zero and approximately 64 volts. When the amplitude of the signal from the source 55 falls to a very low value, the direct current across the resistor 60 decreases since the output from the electrode 72 of the rectifier is small. As a result the net average potential on the screen grid falls to a less positive potential.

Referring now to Figure 3, curve 2, it will be noted that with a low potential on the screen grid 33a, the light output from the slit of the type illustrated as 28 in Fig. 2, will be low, but as the

signal from the signal source 55 increases the average potential on the screen grid will increase, and the light output from the slit will also increase proportionally. The average light issuing from the slit increases, therefore, proportionally with the amplitude of the signal.

It is well known that when print records of sound on film are reproduced, there is considerable noise issuing from the loudspeaker derived from the granular nature of the developed emulsion of the film being reproduced. It is also known that when the transmission of the print is low the amplitude of the disturbing noise is low, and when the transmission of the film is higher the amplitude of the disturbing noise is higher. For good reproduction, however, the amplitude of the signal should be about 100 times the amplitude of the noise.

In the system described the circuit elements are so adjusted that in recording sound on film, with low amplitude signals there is produced a low mean exposure of the negative from which results a low mean transmission of the print, and with higher amplitude signals there is produced a higher mean exposure of the negative from which results a higher mean transmission of the print. Accordingly, the circuit automatically controls the ultimate mean transmission of the print in order that the volume of film noise may be always much below the signal, whether high or low, thus eliminating noise effects which would be annoying to listeners.

It will be understood that in Fig. 4, as in Fig. 2, the bias on the control grid is adjusted to such a value as to provide in the oscillator-modulator non-linearities compensatory to non-linearities of a light valve to which the terminals 15a and 16a may be connected. In a tube of the type mentioned, it was found that biasing the control grid 45 volts positive with respect to the cathode produced a compensatory non-linearity closely approximating curve 3, Fig. 3.

In conclusion, it may be seen that there has been described herein a light-modulating system comprising a non-linear light valve and a non-linear circuit for driving the valve, the non-linearities of the circuit being compensatory to those of the valve, to provide a linear composite system.

In addition to novel apparatus, there has been described a novel method of modulating light as a linear function of a control voltage throughout a wide range. In one embodiment, this method comprises the steps of generating an alternating voltage of ultrasonic frequency, modulating this voltage so that its amplitude is a non-linear function of the control signal, and applying the modulated alternating voltage to a non-linear light valve, said non-linear function being compensatory to the non-linearities of the light valve.

There has also been disclosed a method, for use in driving a non-linear ultrasonic light valve, of generating an ultrasonic-frequency driving voltage having an amplitude which, throughout a wide range, is related to a control signal by a non-linear function compensatory to non-linearities of the light valve, and having characteristics adequate to reduce the annoyance from film noise in reproduction. This last-mentioned method, in one embodiment, comprises the steps of limiting and rectifying a portion of the control signal to obtain a unidirectional noise reduction voltage; adding the noise reduction voltage, a bias voltage, and a portion of the signal to obtain a sum voltage; generating an ultrasonic-frequency voltage;

modulating this ultrasonic-frequency voltage as a non-linear function of the sum voltage with a modulator having a characteristic of bias-controllable shape; and applying to this modulator a bias voltage of such magnitude that non-linearities of its characteristic compensate for non-linearities of the light valve.

While a suitable form of apparatus and method to be used in accordance with the invention have been described in some detail, and certain modifications have been suggested, it will be understood that numerous changes may be made without departing from the general principles and scope of the invention.

What is claimed is:

1. A light-modulating system comprising a source of signal voltage, an ultrasonic light valve including a piezoelectric crystal, the light transmission of said valve being normally a non-linear function of the amplitude of a high frequency alternating voltage impressed on said crystal, means for generating a high frequency alternating voltage of which the amplitude is a non-linear function of a signal voltage, said second-named function being compensatory of said first-named function, means for applying a signal voltage from said source to said generating means to vary the amplitude of the generated voltage, and means for impressing the generated high frequency voltage on said crystal.

2. In a light-modulating system comprising an ultrasonic light valve including a piezoelectric crystal arranged to vary the light transmission of the valve in response to variation in amplitude of an alternating voltage of ultrasonic frequency impressed on the crystal, the response being a non-linear function of the amplitude variation, means for modulating the transmission substantially linearly with a signal voltage comprising means for generating and impressing on the crystal an alternating voltage of ultrasonic frequency including a thermionic vacuum tube having an anode, a cathode, a screen grid, a control grid and an oscillation circuit connected between the anode and the control grid, the crystal being connected in shunt with a portion of said circuit, means for varying the amplitude of the generated voltage comprising a source of signal voltage connected between the cathode and the screen grid, the amplitude variation thereby produced being normally a linear function of the signal voltage, and means for distorting the normally linear function to be compensating of the non-linear function comprising a source of variable potential connected to bias the control grid positively with respect to the cathode and means for varying the bias to control the distortion of the normally linear function.

3. For use with an ultrasonic light valve having a non-linear characteristic, an oscillator-modulator having a compensating characteristic comprising an electron discharge device having an anode, a cathode, a control grid and a screen grid, an oscillatory circuit tuned to an ultrasonic frequency connected between the anode and the control grid, means for applying a signal to said screen grid, and means for biasing said control grid to a potential sufficiently positive with respect to said cathode to give said oscillator-modulator a non-linear characteristic adapted to compensate for non-linearities of the characteristic of said light valve.

4. An oscillator-modulator according to claim 3 in which the positive bias applied to said control grid is substantially 45 volts.

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5. A light-modulating system comprising a source of signals, a non-linear ultrasonic light valve, a compensatory non-linear oscillator-modulator adapted to apply a modulated voltage of ultrasonic frequency to said light valve comprising an electron discharge device having an anode, a cathode, a screen grid and a control grid, means for applying a positive bias voltage to said control grid, and circuit means comprising a plurality of paths coupling said signal source to said screen grid, one of said paths including means for deriving a rectified voltage proportional to the amplitude of the signal and for applying said rectified voltage to said screen grid.

6. A system according to claim 5 in which said last-named means comprises rectifying and filtering means for producing a unidirectional derived voltage which decreases with a decrease of signal level, and means for applying said derived voltage to said screen grid with a polarity to decrease the potential of said screen grid with respect to said cathode with a decrease of signal level.

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7. A system according to claim 6 in which the last-named means includes means for limiting the rectified voltage to a maximum value.

VINCENT PAGLIARULO.

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