June 27, 1950 J. R. ALBURGER 2,512,785

NOISE REDUCTION SYSTEM

Filed Jan. 9, 1948

Fig. 1.

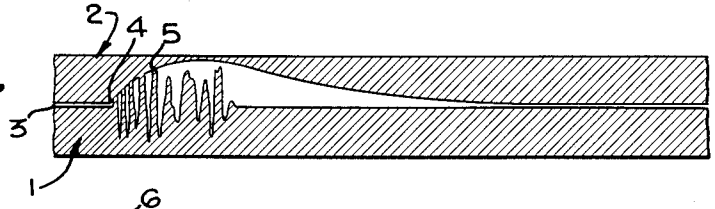
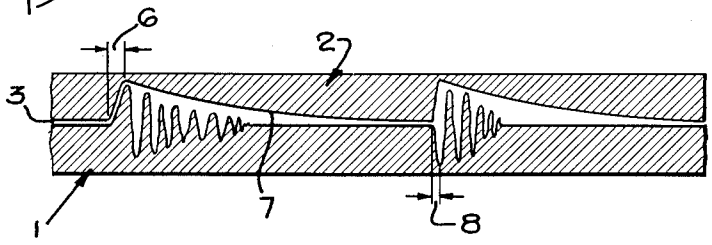


Fig. 2.



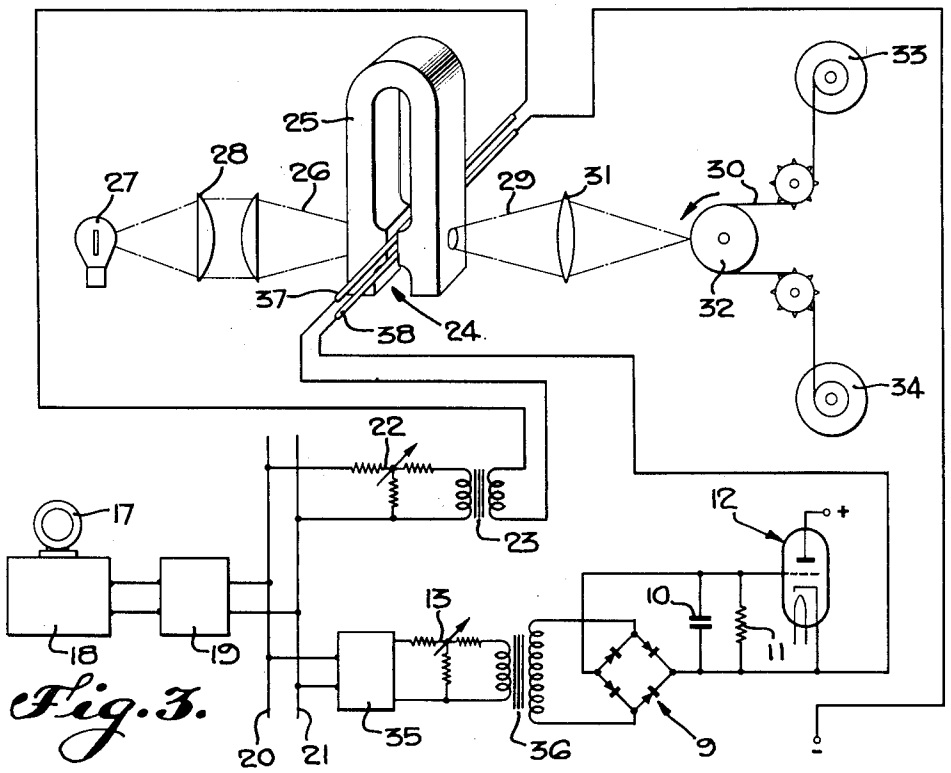


Fig. 3.

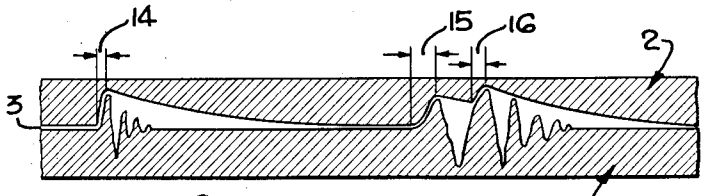


Fig. 4.

INVENTOR.

James R. Alburger

Patented June 27, 1950

2,512,785

UNITED STATES PATENT OFFICE

2,512,785

NOISE-REDUCTION SYSTEM

James R. Alburger, Los Angeles, Calif.

Application January 9, 1948, Serial No. 1,461

1 Claim. (Cl. 179—100.3)

1

This invention relates to a method of recording sound on film, and more particularly to a method of applying noise-reduction to sound-on-film recordings.

The usual practice in applying noise-reduction to sound recordings on film has been to superimpose a so-called noise-reduction envelope on the signal wave form so as to make the dimensions of the sound track, or its average density, dependent on the amplitude of the signal being recorded. This procedure results in a sound track which is very narrow at low signal levels, and which increases in width as the amplitude of the recorded signal is increased, or in the case of variable density track, the average density of the track is high for low signal levels and decreases toward a mean value as the amplitude of the recorded signal is increased. As a specific example, a particular variable area sound track might be found to have a "bias-line" width of about .001 inch at zero signal, and a width of .095 inch when the signal amplitude is increased to the maximum value permissible.

The application of noise-reduction may be accomplished in any one of several ways, and the particular method used is only incidental to this invention. A representative system is found in light valves of the ribbon type, although equivalent effects can be obtained with other systems using galvanometers or other light modulating devices. In the ribbon type light valve, the simplest form of noise-reduction is obtained by a two ribbon valve, where one ribbon carries the signal frequencies while the second ribbon carries the noise-reduction envelope. Many variations of the system can be derived by utilizing additional ribbons in the light valve and/or various types of optical systems or beam splitting devices used in conjunction with the ribbon light valve. Certain of these variations have been used in the past for the purpose of improving quality in the resulting sound reproduction.

In recording a sound track on film by use of a ribbon type light valve, light is directed through the ribbons by means of an optical system, and the image of the ribbons is focused on the moving film. As the ribbons vibrate in accordance with the applied signals, the sound track is produced as a latent image on the film. Subsequent photographic development and printing processes produce the finished sound track. Sound tracks may be made as variable-area or variable density tracks, but the basic premise of light modulation is equivalent in both cases, and the two types of tracks may be reproduced on the same equipment.

2

My invention is applicable to any and all types of sound tracks or sound recording systems in which noise-reduction is effected by a controlled variation of the width of the sound track or of the average density of the sound track.

In ordinary noise-reduction methods, the noise-reduction envelope is made to open as indicated in Figure 1. When no signal is impressed on the speech ribbon 1, the noise-reduction ribbon 2 is closed completely to produce a bias line 3 of predetermined width. When the signal is impressed on the speech ribbon as shown at point 4, the noise-reduction ribbon is caused to open to make more track width available for the recorded signal. It can be seen, therefore, that under these conditions the track width is large for full signal, and small with little or no signal, with the result that when the signal is small a reduction is effected in the "ground noise" of the track.

Heretofore it has been customary to apply an "attack" or opening characteristic to the noise-reduction envelope such that the ribbon opens exponentially in a time interval of from three to twenty-five milliseconds. A typical condition is about 17 milliseconds attack time. This means that when a 100% signal is applied, the noise-reduction ribbon opens to 80% of its full width in 17 milliseconds. A shorter attack time results in objectionable thump or "shutter-bump" due to the introduction of audible frequencies. The attack time can be shortened to about 3 milliseconds in push-pull sound tracks, but this is about the limit due to the difficulty of completely balancing out the noise-reduction thump.

It has been recognized that two very objectionable features attend the use of the conventional noise-reduction method. In the first place, the conventional noise-reduction envelope does not conform in any way to the signal being recorded, except that it is approximately coincidental in time. The result is that additional frequencies are introduced in the recorded track which were not present in the signal applied to the speech ribbon. These added frequencies are often audible in reproduction, and in many cases even though they may not be distinctly audible, they can be detected as an objectionable bumping or fluctuation of the reproduced signal.

A second objection is the fact that ordinarily the noise-reduction ribbon cannot open fast enough to get out of the way of the speech ribbon, with the result that "clipping" of the signal waves takes place as shown at 5 in Figure 1. Thus, it is very often the case that as many as 6 or 8 peaks

of the signal wave are cut off by the noise-reduction envelope. The distortion resulting from clipping is undesirable since it can be readily heard when the sound record is reproduced. Clipping can be avoided by anticipation noise-reduction methods involving the use of delay networks or other special circuits, however, such methods are expensive and inconvenient to use.

I have found that it is possible to apply a noise-reduction envelope to a sound track in such a way that both of the foregoing objections are avoided. By my method, I avoid the introduction of spurious frequencies not present in the signal being recorded, and I avoid the effect of clipping of the signal wave by the noise-reduction envelope.

One object of my invention is to provide an improved method of recording sound on film.

Another object of my invention is to provide a method for producing sound-on-film records with noise-reduction and which are free from frequency distortion due to the noise reduction envelope.

Another object of my invention is to provide a simplified method of applying noise-reduction to sound-on-film recordings.

Other and incidental objects of my invention will be apparent to those skilled in the art by a reading of the following specification.

An essential feature of my invention is illustrated in Figure 2 which shows that the attack characteristic of the noise-reduction envelope is made to conform to the wave shape of the signal transient. The basic premise of my method lies in the fact that by making the shape of the attack wave of the noise-reduction envelope conform exactly to the rising wave front of the signal, no new frequencies are introduced into the recorded wave, and only a certain amount of amplitude distortion is introduced into the sound record. The amplitude distortion thus produced is not objectionable since it occurs only in the transient portion of the signal wave, and is not a steady condition.

Since the noise-reduction envelope opens instantaneously with the signal transient, the effect of clipping is completely avoided. The elimination of clipping distortion far outweighs any amplitude distortion introduced by the method.

Figure 2 shows two possible conditions of the noise-reduction attack wave. At 6 the noise-reduction envelope rises adjacent to the signal transient with the effect that the transient signal is reduced to zero amplitude. The noise-reduction envelope then returns to closure according to a predetermined "release" characteristic 7 which is usually of the order of 250 milliseconds. A different condition is shown at 8, where the signal transient rises in the opposite direction from the noise-reduction envelope. In this case the amplitude of the transient wave is increased to twice its normal value. It is seen that the effect of my noise-reduction method is to introduce only an amplitude change in the rising transient of the signal wave, and no new frequencies are introduced.

A second essential element in my invention is a circuit which provides the desired attack characteristic of the noise-reduction envelope. Since this attack characteristic must conform exactly to the wave shape of the signal transient, I utilize the signal transient itself to provide the noise-reduction attack wave form. To obtain this result, I apply the signal to a full wave rectifier

as shown in Figure 3. The output of the full wave rectifier system 9 is fed into a condenser 10 shunted by a resistor 11. A rising voltage impressed on the rectifier will build up a charge on the condenser 10. If the signal is cut off, the charge on the condenser 10 will be dissipated through the resistor 11. The values of the condenser and resistor may be chosen to provide the desired release or discharge time.

The voltage which appears across condenser 10 may be applied by a variety of methods to control the noise-reduction element in a light valve or galvanometer system, thereby providing noise-reduction.

Although I describe one practical circuit for applying my noise-reduction method, I recognize other possible circuits and I consider that such other circuits and procedures lie within the scope of my invention. For example, the voltage appearing across condenser 10 may be applied to the light valve noise-reduction element by means of various types of amplifiers, direct-coupled, carrier types, etc. However, I prefer to apply the voltage appearing across condenser 10 to the control grid of a vacuum tube 12, the output of which drives the noise-reduction element of the light valve. For this purpose I find that certain grid controlled gaseous discharge tubes are satisfactory. In this circuit it is only necessary that sufficient driving voltage be generated across condenser 10 to effect a cut-off of the current through tube 12.

In operation, the circuit is adjusted so that with zero signal the proper current passes through the light valve noise-reduction element effecting closure to the desired bias line width. Then, with 100% signal, the voltage input to the diode rectifier is adjusted by means of the attenuator 13 so that the current through tube 12 is just cut off and the noise-reduction element is opened fully. The circuit is then operative so as to produce an attack characteristic which coincides in shape with the rising signal transient, and a release characteristic which is determined by the pre-selected constants of condenser 10 and resistor 11.

A so-called margin can be provided by increasing the voltage input to the rectifier 9 by adjustment of the attenuator 13. For example, the voltage input could be adjusted so that the noise-reduction ribbon is fully opened when the signal level is two decibels below 100% on the sound track. Greater or less margin may be provided depending on the desired operating conditions, zero margin being the condition obtained when the noise-reduction ribbon is fully opened at a signal level of 100% corresponding to maximum deflection of the ribbons. Provision of such a margin condition may be found advantageous in preventing interference of the noise reduction ribbon by the speech ribbon in case of any non-linearity in the response of the two ribbons.

The overall action of my noise-reduction system is illustrated in Figure 3 and is described as follows:

Sound waves are picked up by microphone 17 and the resulting electrical impulses are amplified by amplifiers 18 and 19, the amplified signal currents being supplied to the recording bus-bars 20 and 21. Signal currents flow from the bus-bars 20 and 21 through an adjustable attenuator 22, through a transformer 23 and through a signal responsive element 37 of a light modulating device 24. The currents flowing through the

ribbon or shutter 37 of modulator 24 react with the magnetic field of magnet 25 and produce a movement of said ribbon or shutter, thereby causing modulation of a beam of light 26 which is directed through light modulator 24. Light from a lamp 27 is directed through light modulator 24 by means of a lens system 28. The modulated light beam 29 is focused on a moving light-sensitive medium or film 30 by means of a lens system 31. The light-sensitive film is carried at constant speed in accordance with conventional procedure over drum 32, the film 30 being traversed from reel 33 to reel 34. Accordingly, there is impressed on film 30 a record of the light modulations corresponding to sound waves which are picked up by microphone 17.

Signal currents flow from the bus-bars 20 and 21 through an amplifier 35, through an adjustable attenuator 13, and through a transformer 36 to the full-wave rectifier system 9. Amplifier 35 may or may not be needed depending on the available signal level in bus-bars 20 and 21. Transformer 36 may be of the type illustrated or it may have center-tapped windings for use in connection with various kinds of rectifier systems. Rectifier system 9 is indicated as a so-called copper-oxide bridge rectifier, but if desired rectification may be accomplished using vacuum tube diodes arranged either in bridge form as shown or as a full-wave system utilizing a center-tapped winding on transformer 36. The rectified currents from rectifier 9 are applied to condenser 10 which is shunted by resistance 11.

For successful operation of the noise-reduction system, it is important that the time constant of the electrical elements looking into condenser 10 from transformer 36 be of the order of .0001 second or less. This means that the sum of the effective resistances of the transformer 36 plus that of the rectifier 9 multiplied by the capacity of the condenser 10 must give an R. C. time constant which is smaller than .0001 second. If this condition is maintained, then condenser 10 will be charged in faithful accordance with the characteristic of the rising transient of the applied signal current.

When the applied signal is removed, the charge built up on condenser 10 tends to leak away through the shunt resistor 11 in accordance with an exponential characteristic having a time constant equal to the product $R_{11} \cdot C$. As the charge leaks away, the system is gradually restored to its quiescent state. This restoration or "release time" should be as rapid as possible without introducing any audibly noticeable effects on the final sound reproduction. In practice, a time constant of 250 milliseconds is acceptable for this release characteristic, but the release time-constant may be varied over wide limits depending on factors of preference or of some particular effect which may be desired. The smallest practical release time-constant appears to be of the order of .02 second.

As a practical example of circuit constants which may be selected, condenser 10 may be chosen having a capacity of 10^{-8} farad. If resistor 11 is provided with a value of 10^7 ohms, the R. C. time-constant for the release characteristic is $10^7 \times 10^{-8} = 10^{-1}$ or 100 milliseconds. If the sum of the resistances of the transformer 36 and rectifier system 9 is held below 100 ohms, then the charging time-constant for the attack characteristic is $10^2 \times 10^{-8} = 10^6$ or .001 millisecond. This short attack time-constant permits the charging of condenser 10 to respond in very

close conformance to the characteristic of the rising signal transient. The example given above is for the purpose of illustration only, and I do not restrict my invention to the circuit elements thus indicated.

The electrical charge which appears across condenser 10 is applied to the grid of control tube 12, thereby causing control variations in current through tube 12. The current passing through control tube 12 is passed through a signal-responsive element 38 of light modulator 24. Variations in the current passing through element 38 react with the magnetic field of magnet 25 to produce variations in movement of element 38 thereby causing a modulation of the beam of light 26 passing through modulator 24. This second light modulation is superimposed on the light modulation produced by element 36, and both modulations are recorded simultaneously on film 30.

Figure 4 illustrates a typical sound track in which various types of transient impulses are recorded. In the case of a steep transient wave, the noise-reduction envelope also conforms as a steep wave, as shown at 14. When the signal transient is a low frequency impulse as at 15, the noise-reduction envelope conforms as a low frequency wave shape. When more than one rising transient occurs within a limited interval as at 16, the noise-reduction envelope follows a portion of each transient until a maximum displacement is reached. In every case, the noise-reduction envelope contains only frequency components which are present in the signal tranient, and no new frequencies are introduced.

Heretofore it has been thought that the application of a noise-reduction envelope in conjunction with a signal wave on a sound track must inevitably produce a so-called noise-reduction thump. This would of course be true in the case where the noise-reduction envelope introduces a series of frequency components which are not present in the signal being recorded. These added frequencies produce an audible thud or bump. However, by use of my method, no frequencies are added which are not present in the signal transient, with the result that a "bump," if present, cannot be distinguished from the signal itself except as a variation in amplitude. No bump or thud is heard when my noise-reduction system is utilized.

It is generally the case that the impact wave of a signal transient is a pressure wave. By this is meant that a sound wave striking a microphone usually causes an initial deflection of the microphone element in a direction away from the source of sound. This is not always the case, but it is more often true than not. For example, sharp blows such as metallic clicks, notes struck on a piano, explosive sounds, etc., generally produce waves which have pressure fronts. The result is that the transient waves which appear on the sound track rise for the most part in the same direction. By suitably connecting the input to the light valve, these rising transients may be made to move toward the noise-reduction ribbon. Then as the noise-reduction ribbon opens, the amplitude of the recorded transient is reduced to zero. By this means, the impact waves or pressure fronts are removed from the recorded signal. Reversing the connection of the speech ribbon results in an accentuation of the impact waves or pressure fronts. Thus by proper connection of the light valve speech ribbon, the pressure fronts of the

recorded sound transients can be suppressed or accentuated as desired.

It will be apparent to those skilled in the art that I have devised a new and novel method of applying noise-reduction to sound-on-film recordings. In addition, it will be seen that I have devised a simplified electrical circuit which permits application of noise-reduction to a sound track such that the resulting wave form is free from clipping distortion and noise-reduction thump.

I claim as my invention:

A sound recording apparatus, comprising a means for generating a signal, a light sensitive medium, a source of light, means for modulating said light beam in accordance with the instantaneous values of said signal, means for impressing said modulated light on said light sensitive material, means for rectifying a portion of said signal current including an impedance element having a time constant less than .0001 second, and a resistance element, the combination of said resistance element and said impedance element having a time constant greater than .02 second,

means for modulating said light in accordance with said rectified portion of said signal, means for impressing said second light modulation on said light sensitive material, and means intermediate said rectifier and said last mentioned light impressing means for producing substantially the same modulation of light as the first modulation thereof during the initial impression of said light beam on said light sensitive material.

JAMES R. ALBURGER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,993,795	Miller	Mar. 12, 1935
2,073,451	Lord	Mar. 9, 1937
2,237,904	Hack	Apr. 8, 1941
2,280,740	Belar	Apr. 21, 1942
2,323,032	Hack	June 29, 1943
2,414,666	Poulsen	Jan. 21, 1947