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Marie et al.

[11] 3,878,328
[45] Apr. 15, 1975

[54] **METHOD OF AND DEVICE FOR ELECTRONICALLY COMPENSATING FOR MECHANICAL STRESSES IN AN OPTIC RELAY**

[75] Inventors: **Gerard J. M. Marie,** Hay-Les-Roses; **Jacques Donjon,** Yerres; **Auguste Raymond LePape,** Viry-Chatillon; **Bernard Monod,** Limeil-Brevannes, all of France

[73] Assignee: **U.S. Philips Corporation,** New York, N.Y.

[22] Filed: **May 16, 1973**

[21] Appl. No.: **360,773**

[30] **Foreign Application Priority Data**

July 17, 1970 France.....7026420

**Related U.S. Application Data**

[63] Continuation of Ser. No. 162,507, July 14, 1971, abandoned.

[52] **U.S. Cl.**..... **178/7.5 D;** 178/DIG. 39; 350/150; 350/153

[51] **Int. Cl.**..... **H04n 5/68;** H04n 5/74; G02f 1/26

[58] **Field of Search**..... 178/5.4 BD, 7.3 D, 7.5 D, 178/7.85, DIG. 17, DIG. 39; 350/149, 150, 153

[56] **References Cited**

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| | | | |
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| 3,520,589 | 7/1970 | Angel et al. | 350/150 |
| 3,637,931 | 1/1972 | Donjon et al. | 178/5.4 BD |

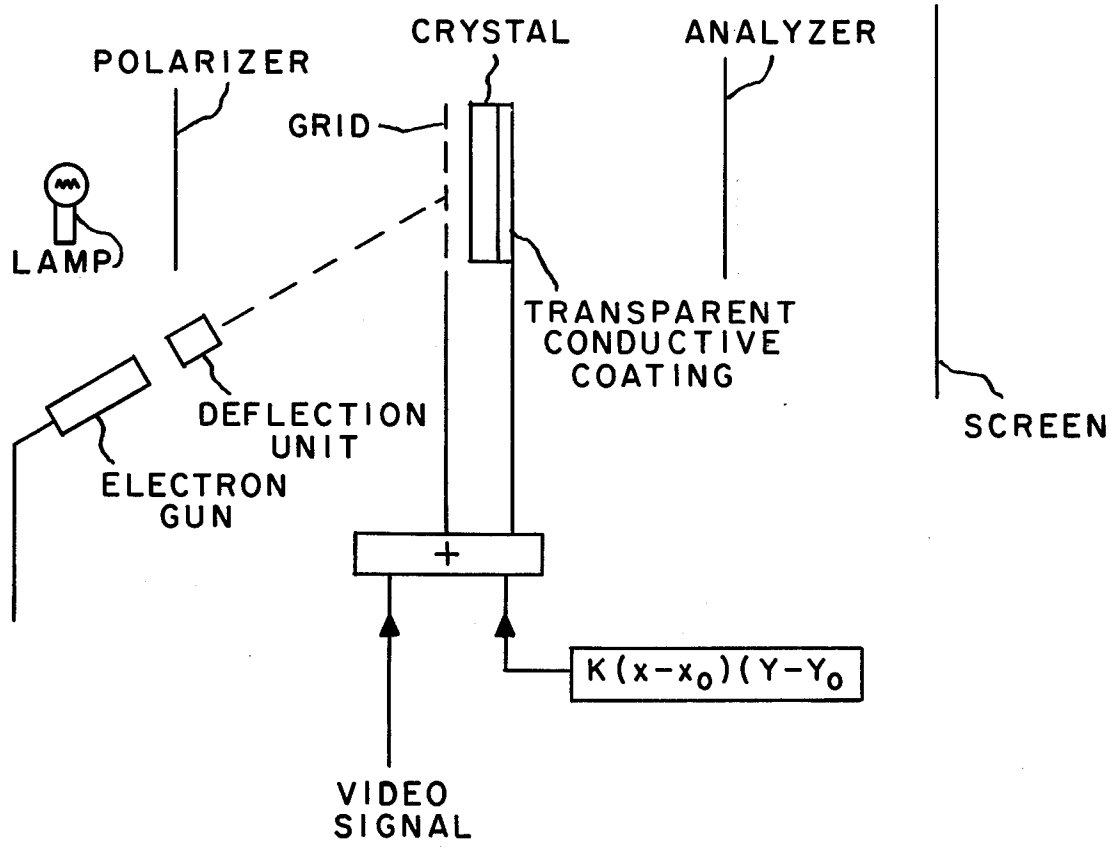
*Primary Examiner*—Robert L. Griffin
*Assistant Examiner*—George G. Stellar
*Attorney, Agent, or Firm*—Frank R. Trifari; Simon L. Cohen

[57] **ABSTRACT**

A method and a device for electronically compensating for stresses in an optic relay. In order to compensate for the mechanical stresses which occur especially during the cooling of the target in the relay, a sawtooth correction signal of line frequency is superimposed upon the video signal, the slope of the signal varying with the frame frequency.

Field of application: Projection of television pictures, FIG. 4.

**7 Claims, 5 Drawing Figures**




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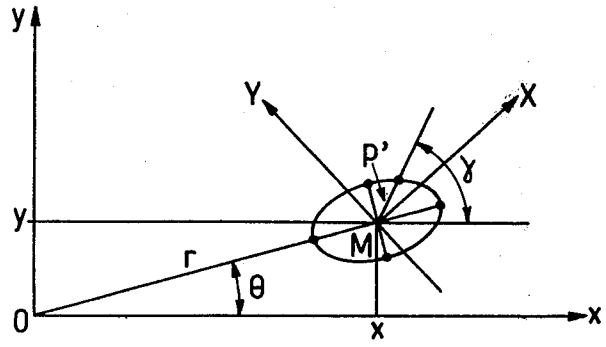



Fig.1

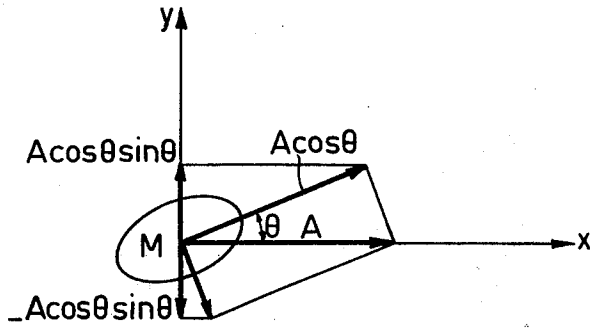



Fig.2

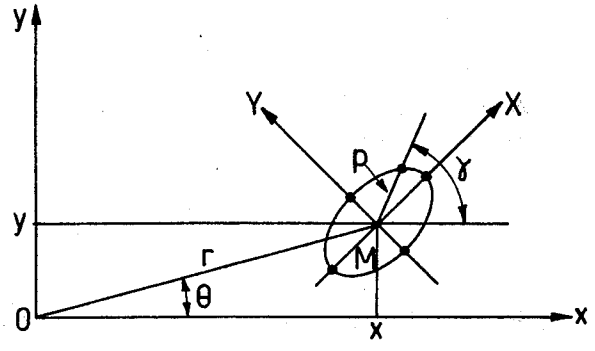



Fig.3

*INVENTORS*
GERARD JOSEPH MARCEL MARIE
JACQUES DONJON
*BY* AUGUSTE RAYMOND LE PAPE
BERNARD MONOD
AGENT

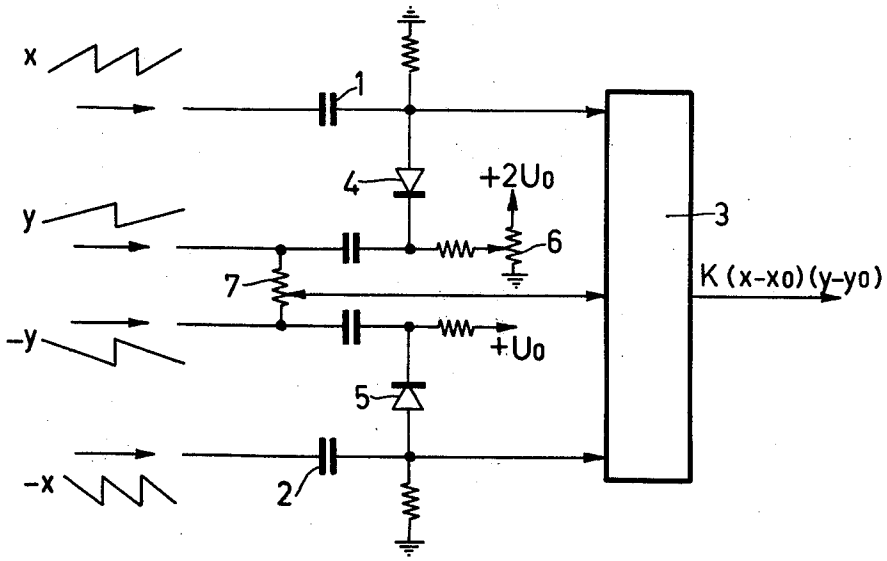



Fig.4

*INVENTORS*
GERARD JOSEPH MARCEL MARIE
JACQUES DONJON
*BY* AUGUSTE RAYMOND LE PAPE
BERNARD MONOD
AGENT

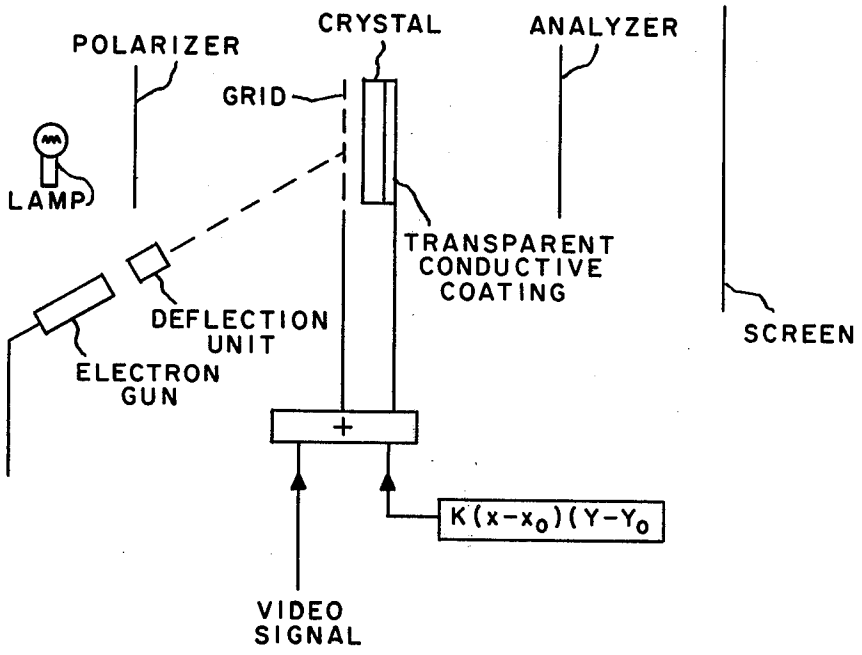

POLARIZER
CRYSTAL
ANALYZER
GRID
LAMP
TRANSPARENT CONDUCTIVE COATING
SCREEN
DEFLECTION UNIT
ELECTRON GUN
+
K(x-x0)(Y-Y0
VIDEO SIGNAL

Fig. 5

# METHOD OF AND DEVICE FOR ELECTRONICALLY COMPENSATING FOR MECHANICAL STRESSES IN AN OPTIC RELAY

This is a continuation of Application Ser. No. 162,507, filed July 14, 1971, and now abandoned.

The invention relates to a method of and a device for electronically compensating for mechanical stresses which occur in an optic relay comprising on the one hand a crystal having Pockels effect, hereinafter termed target, and on the other hand means for electronically scanning a first surface of said target. Such a relay is described in Applicant's French Pats. Nos. 1,473,212 and 1,479,284 the lateral French patent corresponding to U.S. Pat. No. 3,520,589. In the case described in these two patents, the target is cooled to in the proximity of the Curie temperature. This cooling consequently gives rise to certain mechanical stresses which are due to the difference of the coefficients of expansion of the target support and the target itself. These mechanical stresses cause brightness variations of certain zones and in particular the occurrence of stray light in zones which normally would have to be dark.

The mechanical stresses to be compensated for are rotationally symmetric, i.e., radial or tangential stresses the centre of symmetry of which has the coordinates $x_o$ and $y_o$. When $x_o = y_o = 0$, one has to do with rotationally symmetric stresses around the centre of symmetry of the target, of the target support or of the window. This is the most frequently occurring case and, during the manufacture of the tube, may occur:

- for the window: when same is secured to a ring constituted by another material, for example metal;
- for the target support: during the connection in the tube;
- for the target: when same is adhered to the support.

The said most frequently occurring case may also occur during operation and is then caused by temperature variations:

- for the window, the target and the target support, the temperature of which rises under the influence of the exposure to a strong light beam;
- for the target and the target support the temperature of which falls to in the proximity of the Curie temperature of the crystal under the influence of the cooling in the case of an optic relay of the type described the said patents.

Since the intensity of the exposure in variable, or as a result of the presence of an asymmetric mechanical stress during the manufacture of the window or during the construction of the tube elements, it is possible that the centre of symmetry of the stresses no longer coincides with the centre of symmetry of the tube elements.

It is the object of the invention to eliminate the said drawbacks.

The method of electronically compensating for mechanical stresses which occur in an optic relay comprising on the one hand a crystal having Pockels effect, hereinafter termed target, and on the other hand means for electronically scanning a first surface of said target, is characterized in that on the video signal supplied to the tube a voltage is superimposed which corresponds to the formula

$$v = k\,(x - x_o)\,(y - y_o) \tag{1}$$



where

$x$ and $y$ = the Cartesian scanning coordinates,

$x_o$ and $y_o$ = the coordinates of the centre of symmetry of the stresses,

$k$ = a factor which is proportional to the stresses to be compensated for.

This correction signal (compensation signal) has the form of a sawtooth of line frequency the slope of which is modulated proportional to a sawtooth signal of frame frequency.

In order that the invention may be readily carried into effect, it will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:

FIG. 1 is a cross-sectional view of the ellipsoid of the index of refraction of the material of the target in a plane which is parallel to the plane of the $x$ and $y$ axes, in which the index of refraction is determined by the mechanical stresses only.

FIG. 2 shows the resolution of the polarized light carried out parallel to the $x$ axis in two components which are parallel to the ellipse axes.

FIG. 3 is a cross-sectional view of the ellipsoid of the index of refraction in the case in which this is determined only by the signal.

FIG. 4 is an electronic circuit diagram to obtain the desirable correction signal.

FIG. 5 is a diagrammatic representation of a known optic relay attached to the device of FIG. 4.

With the signal voltage $v = k\,(x - x_o)(y - y_o)$ it is possible to compensate for the rotationally symmetric stresses to the 4th order. When, in order to simplify the calculations, the centre of symmetry of the stresses is chosen as the coordinate zero point, where $\theta$ and r are the polar coordinates of a point, the following relations exist between said coordinates and the rectangular system of axes $x$ and $y$:

$$x = r\cos\theta$$
$$y = r\sin\theta \tag{2}$$

A rotationally symmetric stress, i.e., a stress of which the orientation is radial or tangential, gives rise to a difference $\Delta' n$ (which may be positive or negative) of the indices of refraction in a radial and in a tangential direction. Due to the symmetry, $\Delta' n$ is independent of $\theta$; so one has:

$$\Delta' n(r, \theta + \pi) = \Delta' n\ (r, \theta),$$

which may be written as:

$$\Delta' n(-r, \theta) = \Delta' n(r, \theta),$$

which means that $\Delta' n$ is an even function of $r$.

So to the 4th order it holds that:

$$\Delta' n(r, \theta) = ar^2 \tag{3}$$

where $a$ is a positive or a negative constant value.

In a point M which has $x$, $y$ or r, $\theta$ as coordinates, the ellipsoid of index of refraction in a plane parallel to the system of axes $x - y$ is an ellipse of which one of the axes (the large or the small axis) passes through the centre of symmetry 0, as shown in FIG. 1.

An optic picture relay in which the Pockels effect is used functions between two crossed polarizers the directions of polarisation of which are parallel to the $x$ axis and to the $y$ axis, respectively. When the polarisation of the incident light of amplitude A is parallel to, for example, the $x$ axis, said light is resolved in the material of the target which is under stress into two components of the same phase which are parallel to the ellipse axes as is shown in FIG. **2.** After having traversed a track **1** in the medium, said two components at the output are shifted in phase over an angle $\phi' = 2\pi l \Delta' n/\lambda$ which according to formula (3) may be written as

$$\phi' = 2b\, r^2,$$

where $b$ is a constant value which is independent of $x$ and $y$.

The resultant in the direction $y$ of the output polarizer thus is equal to (FIG. **2**) the difference of two components of the same amplitude, A sin $\theta$ cos $\theta$ with a phase shift angle $\phi'$; so the amplitude of this resultant is:

$$T' = 2\mathrm{A} \sin\theta \cos\theta \sin\phi'/2$$

$$T' = A \sin(2\theta) \sin(br^2) \qquad (4)$$

A passed quantity of stray light thus occurs between the arms of a black cross which coincides with the coordinate axes.

During normal operation of an optic picture relay, a voltage V is applied between the surfaces of a crystal plate in the point M having $x$ and $y$ as coordinates and this voltage V gives rises to a double refraction. In the plane of the $x$ and $y$ axes, the axes of the ellipsoid of index of refraction are parallel to the bisectrices X, Y of the axes $x$, $y$ as shown in FIG. **3,** while the index difference $\Delta n$ of the directions X and Y is proportional to the intensity of the electric field. At the output, the phase shift angle $\phi$ between the two components directed according to X and Y thus is proportional to V:

$$\phi = 2\, cV.$$

By a calculation analogous to that of the mechanical stresses it is found that the amplitude of the light passed according to the direction of polarisation $y$ is equal to:

$$T = A \sin\phi/2$$

or

$$T = A \sin(cV) \qquad (5)$$

The ellipsoids of index of refraction which correspond to the mechanical stresses (FIG. **1**) and to the effective signal (FIG. **3**) have the same orientation for all points which are situated on two bisectrices X and Y of the coordinate axes. So the stresses can be compensated for when a component $v$ is superimposed upon the signal V which component, according to the equations (4) and (5) above, must satisfy the condition:

$$cv = -br^2 \sin(2\theta),$$

where

$$\theta = \pi/4,\ 3\pi/4,\ 5\pi/4 \text{ and } 7\pi/4.$$

This compensation is correct for any level of the signal V.

For the points ($\theta = \theta,\ \pi/2,\ \pi$ and $3\pi/2$) situated on the $x$ and $y$ axes, no stray light is passed when the signal V has zero amplitude. When this is not the case and the stresses occur in the target, the resultant transmission does not correspond to the transmission T given by the equation (5). When nevertheless it is supposed that the stresses cause a weak double refraction relative to the double refraction caused by the signal of maximum amplitude, the deformation which is caused in the characteristic T as a function of V is only of the 4th order and can hence be neglected. For these points the correction signal therefore is zero.

When the angle $\theta$ is arbitrary and the stresses occur in the target itself, the index ellipsoid herein will be the resultant of the ellipses shown in FIGS. **1** and **3.** Since the index variations $\Delta$n and $\Delta' n$ are never larger than approximately one thousandth, the eccentricity of the ellipses is very small and their polar equations may be written as:

in the case of the signal only (FIG. **3**):

$$\rho = n_o + \Delta n/2 \sin(2\gamma)$$

and in the case of the mechanical stresses only (FIG. **1**):

$\pi' = n_o + \Delta' n/2 \sin 2(\gamma + \pi/4 - \theta)$ where $\gamma$ is the angle between the $x$ axis and the direction in which the index is measured. Since $\Delta n$ and $\Delta' n$ are small, the ellipse equation which corresponds to the simultaneous presence of the signal and of the mechanical stresses may be written as:

$$\rho'' = n_o + \Delta n/2 \sin(2\gamma) + \Delta' n/2 \sin[2(\gamma + \pi/4 - \theta)]$$

In order that no light at all be transmitted when the amplitude of the voltage V is zero, it is sufficient for the axes of the resultant ellipse to be parallel to the $x$ and $y$ axes. For that purpose it is required only that:

$$\rho'(\pi/4) = \rho''(-\pi/4).$$

This condition may be written as:

$$\Delta n/2 + \Delta' n/2 \sin(2\theta) = -\Delta n/2 - \Delta' n/2 \sin(2\theta)\ \Delta n$$
$$= -\Delta' n \sin(2\theta)$$

or

$$\phi = -\phi' \sin(2\theta).$$

According to the expression founds for $\phi$ and $\phi'$, the value of the correction voltage $v$ to be applied is equal to:

$$v = -2\, b/c\, r^2 \sin\theta \cos\theta \qquad (6)$$

This expression corresponds to the already found results for the points which are situated on the axes and the bisectrices. As already said for the points situated on the axes, the caused deformation is only of the fourth order when the amplitude of the effective signal V differs from zero and the deformation can be neglected when the double refraction caused by the stresses is small compared with that which is caused by the signal of maximum amplitude.

When the angle $\theta$ arbitrary and the stresses occur in the target support or in the window, it is sufficient to perform the correction for the effective signal of ampli-

tude zero when one always starts from the assumption that the double refraction caused by this stress is small as compared with that caused by the signal of maximum amplitude. Since the light moves successively through several media the index ellipses of which usually do not have the same orientation, it is necessary to resolve the light successively two times.

Starting, for example, from the assumption that the medium subjected to stress is traversed by the light before said light reaches the target, components which are parallel to the $x$ and $y$ axes are obtained at the output of said medium the amplitude of the second component is given by the equation (4):

$$A'' = A \sin (2\theta) \sin (b r^2)$$

After having traversed the target, the amplitude of the said component will be equal to:

$$A'' \cos (cv) = A \sin (2\theta) \sin (br^2) \quad \sqrt{1-\sin^2(cv)} \quad (7)$$

The component emerging from the medium and the direction of which is parallel to the $x$ axis has the amplitude:

$$A' = \sqrt{A^2 - A''^2} = A \quad \sqrt{1 - \sin^2(2\theta) \sin^2(br^2)}.$$

With reference to the diagram of vectors shown in FIG. 2 it can easily be calculated that the said component has a phase shift over an angle $\Psi$ relative to the original component, said angle corresponding to the relation:

$$tg\ \Psi = tg(br^2) \cos (2\theta) \quad (8)$$

After having traversed the target, said component in the direction of the $y$ axis gives another component the amplitude of which can be derived from equation (5) and is equal to:

$$A'(\sin(cv) = A \sin(cv) \quad \sqrt{1 - \sin^2(2\theta) \sin^2(br^2)} \quad (9)$$

At the output the sum of two components is thus obtained the amplitudes of which are given by the expression (7) and (9) and the phase difference $\Psi$ of which is given by the relation (8). Since the angle $\Psi$ in absolute value is smaller than or equal to the value $br^2$ which is assumed to be small, a situation of minimum transmission is thus reached when the sum of the amplitudes of the two components is equal to zero, that is to say when:

$$A \sin(2\theta) \sin(br^2) \quad \sqrt{1-\sin^2 cv} + A \sin(cv-) \sqrt{1-\sin^2(2\theta)} \sin^2(br^2) = 0$$

This is the case when:

$$\sin (cv) = -\sin (2\theta) \sin (br^2)$$

In light intensity, this minimum value is of the fourth order in $(br^2)$, which thus can be neglected.

Since one has started from the assumption that the quantities $(cv)$ and $(br^2)$ are small, the above relation applies, to the third order as regards the amplitude and hence to the fourth order as regards the light intensity, when the expression is satisfied:

$$v = -b/c\ r^2 \sin (2\theta)$$

which corresponds to the same correction signal as in the case in which the mechanical stresses occur in the target (equation 6).

It may be seen that this is the case also when the medium showing the stresses is traversed by the light after this has traversed the target, and when the light traverses the medium in front of and behind the target which occurs when the optic relay is traversed two times by the light.

The equation (6) may also be written as: $v = -2 - r^2 \sin\theta \cos\theta$, $v = -2\ b/c\ xy$ when the cylindrical coordinates $r$, $\theta$ are replaced by the rectangular coordinates $x$, $y$ (formula 2).

So the correction signal corresponds to the form:

$$v = kxy,$$

while, in the general case in which the coordinate centre is the centre of the tube elements, the formula (1) is again found:

$$v = k\ (x - x_o)\ (y - y_o).$$

FIG. 4 shows by way of example an electronic diagram which can supply the correction signal corresponding to the form $k\ (x - x_o)\ (y - y_o)$ in the case of a scanning system of the television type: two sawtooth symmetrical signals $x$ and $-x$, of line frequency, are supplied to a mixer 3 via two modulatable dividers each of which is mainly formed by the series arrangement of a fixed capacitor (1, 2) and a variable capacitance (4,5) of the varicap type; the two variable capacitances are modulated in opposite phases by means of two sawtooth symmetrical signals $y$ and $-y$ of frame frequency. The average voltage supplied to one of the variable capacitances has a fixed value and the other had a value which can be controlled by means of the potentiometer 6 which permits of controlling the ordinate of the centre of symmetry of the correction so as to cause said ordinate to coincide with the ordinate $y_o$ of the centre of symmetry of the mechanical stresses. In order to cause the abscissa of the centre of symmetry of the correction to coincide with the abscissa $x_o$ of the centre of symmetry of the mechanical stresses, a component is introduced into the mixer which is proportional to $y$ and the sign and amplitude of which can be controlled by means of the potentiometer 7.

FIG. 5 shows how the apparatus of FIG. 4 may be used to add a correction signal to a video signal in a known optic relay described in U.S. Pat. No. 3,520,589.

The invention also relates to the compensation of rotationally symmetric stresses in the case of a polar scanning system when the scanning centre and the centre of symmetry of the mechanical stresses coincide: radial scanning, for example of the radar type, or spiral scanning. The equation (6) corresponding to the form:

$$v = k'r^2 \sin (2\theta)$$

demonstrates that the correction voltage must then be proportional to the second power of the distance $r$ between the point in question and the centre and also proportional to the sine of the double value of the scanning angle $\theta$.

The correction signal $v$ given by the expression (1) (rectangle coordinates) or (6) (polar coordinates) is alternately positive and negative. In the case of the optic relay already described in the said patents and shown in FIG. 5, the correction signal superimposed upon the video signal is supplied between on the one hand a transparent conductive coating on a surface of the crystal plate having Pockels effect and on the other hand a grid placed near the other surface; but for a few volts, an electron beam from an electron gun con-

trolled by a deflection unit plays the part of "flying short circuit" between said other surface and the grid. As described in said patent the electric field pattern resulting from interaction of the electron beam and the signal on the grid causes the light from a lamp polarized by a polarizer to be selectively rotated in polarization and thereby to be spatially modulated in intensity before impinging on a screen. Since it is possible to supply between the two surfaces of the plate either positive or negative voltages, one is then not confronted with some recording problem or other of the alternately positive and negative corrections signals, whichever is the amplitude of the video signal.

When an optic relay is used of the type in which the recording occurs via the modulation of the intensity of an electron beam (see, for example, the article by D. H. Pritchard in the paper "RCA Review," volume 30, pp. 567 to 592, December 1969), only signals of the same polarity can be recorded on the crystal plate. In order to electronically compensate for the mechanical stresses when the overall signal, constituted by the superposition of the compensation signal on the video signal, is alternately positive and negative, a direct voltage component must be added to said overall signal to give said overall signal always the same polarity and a phase plate must be placed in the optical track the neutral lines of which are parallel to the bisectrices X and Y of the axes and which gives a constant phase shift angle the sign of which is opposite to the phase shift angle in the optic relay. The control of the zero transmission level can be carried out either by controlling said phase shift when a controllable compensator is used, for example of the Bravais type, or by controlling the direct voltage component of the signal when a simple phase plate is used. For the superposition of the correction signal on the video signal the non-linearity of the modulation characteristic of the beam current must be taken into account in all cases and possibly a $\gamma$ correction which is used in television cameras must be used. As in the device shown in FIG. 5, the electrical field pattern on the crystal is connected to an optical phase pattern that locally rotates the polarization of light from a lamp that was initially passed through a polarizer. As described above, a phase shifter placed in the optical path of the light passing through the crystal for adding a uniform phase shift to the light, combined with the D.C. voltage add to the video signal aids in the compensation of mechanical stresses.

What is claimed is:

1. A method of electrically compensating for mechanical stresses occuring in a Pockels effect crystal used in conjunction with a television type electronic scanner in an optic relay supplied with video information signals comprising the steps of generating a voltage corresponding to the formula:

$$v = k\,(x - x_o)\,(y - y_o),$$

where

$x$ and $y$ = the Cartesian scanning coordinates,

$x_o$ and $y_o$ = the coordinates of the center of symmetry of the stresses,

$k$ = a factor which is proportional to the stresses to be compensated for,

and superimposing the generated voltage on the video information signal.

2. A method as claimed in claim 1 for use in conjunction with an optic relay where the video information signal is applied in the form of an electric field across the crystal, wherein the step of superimposing the generated voltage on the video signal comprises the step of applying the generated voltage in the form of an additional electrical field across the crystal.

3. A method as claimed in claim 1 wherein the step of generating the voltage comprises the step of separately modulating two symmetrical sawtooth signals of line frequency with two sawtooth signals of frame frequency, and adding the results of the modulation.

4. A method as claimed in claim 1 for use in conjunction with an optic relay where the video signal modulates the electronic scanner, wherein the step of superimposing the generated voltage on the video signal comprises the step of applying the generated voltage in the form of an additional modulating signal to the electronic scanner signal.

5. A method for electronically compensating for stresses occurring in a Pockels effect crystal used in conjunction with a polar-type electronic scanner of an optic relay supplied with video information signals, comprising the steps of generating a voltage corresponding to the formula:

$$v = k' r^2 \sin (2\,\theta)$$

where:

$r$ and $\theta$ are the polar scanning coordinates and

$k'$ is a factor which is proportional to the stresses to be compensated for, and superimposing the generated voltage on the video information signal.

6. A method as claimed in claim 5 for use in conjunction with an optic relay where the video information signal is applied in the form of an electrical field across the crystal, wherein the step of superimposing the generated voltage on the video signal comprises the step of applying the generated voltage in the form of an additional electric field across the crystal.

7. A method as claimed in claim 5 for use in conjunction with an optic relay where the video signal modulates the electronic scanner, wherein the step of superimposing the generated voltage comprises the step of applying the generated voltage in the form of an additional modulating signal to the electronic scanner.

* * * * *

# UNITED STATES PATENT OFFICE

# CERTIFICATE OF CORRECTION

Patent No. 3,878,328 Dated April 15, 1975

Inventor(s) Gerard J. M. Marie et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 4, line 30, the equation should read:

$$--\rho' = n_o + \frac{\Delta' n}{2} \sin 2(\gamma + \frac{\pi}{4} - \theta)--;$$

line 42, "$\rho'$" should be --$\rho$"--;

Col. 5, line 24, the line should read as follows:

$$--A' = \sqrt{A^2 - A''^2}$$

$$= A\sqrt{1 - \sin^2(2\theta) \sin^2(br^2)}--;$$

Col. 6, lines 5 and 6, the equation should read as follows:

$$--v = -2 \frac{b}{c} r^2 \sin\theta \cos\theta$$

$$v = -2 \frac{b}{c} xy--;$$

Claim 4, line 7, cancel "signal".

Signed and Sealed this

sixteenth Day of December 1975

[SEAL]

*Attest:*

RUTH C. MASON
*Attesting Officer*

C. MARSHALL DANN
*Commissioner of Patents and Trademarks*