

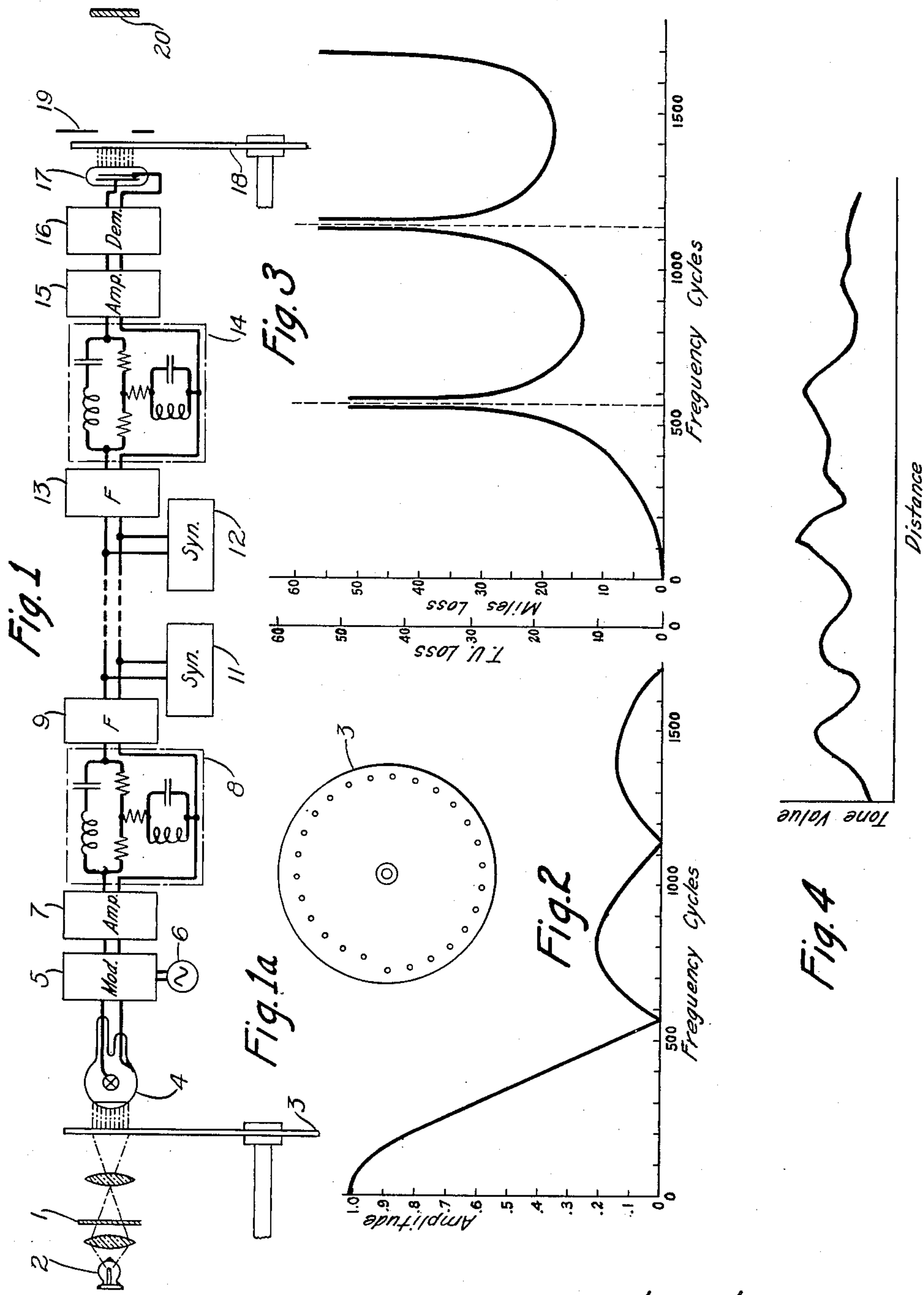
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SYSTEM FOR CONVERTING LIGHT ENERGY INTO ELECTRICAL ENERGY AND VICE VERSA

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UNITED STATES PATENT OFFICE

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SYSTEM FOR CONVERTING LIGHT ENERGY INTO ELECTRICAL ENERGY AND VICE VERSA

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This invention relates to distortion correction in systems employing scanning operations and more particularly in television, telephotographic and sound recording and reproducing systems.

An object of the invention is to improve the operation of systems employing scanning by taking account of, and compensating for, at least in part, the distortion due to the finite dimensions of scanned elemental areas.

Considering for example, ordinary picture transmission systems and television systems in which the light from successive small areas of an optical field is used to set up current variations in an electrical circuit, and these variations are used to control a beam of light at the receiving station to produce the image, the elemental areas of the field at the transmitter and those at the receiver which are at any instant illuminated and scanned are necessarily of finite size. The result of the finite dimensions of the elemental areas involved in the scanning operation is to produce distortion in that neither the electrical waves produced by the light at the transmitting station nor the impression upon the photographic film or the eye produced by the light at the receiving station exactly corresponds respectively to the point-to-point variations of the light tone values of the field which is scanned at the transmitter and the current which is received at the receiver. Similarly, every scanning operation involving elemental areas of finite dimensions however performed introduces distortion due to the finite dimension of the elemental areas in the direction of scanning.

Applicant has discovered that distortion of this type can be represented as an attenuation variable with respect to frequency and that, for a fixed width of aperture and velocity of scanning (that is, velocity of either the image or aperture with respect to the other) it can be corrected, at least in part, by means of an attenuation equalizer of fixed value in the electrical circuit.

In a specific embodiment herein described for purposes of illustration, this invention comprises a picture transmission system employing a rotating disc with a series of aper-

tures of fixed size by means of which the image to be transmitted is scanned in line series of elemental areas of finite dimensions as the disc rotates. The light passing through the apertures impinges on a photoelectric cell generating electrical waves, which represent the integrated light of each elemental area of the image exposed. An electrical network having such an attenuation characteristic as to tend to correct for the distortion produced by the finite dimensions of the elemental areas is connected in the electrical circuit so that the final electrical wave corresponds substantially to the time variations of the tone value of the elemental areas of the picture as it is scanned. Similarly, at the receiving end of the system there is employed an electrical network which will so attenuate the electrical waves as to at least largely compensate for the distortion produced by the finite dimensions of the elemental areas in the direction of the apertures of the receiving disc, with the result that the final exposure will more nearly correspond to the original image. Obviously, if desired, the system may be modified by employing one electrical network for correcting for the distortions produced by the finite dimensions of the elemental areas in the direction of motion at both the transmitting and receiving stations.

Although this invention is illustrated in connection with a picture transmission system, it is also applicable to other systems employing apertures of fixed size or equivalents, as hereinafter explained in more detail.

In the drawings, Fig. 1 shows in diagrammatic form a moving picture transmission or television system embodying the invention; Fig. 1^a shows a front view of one of the scanning discs employed in the system of Fig. 1; Fig. 2 is a scanning response curve, the ordinates indicating on a percentage basis the current transmitted by the system at any particular frequency without the aid of equalizing networks; Fig. 3 is also a scanning response curve based on the same data as the curve shown in Fig. 2 but showing the relation of frequency to loss in transmission units.

and in miles; and Fig. 4 is a tone value-distance curve, the ordinates being the tone values of the different elemental areas of a single line-series of elements of a picture or object whose image is to be produced and the abscissæ being distances along the line-series.

An aperture of finite dimensions when positioned opposite any part of a picture or scene to be transmitted will usually cover an area which is not uniformly illuminated. One edge of the exposed area may, for example, be very dark, while the other edge may be very bright. The pencil of light passing through the aperture from this area to the photo-electric cell will give rise to a current which will be proportional to the average brightness of the area. As the aperture and picture move with respect to each other, the current varies in accordance with the average brightness of the picture over its elemental areas. If the motion carries the aperture over a sharp vertical division between white and black, the resulting current will vary from a maximum before the aperture reaches this division line, to a minimum after the aperture leaves the division line, through a constantly diminishing value as more of the aperture is covered by the black. The opposite effect occurs when the aperture moves over a sharp vertical division between black and white. If now the picture is made up of a number of vertical stripes of black on a white background, and the stripes are narrower than the aperture, even with the whole stripe centered behind the aperture some white will be exposed and the photoelectric current will never reach the minimum corresponding to black. Such results occur when the details of the picture to be transmitted are comparable in size to the dimensions of the aperture. They produce, in the reproduced picture, a blurred effect where there should be an abrupt change in shade.

A mathematical expression for the distorting effect of the finite width of aperture may be developed and this will first be discussed.

Any finite elemental area may be considered as made up of a number of component areas each one small enough so that its tone value does not perceptibly vary. These component areas may be considered as being arranged in rows and columns, and a beam of light transmitted by a practical aperture may be considered as made up of numerous small beams, each produced by one of the component areas. As the aperture and film move past one another each component beam varies in intensity with the nature of the optical field. Each component beam contributes a certain amount of light to the illumination of the photoelectric cell and the total light incident on the cell at any instant is the sum of the contributions from all the component areas.

Assume now that the aperture is moving past the picture with a uniform speed in a direction parallel to the rows and perpendicular to the columns of component areas. Any one row of component areas has the same succession of picture light intensities and constitutes a strip having the width of a single component area. The illumination received by the photoelectric cell from each component area in the row goes through the same series of variations, but will be in slightly different phase for each such area.

A column of component beams may be considered as a unit contributing a total light flux corresponding to the average density in a narrow transverse band of the picture. The contribution of a column to the illumination of the photoelectric cell may be represented by a curve or wave showing the illumination as a function of time or of distance along the picture such as shown in Fig. 4. Successive columns in the entire elemental area (where rectangular) contribute the same light variations, but at a later time so that their contributions may be represented by a series of curves like that of Fig. 4 in different phase positions. The sum of the curves representing the contributions of all the columns gives a single curve which represents approximately the photoelectric current as a function of time. The exact form of the current curve may be found by assuming the component areas to be infinitesimally small and integrating to obtain the total effect. This process assumes, of course, that the electrical circuits associated with the photoelectric cell introduce no change in the wave form.

The fundamental curve corresponding to a single column of component areas may be resolved into single frequency components by means of Fourier's series, of Fourier's integral as the case requires. This fundamental wave represents the light variations of the picture and also the current which would result from scanning the picture with a beam of unvarying dimensions produced by a single infinitely narrow aperture. The curve representing the actual current is therefore obtained by adding together a large number of copies of the fundamental wave displaced in phase by various amounts. Alternatively the actual current may be found by first summing up the phase displaced copies of each component frequency and then combining the effects of the various frequencies. A typical component wave due to a single column of the very small apertures (assuming that the aperture is of the same size as each elemental area scanned thereby) may be assumed to have an amplitude A , phase angle zero and a wave length KX (X being the width of the aperture). The wave length will have this definite relation to the aperture width because of the uniformity of the scanning velocity. If x denotes the distance along the picture

from any reference point to the centre of the aperture and I the brightness at the point corresponding to $x + \lambda$, the equation representing this particular wave component will be

$$I = A \sin \frac{2\pi (X + \lambda)}{KX} \quad (1)$$

where λ is the distance of the elemental aperture from the centre of the physical aperture.

The electrical response dy due to light flux through the elemental aperture of width $d\lambda$ will be proportional to the product $I d\lambda$, or

$$dy = A \sin \frac{2\pi}{KX} (x + \lambda) d\lambda \quad (2)$$

The response due to the whole square aperture which is designated by y_s is therefore

$$y_s = \int_{-\frac{X}{2}}^{+\frac{X}{2}} A \sin \frac{2\pi}{KX} (x + \lambda) d\lambda$$

$$= \frac{AKX}{\pi} \sin \frac{\pi}{K} \sin \frac{2\pi x}{KX} \quad (3)$$

By reason of the uniform velocity of scanning, denoted by s , the time α for the whole aperture to pass a given point on the picture is given by

$$\alpha = \frac{X}{s}, \quad (4)$$

and hence Equation (3) may be written

$$y_s = \frac{AKX}{\pi} \sin \frac{\pi}{K} \sin \frac{2\pi}{K\alpha} t, \quad (5)$$

which expresses the electrical response in terms of the time t , and a frequency defined by

$$\frac{1}{K\alpha}, \text{ since } t = \frac{x}{s}$$

The amplitude of the response varies in accordance with the factor

$$K \sin \frac{\pi}{K}, \quad (6)$$

which, accordingly, is a measure of the distorting effect of the aperture. Since an aperture such as is used in practice is not infinitely narrow but has a finite width, there is a discriminatory response with respect to aperture width and the wave lengths of the component variations in the pattern of the picture or field, as evidenced by the expression (6), in which the amplitude of the response is given as a function of the ratio of wave length to aperture width.

The above analysis shows that the action of the aperture is to set up a current having frequency components of incorrect relative amplitudes. Compensation may be effected by introducing a complementary frequency discrimination.

The derivation of a mathematical expression for a square-shaped aperture as given above illustrates the manner in which similar derivations may be made for apertures of other shapes; for example, circular and elliptical apertures. The derivation of an expression for a circular aperture and comparison of the equations for square and circular apertures is subsequently made herein.

Fig. 2 and Fig. 3 represent the variation with frequency of the electrical components transmitted by the system and are generally typical for different scanning velocities and for different widths of aperture, though they are based on calculations for the particular case in which the scanning velocity is 8.5 inches per second, and the aperture width is 0.015 inches. The curves show that at certain frequencies the response falls to zero. These frequencies correspond to the cases where the aperture width is equal to one or more wave lengths of the component waves of the space-density distribution. In practice it is desirable to use an aperture of small enough width so that frequency of the first zero point is above the highest necessary for a good reproduction of the picture.

It is seen from the foregoing analysis of the action of a square aperture a scanning area of any shape may be resolved into a number of narrow elemental strips having lengths equal to the chords of the scanning aperture area and extending lengthwise in a direction parallel to the direction of the scanning.

Each such elemental strip or chord constitutes an elemental scanning area having an infinitesimal width and a finite length, measured in the direction of the motion, equal to the length of the chord.

Except for a specially selected scanning area, for example, one in the form of a square or parallelogram, the elemental scanning strips or chords comprising the complete scanning area will not be of equal length but the length of each will depend upon the location of the particular strip or chord.

The distorting effect of any one of the component elemental scanning areas is given as before by Equation (5), the symbol K therein being given a different value for each length of elemental area.

The distorting effect of the complete scanning area is for all practical purposes a weighted average of the distorting effects of the component scanning areas.

On the right hand side of Equation (5), the sole factor which determines the distorting effect due to the shape of the scanning area is $\sin \frac{\pi}{K}$. This will be apparent when it is observed that KX is by definition the wave length of a component of the pattern

of the optical field or image. The dimensions of the pattern are, of course, unchanged by any variation in the shape of the scanning area.

5 In the case of a scanning area of circular outline, the average value of the factor $\sin \frac{\Pi}{K}$ weighed for the varied lengths of the component scanning areas of the aperture, may be
10 derived by the following mathematical integration.

For purposes of convenience in performing the integration, the symbols K_0 and h will be introduced but these symbols will be eliminated from the mathematical expressions before the final result is reached. K_0 denotes
15 the particular value of K corresponding to a rectangular aperture of the same length as the diameter of the circular aperture under consideration. The symbol h denotes the distance of any component elemental rectangular aperture or chord from the center of the
20 circular aperture.

25 The value of K for any particular chordal elemental aperture is dependent upon the distance h of the chord from the center of the whole circular aperture, in a manner defined by the following equation:

$$30 \quad K = \frac{K_0}{\sqrt{1 - K_0^2 h^2}} \quad (8)$$

This value of K may be substituted in the
35 expression $\sin \frac{\Pi}{K}$ and the latter integrated between the limits $h = \pm \frac{\Pi}{K_0}$. The average

40 value of $\sin \frac{\Pi}{K}$ is obtained by dividing the value of the integral by the difference $\frac{2}{K_0}$

between the limiting values of h . The result
45 is given by the following equation:

$$50 \quad \frac{K_0}{2} \int_{-\frac{1}{K_0}}^{+\frac{1}{K_0}} \sin \frac{\Pi \sqrt{1 - K_0^2 h^2}}{K_0} dh$$

$$55 \quad = \int_0^{\frac{1}{K_0}} \sin \frac{\Pi \sqrt{1 - K_0^2 h^2}}{K_0} (K_0 dh) \quad (9)$$

To facilitate a transformation of the above definite integral into a standard form, the solution of which is given in mathematical
60 treatises, it is necessary to make a substitution of a new variable θ , defined as follows:

$$65 \quad \cos \theta = \sqrt{1 - K_0^2 h^2} \quad (10)$$

The following corollaries also hold between

the new variable θ and the old variable, h :

$$\sin \theta = K_0 h \quad (11)$$

$$K_0 dh = \cos \theta d\theta \quad (12)$$

The substitution of (10), (11) and (12) in
70 (9) gives the following result:

$$75 \quad \int_0^{\frac{\Pi}{2}} \cos \theta \sin \left(\frac{\Pi}{K_0} \cos \theta \right) d\theta \quad (13)$$

By reference to Formula (8) on page 21 of "A Treatise on the Theory of Bessel Functions", by G. N. Watson, University Press,
80 Cambridge, 1922, the evaluation of the definite integral (13) is seen to be given by the following equation:

$$85 \quad \int_0^{\frac{\Pi}{2}} \cos \theta \sin \left(\frac{\Pi}{K_0} \cos \theta \right) d\theta = \frac{\Pi}{2} J_1 \left(\frac{\Pi}{K_0} \right) \quad (14)$$

In Equation (14), $J_1 \left(\frac{\Pi}{K_0} \right)$ signifies a Bessel
90 function of the first order, for the argument $\frac{\Pi}{K_0}$. The ratio K_0 is measured as between the wave length of a given component of the pattern of the optical field or image and the di-
95 ameter of the circular scanning area.

The diameter of a circular aperture of the same area as a square aperture, with a side of
100 length X , is $\frac{2}{\sqrt{\Pi}} X$. Since $KX = \lambda$, for all values of λ , the value of K_0 for the circular aperture of diameter $\frac{2}{\sqrt{\Pi}} X$ is necessarily $\frac{\sqrt{\Pi}}{2} K$.

The amplitude A was used in Equation (1)
105 in connection with the response from the square aperture in order to proportion the response to the width of the aperture measured at right angles to the direction of scanning. In calculating the response from a
110 circular aperture of equal area to the square aperture the amplitude A must be multiplied by $\frac{2}{\sqrt{\Pi}}$.

The distorting effect of the circular aperture of area equal to that of the square aperture will be denoted by y_c and is found by
115 substituting $\frac{\Pi}{2} J_1 \left(\frac{\Pi}{K_0} \right)$, from the right hand side of Equation (14), for $\sin \frac{\Pi}{K}$ in Equa-

tion (5) and in addition substituting $\frac{\sqrt{\Pi}}{2} K$
120 for K_0 and $\frac{2}{\sqrt{\Pi}} A$ for A for the reasons given above. The result of these substitutions is

$$130 \quad y_c = \frac{AKX}{\sqrt{\Pi}} J_1 \left(\frac{2\sqrt{\Pi}}{K} \right) \sin \frac{2\Pi}{K\alpha} t \quad (15)$$

A comparison of Equations (5) and (15) shows that the right hand members differ in the numerical constant factors $\frac{1}{\Pi}$ and $\frac{1}{\sqrt{\Pi}}$ respectively, and in the functional expressions $\sin\left(\frac{\Pi}{K}\right)$ and $J_1\left(\frac{2\sqrt{\Pi}}{K}\right)$ trigonometric and Bessel functions, respectively.

The responses of the two apertures if of equal area must, however, come to be identical in case each is used to scan a uniform field of the same intensity. The value of K for such a field with any finite aperture is infinite, because the wave length of the pattern of the field is then infinite in comparison with the length of the aperture. For K infinite, the limiting values of the respective functions are as follows:

$$\sin \frac{\Pi}{K} = \frac{\Pi}{K} \quad (16)$$

$$J_1\left(\frac{2\sqrt{\Pi}}{K}\right) = \frac{1}{2}\left(\frac{2\sqrt{\Pi}}{K}\right) = \frac{\sqrt{\Pi}}{K} \quad (17)$$

Under these limiting conditions

$$y_s = \left(\frac{AKX}{\Pi}\right)\left(\frac{\Pi}{K}\right) \sin \frac{2\Pi}{K\alpha} t$$

$$= AX \sin \frac{2\Pi}{K\alpha} t \quad (18)$$

$$y_c = \left(\frac{AKX}{\sqrt{\Pi}}\right)\left(\frac{\sqrt{\Pi}}{K}\right) \sin \frac{2\Pi}{K\alpha} t$$

$$= AX \sin \frac{2\Pi}{K\alpha} t \quad (19)$$

Thus it is evident that when $K = \infty$

$$y_s = y_c \quad (20)$$

As is well understood, light which is employed for scanning may be either transmitted directly from the source or may be refracted or reflected before reaching the object or field being scanned. If small mirrors were distributed around a scanning disc in the usual position of the holes there-through, reflected instead of transmitted light would be used. The boundary of each mirror would then determine an optical aperture. The term aperture is herein used to denote such an optical or light aperture. The shape and size of the aperture determines the shape and size of the boundaries of the light beam, other conditions being fixed. The light beam may, of course, consist either of parallel, convergent or divergent rays.

The term light is used herein in its broader sense to include not only wave lengths within, but also wave lengths both above and below, the visible spectrum. The term optical is likewise used in its broader sense. The "field", as the term field is employed herein, may be at a transmitting point or a receiving point. It may be either primary or secondary—that is, it may comprise physical ob-

jects or it may merely contain images of such objects, and the images may be either real or virtual.

In many picture transmission systems, the electric current is used at the receiving end to vary the intensity of the light which passes through a fixed aperture and illuminates an elemental area of fixed size, the illumination being uniform over the entire aperture and over the entire elemental area at any instant. As in the case of the aperture at the transmitting end, the aperture at the receiving end may be conceived of as being divided into partial apertures, and a column of such apertures may be considered as a unit. Each such single column exposes a strip of film so that its tone values will follow the variations of the electric current and each column making up the total aperture will produce the same series of tone values, but the series will be displaced by varying distances along the surface of the received picture. Assuming that the film or other receiving surface does not introduce additional distortion, the exposures made by the various columns of partial apertures may be added together and are equally effective in producing the final tone values. As a consequence, the frequency characteristic of the receiving aperture can be calculated in the manner above described for the transmitting aperture.

The following examples will serve to illustrate ways in which the receiving aperture distorts the received picture. If the current wave suddenly changes from one steady value to another the amount of light going through the aperture changes accordingly but the received picture shows a gradual change extending over the distance covered by the entire aperture at the instant of the change in current. Again, if the current has a component at one of the critical frequencies that component will be absent entirely in the received picture.

Knowing the frequency characteristic or the equations of electrical response, Equations (5) and (15), of the apertures, and the size of the apertures and the rate of scanning, an electrical equalizer may be designed from the well known principles of such design bearing in mind the limitation that at the frequencies at which the aperture width equals one or more complete wave lengths there is a complete loss.

A picture transmission system including equalizers having suitable characteristics for use over the essential range of frequencies is shown in Fig. 1. The picture is represented by film 1 illuminated by lamp 2. This film may be a moving picture film. An image of the picture is focused on a disc 3 in which the scanning apertures are arranged as shown in Fig. 1^a. The light passing through the apertures impinges on photoelectric cell 4 generating a photoelectric current. Modula-

tor 5 causes this photoelectric current to modulate the carrier current generated by source 6. This modulated wave is then amplified, by amplifier 7, passed through equalizer 8 and filter 9 to the transmission line 10. Rectangles 11 and 12 indicate the apparatus employed for maintaining the disc 3 and the receiving scanning disc 18 in synchronism. The apertures in disc 18 are arranged in the same way as those in disc 3.

At the receiving station the filter 13 separates the synchronizing current from the picture current; equalizer 14 attenuates certain frequencies of the received current to compensate for the distortion to be introduced by the aperture of disc 18; amplifier 15 increases the strength of the current and demodulator 16 separates the variations representing the photoelectric current from the carrier wave. The demodulated current then varies the intensity of the light emitted by lamp 117. As disc 18 moves past the lamp 17, the recording means 20 registers a moving beam of light which varies in intensity making up a picture which is a reproduction of the original.

The equalizers 8 and 14 employed in this embodiment are of the type disclosed and claimed in Patent No. 1,606,817, granted to G. H. Stevenson, November 16, 1926 though obviously other types well known in the art may be employed.

While the invention is illustrated as embodied in either a still or moving picture transmission system, it is equally applicable to television systems or other signal systems employing apertures or their equivalents for scanning elemental areas of finite dimensions of a field, either in transmission or in reception or in both. In television transmission the apparatus at the transmitting and at the receiving stations is arranged to transmit and produce, respectively, images within the period of the persistence of vision. This invention may be applied to other systems such as a system for the photographic recording and reproducing of sound. In such a system the incoming electrical waves representing the sound are impressed upon the sound recording apparatus at the receiving station so as to affect at each instant a finite area of a film or other recording element arranged to move continuously past a given point. In such an arrangement light may be transmitted from a sound controlled receiving light source through a fixed aperture to a moving film. The sound record may thus be made on the film with somewhat simpler apparatus than required for picture transmission, since the sound record can be made in a continuous line upon the recording film. When this sound record is used for reproducing the sound, it is moved continuously in front of a fixed aperture transmitting a beam of light of finite size which causes

varying light energy to impinge on a photoelectric cell which in turn is connected with a loud speaker or other sound reproducing device. Networks similar to those used in picture transmission and reception for correcting for distortion due to the finite dimensions of the elemental areas of the recording element acting at any instant are, in accordance with this invention, applicable in sound recording and reproduction.

What is claimed is:

1. In a system for converting light energy into electrical energy or vice versa, a light source, a control element for light from said source having an aperture associated therewith, an optical field, means for causing relative motion between said aperture and said field, and means having such a frequency-attenuation characteristic as to compensate, in part at least, for the distortion produced by said aperture.
2. In a system for converting light energy into electrical energy or vice versa, a light source, a control element for light from said source having an aperture of fixed size associated therewith, means for producing a relative motion between said aperture and the optical field, and an electrical network having a frequency-attenuation characteristic dependent upon the size of said aperture and the velocity of the motion of the aperture and optical field relative to one another, to compensate, in part at least, for the distortion produced by said aperture.
3. In a system for converting light energy into electrical energy, a device for producing electrical waves under control of the light energy from an optical field, a light aperture of fixed size associated therewith, means for producing a relative motion between the aperture and the optical field, and an electrical network having a frequency-attenuation characteristic dependent upon the size of the aperture and the velocity of motion of the aperture with respect to the optical field for compensating, in part at least, for the distortion produced by said aperture.
4. In a system for converting electrical waves into light energy, a source of electrical waves, a device producing light energy corresponding to electrical waves, a surface to be affected by the light energy, an aperture of fixed size, means for producing a relative motion between the aperture and the surface, and an electrical network having a frequency attenuation characteristic dependent upon the size of the aperture and the velocity of motion of the aperture relative to the surface for compensating, in large part at least, for the distortion due to the finite size of the aperture in the direction of said motion.
5. In an electro-optical system, means for producing variations corresponding to the successive, separate, integrated tone values of successive, finite, overlapping elemental areas

successively infinitesimally displaced along a path on a picture or other object whose image is transmitted, and frequency discriminating means for so modifying said variations as to produce variations corresponding more nearly to the successive tone values of the successive infinitesimal portions of said path which constitute said displacements.

6. In an electro-optical system, means for producing electrical variations corresponding to the successive, separate, integrated tone values of successive, finite, overlapping elemental areas successively infinitesimally displaced along a path on a picture or other object whose image is transmitted, and an electrical network so constructed and proportioned and associated with said means as to produce variations corresponding more nearly than said first variations to the successive tone values of the successive infinitesimal portions of said path which constitute said displacements.

7. The method of compensating in a transmission system for the distortion effects produced by a moving aperture of finite area which comprises so attenuating electrical waves, produced in response to light waves passing through said aperture, as to compensate, in large degree at least, for the distortion produced by said aperture due to its finite dimension in the direction of motion.

8. In a transmission system in which electrical waves are produced in response to light waves passing through an aperture, the method of compensating for the distortion in the photoelectric response characteristic resulting from a definite ratio of aperture width to speed of scanning, which comprises so attenuating the electrical waves, as to compensate, in large degree at least, for the distortion.

9. In a system in which light waves are produced in response to electrical waves and transmitted through an aperture to a light sensitive surface, the method of compensating for the distortion effects produced by the aperture which comprises so attenuating the electrical waves that the exposure of the light waves substantially corresponds to the time variations in the electrical waves.

10. The method of electro-optical transmission which comprises scanning successive elements of a path on a picture surface, producing electrical variations corresponding to the tone values of the finite elemental portions of the path as they are successively traversed in said scanning, and attenuating said electrical variations by such different amounts for different frequencies as to compensate in the direction of the scanning, in large degree at least, for distortion introduced in the picture transmission by said scanning.

11. The method of electro-optical transmission, which comprises producing sets of vari-

ations, each set in different time phase and representing the density variations along the same path on a picture surface, combining at each instant said sets of variations to produce a resultant set of variations, producing an electrical characteristic varying in a complex manner corresponding to said resultant set of variations, and transmitting the different frequency components of the varying electrical characteristic with such relatively different attenuations as to compensate, in part, for distortion introduced in said transmission due to the fact that the value of the electrical characteristic at each instant represents a portion of the picture having a plurality of tone values.

12. In electro-optical transmission, the method which comprises producing a light beam moving relatively to a picture surface and having a finite dimension in the direction of said motion and having illuminating power varying in accordance with the tone values of the elemental picture areas successively traversed, producing electrical variations corresponding to said variations of illuminating power, and transmitting different frequency components of said electrical variations with such different relative transmission efficiencies as to compensate, in part, for distortion introduced in said transmission due to the finiteness of said dimension.

13. In a system for converting light energy into electrical energy or vice versa, means for scanning a field comprising means for projecting a beam of light, means for producing relative movement between said beam and said field, and frequency discriminating means for compensating, in large degree at least, for distortion due to the finite dimension of said beam in the direction of relative movement.

14. The method of compensating in a transmission system for the distortion effects produced by an aperture of finite width which comprises so attenuating electrical waves having characteristics corresponding to light waves passing through said aperture as to compensate, in large degree at least, for the distortion produced by said aperture.

15. The combination of means for scanning in succession small areas of a surface or field and frequency discriminating means for compensating, in large part at least, for distortion introduced by the scanning operation due to the finite width of said small areas in the direction of scanning.

16. The method of operating a translating system in which electrical impulses characteristic of light tone values are utilized and comprising means for scanning in succession small areas of a surface or field, which method comprises attenuating said electrical impulses by passing them through an electrical network whereby the relative amplitudes of the impulses are varied to substantially compen-

sate for distortion due to the finite width in the direction of scanning of said elemental areas.

17. In an image producing system in which image impulses characteristic of light tone values of the object or field of view at the transmitter are utilized, the combination of means for scanning in succession small areas of a field, the width of said areas in the direction of scanning being not greater than the shortest wave length of the object or field structure which it is desired to reproduce in the image, and frequency discriminating means through which the image impulses pass for substantially compensating for distortion due to the finite width of said elemental areas in the direction of scanning.

18. The method of compensating in a transmission system for the distortion effects produced by a moving aperture of finite area which comprises so attenuating electrical waves, produced under control of said aperture as to compensate, in large degree at least, for the distortion produced by said aperture due to its finite dimension in the direction of motion.

In witness whereof, I hereunto subscribe my name this 6th day of April, A. D. 1927.

FRANKLIN MOHR.