

June 2, 1931.

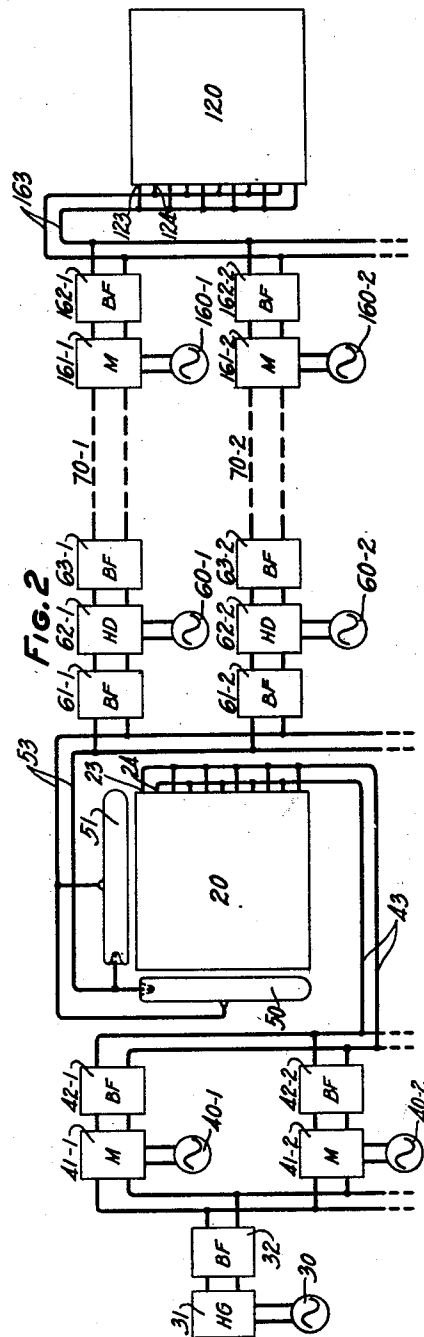
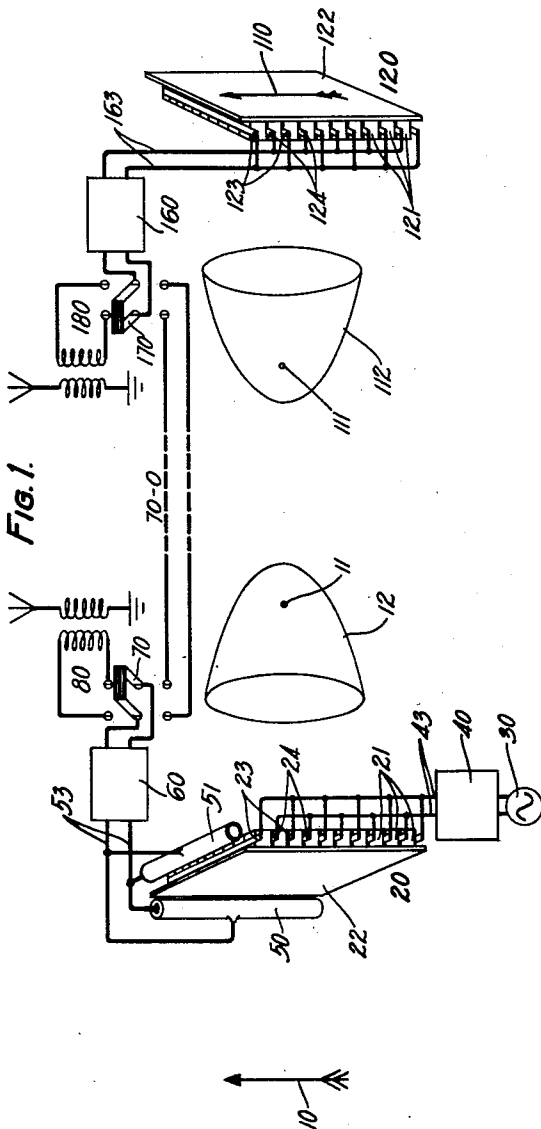
R. V. L. HARTLEY

1,808,137

ELECTROOPTICAL SYSTEM

Filed Aug. 28, 1928

2 Sheets-Sheet 1



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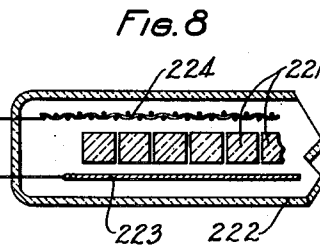
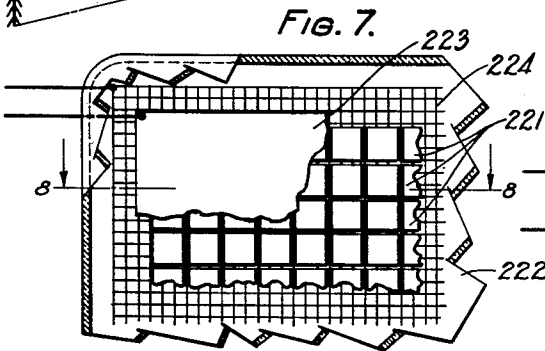
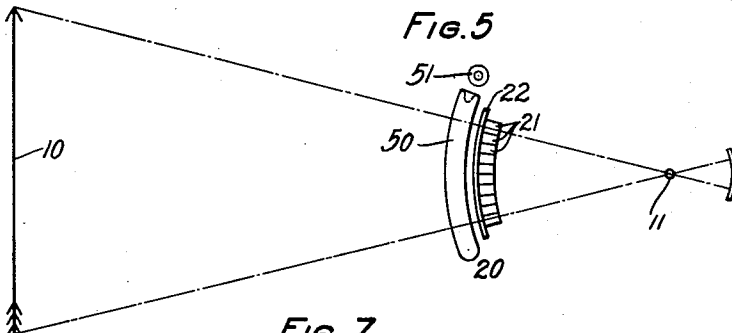
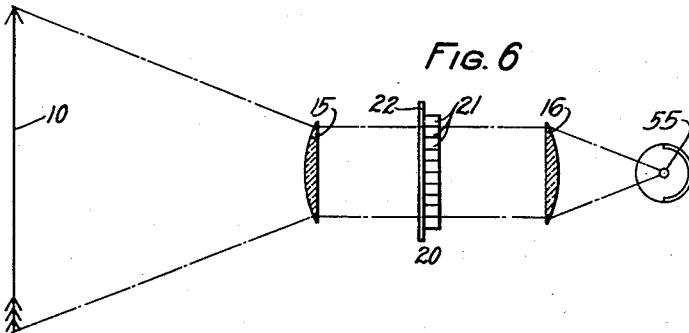
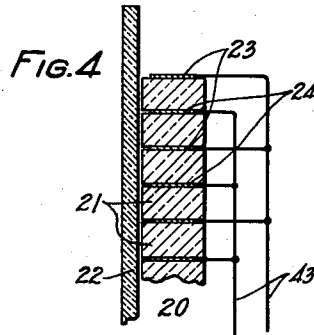
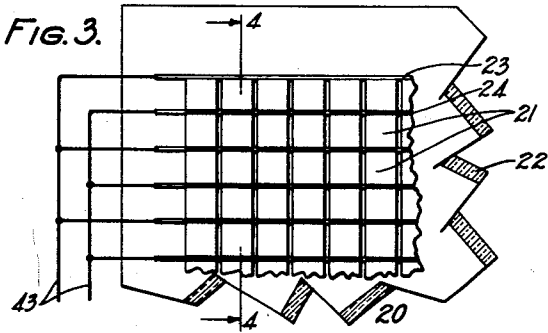
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ELECTROOPTICAL SYSTEM

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2 Sheets-Sheet 2



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ELECTROOPTICAL SYSTEM

Application filed August 28, 1928. Serial No. 302,448.

This invention relates to electro-optical systems and methods and more particularly to television systems of the type in which a separate line or channel is provided for each elemental area of the field of view.

In systems of this type heretofore suggested as many physical channels have been employed as there are elemental areas involved. In accordance with the present invention the energy controlled by each elemental area of the field of view at the transmitter is given a distinctive characteristic, preferably a frequency characteristic such that the currents for all or many of the elemental areas may be superimposed in a single physical circuit or medium and separated again at the receiver, and each elemental area at the transmitter acts continuously in its control of its channel so that maximum illumination at the receiver is obtained.

The invention is particularly applicable to television of still pictures or objects, in which case a range of frequencies no greater than that used in ordinary broadcasting of speech and music is required for a receiving field having eight or ten thousand elemental areas. In the case of television of still pictures which are viewed in rapid succession, as motion pictures, the range of frequencies would be greater, but not as great as in television of constantly moving objects.

In accordance with this invention in its preferred form simple means are provided for selectively generating and transmitting carrier currents of distinctive frequency which are respectively given a characteristic corresponding to the light tone character, or modulated by the light tone value, of each elemental area and which may be simultaneously transmitted over a single circuit or medium, and for analyzing received currents and translating them into light tone values over a screen or field of view corresponding to the original. Such a preferred embodiment comprises at the transmitting station a plurality of light interrupters, preferably quartz crystals operated at different frequencies, each in the path of light from a source to some one elemental area of a field of view. The light reflected from all of the

elemental areas may be collected in one or more common light sensitive cells. The resulting photoelectric currents consist of a large number of components each of which represents a carrier frequency equal to one of the interruption frequencies, which carrier is modulated by a signal wave which represents the light tone values of the corresponding elemental area of the field of view. These modulated carrier current waves may be either transmitted directly by a radio or a wire circuit capable of transmitting a wide band of frequencies or they may first be grouped and shifted to some other part of the frequency scale by further modulation so that each group comprises a moderately wide band of comparatively low frequencies which may be transmitted over several circuits having a limited frequency range. The receiving station comprises means for separating the various modulated components and for using them to control the illumination of the various elemental areas of the field of view where an image is produced. This means preferably includes quartz crystals, one for each channel, having a natural frequency equal to that of the carrier current in that channel.

The interruption of the light at the transmission station may be effected by a plurality of piezo-electric crystals, preferably quartz, set in resonant vibration by impressing current of varying voltage across the crystals. The light from the field of view is passed through the crystals parallel to the direction of their longitudinal vibration. A plane face of each of the crystals perpendicular to the direction of vibration is set close to a plane of glass plate or other transparent material so that the distance of separation is of the order of the wave length of light. This distance may then be adjusted so that a change in length of the crystals of a similar magnitude is sufficient to cause a change from a condition of a total light reflection to one of total transmission. Light is therefore transmitted through each crystal once during each frequency cycle of the driving current.

At the receiving station if multiple circuit transmission wherein the frequencies have

been reduced to come within the frequency range of the lines is used the components may be restored to their original frequencies by suitable electrical networks and the current representative of the light tones of each elemental area of the field of view applied to a crystal to control the lighting of a field of view accordingly. An arrangement which might be used is one in which the vibration of the crystals controls the transmission or reflection of light in a manner similar to that used for interrupting the light at the transmitting station. Here the crystals may be so placed as to cut off all the light when at rest and transmit light during each cycle of their vibration, the amount depending upon the amplitude of vibration.

An alternative arrangement is based upon the fact that when a quartz crystal is made to vibrate in a gas such as neon at reduced pressure a glow discharge is set up on the crystal having an intensity which varies with the voltage of the driving current. Each crystal is tuned to the frequency of the corresponding crystal used at the transmitting station for interrupting the light of its particular elemental area. The driving voltage of its frequency therefore depends upon the reflecting power of the elemental area of the field of view. Common electrodes may be used in the glow discharge lamp consisting of a plate at the back and a screen at the front between which the crystals are positioned. The whole is enclosed in a glass envelope containing rarefied gas.

The term "multiple channel" as used herein is intended to cover either a plurality of physical channels or a plurality of frequency channels in or over the same or different physical media or combinations of these.

The terms "modulation" and "modulated" as herein applied to the carrier waves of different frequency are intended to cover not only gradually and continuously changed waves but also those in which a characteristic of the waves is merely changed from time to time from one value to a different value, remaining constant between changes, and also when discontinuities in the carrier wave occur from time to time.

A more detailed description of the invention follows and is illustrated in the accompanying drawings.

Fig. 1 is a general schematic representation of a multiple channel television system arranged for simultaneously and continuously transmitting the light tone values of each elemental area of a field of view.

Fig. 2 is a general schematic circuit arrangement of the system showing the interconnecting apparatus employing a small number of similar circuits of limited frequency range between the transmitting and receiving stations.

Fig. 3 is a rear side view of a portion of

the bank of multiple cell piezo-electric light controlling terminal element.

Fig. 4 is an end section view of Fig. 3 at the plane 4—4.

Fig. 5 is a schematic representation of the light controlling apparatus with the bank of multiple piezo-electric cells spherically positioned.

Fig. 6 is a schematic representation of the terminal apparatus arranged for operating with the field of view illuminated by natural light or from a general flood light source.

Fig. 7 is a rear section view of a portion of a neon gas piezo-electric control multiple channel receiving lamp.

Fig. 8 is an end section view of Fig. 7 at the plane 8—8.

Referring to Fig. 1 the transmitting apparatus is diagrammatically shown at the left and the receiving apparatus at the right. An object or field of view 10 is positioned in front of the transmitting apparatus so that beams of light from a source 11 are projected upon it. In the arrangement shown the rays are generally directed in parallel lines by means of any suitable means such as a parabolic reflector 12. Between the source of light 11 and the field of view is positioned a light controlling element 20 which consists primarily of a plurality of piezo-electric crystals 21 uniformly positioned in close proximity to the surface of a light transmitting member 22 such as plate glass. The piezo-electric crystals preferably have a square or rectangular cross section and are shown positioned in coordinate arrangement. The crystals are placed with a slight separation between them and multiple electrodes 23 and 24 of opposite polarities are positioned between each alternate row of crystals. These electrodes permit impressing an electrical potential upon the crystals which causes them to vibrate in a direction at right angles to the impressed current. The plane face of each crystal perpendicular to its direction of vibration is set so close to the plate glass 22 that the distance of separation is comparable with the wave length of light. This distance may then be adjusted so that a change in length of the crystal of a similar magnitude is sufficient to change from a condition of total light reflection to one of total transmission. If these crystals are made to vibrate by means of applying an alternating electrical potential to them, then light is transmitted during each cycle of the driving frequency. In this arrangement each crystal acts as a light valve or chopper and interrupts the light passing through it at a rate in accordance with the frequency with which the crystals vibrate. If each crystal is designed to have a different resonant frequency of vibration and the applied driving frequency causes it to continuously vibrate at its natural rate then the light passing through the different crystals is in-

interrupted at corresponding frequencies and consequently each elemental area of the field of view, as determined by the transverse cross-section area of the crystals, is illuminated by light interrupted at a different frequency. The driving current may be supplied from an oscillator 30 operated through a suitable electrical network 40, the details of which are described later, which connects with the multiple crystal electrodes through the common circuit 43.

Light from the different elemental areas of the field of view which are illuminated with light interrupted at different frequencies is reflected upon one or more light sensitive cells 50 and 51 thus causing the generation of a plurality of currents each having a frequency corresponding to the frequency of interruption of the light impressed upon the field of view and an amplitude modulated in accordance with the light tone value of the corresponding elemental area of the field of view, that is, having a characteristic corresponding to the light tone character of the areas. The large number of modulated carrier currents thus generated are transmitted over the common circuit 53 to suitable electrical translating networks 60 and from there impressed upon suitable transmission medium such as a radio or wire transmission system, the translating networks being arranged accordingly. Either a wire transmission system 70—0 or a radio transmission system 80 and 180 may be used depending upon the position of the switches 70 and 170 and the arrangement of the translating networks. Radio broadcasting circuit apparatus 80 and 180 is schematically shown at each station.

The terminal apparatus at the receiving station is in many respects similar to that at the transmitting station. The large number of incoming modulated carrier currents are received through suitable electrical translating networks 160. In the arrangement shown an image 110 of the object or field of view which is being transmitted appears on the viewing field of the receiver associated with the light controlling element 120. A source of light 111 is directed by means of any suitable device such as a parabolic reflector 112 upon the light controlling member comprising a plurality of piezo-electric crystals 121 and a light transmitting member 122 such as a plate glass, all of which may be similar to the corresponding apparatus in the transmitting station. Each of the piezo-electric crystals acts as a light valve for an elemental area of a produced image and therefore controls the light tone value of that elemental area. The amplitude of vibration of each crystal is electrically controlled by means of currents of different frequencies being impressed from the common input circuit 163 across them through connection with electrodes 123 and 124. The crystals are designed to have dif-

ferent natural frequencies which correspond to the natural frequencies of crystals similarly positioned in the transmitting station. For example, if crystals No. 1 at the transmitting and at the receiving stations have the same resonant frequency of 100,000 or any other suitable number of cycles per second only the light interrupted by crystal No. 1 at the transmitting station, which illuminates one elemental area of the field of view and generates current having this frequency and an amplitude corresponding to the light tone values of this elemental area, controls the actuation of crystal No. 1 at the receiving station and the action is proportional to the amplitude of the received current. Therefore, the light which is permitted to pass from the source 111 through each of the crystals 121 and the plate glass 122 has an intensity corresponding to that of each elemental area of the field of view at the transmitting station and the light tone value of each elemental area changes substantially simultaneously with changes in the original. There are no appreciable periods during which the light tone variations of each elemental area at the transmitter are not reproduced at the receiver in this system, as is the case in systems employing the successive scanning arrangement. Also, the factor of the persistence of vision so essential in the successive scanning systems is entirely absent in this system and large mechanical moving elements are absent.

The general arrangement of the associated electrical apparatus and the interconnection of a transmitting and a receiving station by means of a small number of similar circuits of limited frequency range is shown in Fig. 2. An oscillating current having a suitable fundamental frequency is generated by the oscillator 30. The current from this oscillator is impressed upon a harmonic generator 31 which produces a series of components having a frequency separation equal to the frequency of the fundamental. A convenient number n of these frequencies are transmitted by a band or low pass filter 32 to the input circuits of a series of modulators 41—1, 41—2 etc., whose frequencies are such that the piezo-electric crystals 20 may be conveniently driven. The first modulator produces a pair of side bands which, together with the carrier, constitute a series of $2n+1$ components separated by the desired frequency interval. A similar series is produced by each modulator. These carrier frequencies are produced by oscillators 40—1, 40—2 etc., associated with each modulator. The high frequency carrier currents are so chosen that their side bands do not overlap. The output currents are led through suitable band filters 42—1, 42—2 etc., to the common driving circuit 43 to the multiple electrodes 23 and 24 associated with the bank of piezo-electric crystals of the light control element

20. A crystal is tuned to each component.

In case the photoelectric currents generated in the light sensitive cells 50 and 51 have a frequency range too wide to be conveniently transmitted over a single circuit, they may readily be divided into groups of narrower frequency range. The groups of photoelectric components determined by the modulators are then separated by band filters 61—1, 61—2, etc., connected with the common input circuit 53, and impressed upon heterodyne detectors 62—1, 62—2, etc., whose frequencies are so chosen and determined by associated oscillators 60—1, 60—2, etc. as to generate a band of component frequencies of the proper frequency range to permit transmission over the available transmission lines or circuits 70—1, 70—2, etc. with which band filters whose pass bands are of relatively low frequency 63—1, 63—2, etc. are associated.

For ordinary television operation with a system of the kind here described in which the maximum width of each carrier frequency band is such that no overlapping of bands occur, the total transmission band width will depend upon the number of elemental areas, or resolution. For the transmission of images of still pictures or objects the same relation exists, but the total band width is small since the adjacent bands shrink to single adjacent frequencies. For practical reasons, however, the carriers would in general be a few cycles apart.

If the transmission is by radio then all of the photoelectric components may be transmitted by one carrier frequency and the apparatus for grouping the photoelectric components and changing their frequencies by groups for transmission is unnecessary.

When a plurality of circuits of limited frequency range are used for transmission, as shown in Fig. 2 the component frequencies of the different groups are restored to their original frequencies at the receiving station. The received signal currents of each circuit are impressed upon modulators 161—1, 161—2, etc., which are supplied with high frequency currents of suitable frequency by means of oscillators 160—1, 160—2, etc. The outputs of these modulators are passed through band filters 162—1, 162—2, etc., to the common circuit 163 leading to the light control element 120 associated with the viewing screen where the image is produced. The light control element here shown employs a plurality of crystals tuned to vibrate in synchronism with those similarly positioned in the transmitting station. Each crystal has impressed upon it the signal currents by means of a common circuit 163 which connects with the plurality of crystal electrodes 123 and 124 in the light control element 120. The amplitude of vibration of each crystal is controlled only by the current whose frequency it is tuned to. The light transmission

through each crystal and the plate glass 122 at each elemental area varies in accordance with the light tone of the image being transmitted as described in connection with Fig. 1. While not shown in the drawing suitable amplifying apparatus is ordinarily employed at the transmitting and receiving stations and other well known means for controlling the level of or equalizing or correcting the currents of the various channels may be used if desired.

The details of the light control element 20 employing a plurality of piezo-electric crystals are shown in Figs. 3 and 4. The crystals 21 are positioned in close proximity to one side of a light transmitting member 22 which may be plate glass. The electrodes 23 and 24 of opposite polarity are placed between alternate rows of the crystals and in turn are multiplied to a common input circuit 43. Light is passed through each of the crystals and the plate in front of them in a direction in general perpendicular to the plate and parallel with the lengthwise axis of the crystals. Each crystal interrupts the light at a frequency corresponding to its rate of vibration. The crystals are caused to vibrate longitudinally by impressing a voltage across them. A plane face of each crystal adjoins the plane glass plate in front of all of the crystals and the distance of separation of the crystals from the plate is comparable with the wave length of light. When the crystals are set in vibration this distance varies and the light transmitting power changes from one of total reflection to one of total transmission once during each cycle of the driving current. Each crystal in effect constitutes a separate light valve and is capable of independently controlling the amount of light transmitted. As shown in Fig. 1, the crystal light control arrangement may be used both at the transmitting and receiving stations. At the receiving station the crystals may be so placed as to cut off all light when at rest and transmit light during each cycle of their vibration, the amount depending upon the amplitude of the vibration. Crystals correspondingly positioned and representing the same elemental areas of the field of view at both the transmitting and the receiving stations are designed to have the same natural or resonant frequency or frequencies at the receiver which differ from those at the transmitter by the same amount.

A modification of the arrangement of the crystals in the controlling element 20 is shown in Fig. 5. They are here spherically positioned embracing a solid angle of the order of 20 to 30 degrees. The light source 11 is positioned at the center of the spherically positioned crystals 21 and associated spherically shaped glass member 22 so that the light passing from it to and through each of the crystals passes in a direction parallel to the

axis of each crystal. In this arrangement the rays diverge and thus permit the fields of view to be of widely different sizes depending upon the distance from the crystals. The light sensitive cells 50 and 51 are positioned to receive light from the object or field of view. This spherical arrangement may be used either at the transmitting or the receiving stations.

A further modification of the arrangement of the crystals in the controlling element 20 for fields of view of different sizes is shown in Fig. 6. The crystals 21 are here arranged in a plane adjoining the plane plate of glass 22 and a lens system 15 and 16 is associated with the crystals. These lenses produce parallel rays through the crystal and focus the light from the field of view 10 upon the light sensitive cell 55. This arrangement, while shown for the transmitting station, is equally applicable at the receiving station by substituting for the light sensitive cell 55 a light source and for the object 10 a screen upon which the image of a produced picture may be projected.

A glow discharge lamp employing a plurality of quartz crystals to control the illumination of its elemental areas may be used at the receiving station and is shown in Figs. 7 and 8. When a quartz crystal is made to vibrate in a gas such as neon at a reduced pressure, a glow discharge is set up on the quartz crystals, the intensity of which varies with the driving voltage. Each crystal is tuned to the frequency of the crystal used at the transmitting station for interrupting the light of its corresponding elemental area of the field of view. The voltage of the driving current of each frequency at the receiver depends upon the reflecting power of that elemental area of the scene or field of view. Fig. 7 shows in partial cross-section a rear view and Fig. 8 a cross-section of such a lamp. The crystals 221 are placed so that each elemental area of the field of view is represented by a crystal. The driving current is impressed across a crystal by means of the common electrodes 223 and 224 at the front and rear of the crystals, respectively. The front electrode is an open mesh screen to permit the passage of light and the rear electrode may be a solid plate. These elements are all encased in a glass envelope 222 and are surrounded by a suitable gas such as neon at a low pressure. When a plurality of carrier currents of different frequencies and different amplitudes are applied to the electrodes 223 and 224, the quartz crystals whose resonant or natural frequencies are similar to the impressed frequencies are set into vibration and are caused to glow with an intensity which varies with the voltage of the driving current of the different carrier frequencies.

An alternative way of controlling the light

by means of a plurality of resonant crystals is that shown in R. V. L. Hartley Patent No. 1,742,912, issued Jan. 7, 1930. This application discloses an electro-optical system comprising a piezo-electrical transparent crystal positioned between two crossed Nicol prisms to control the transmission of light there-through. In applying this arrangement to the present invention, a bank of resonant piezo-electric crystal elements is employed instead of a single crystal as shown in the earlier application.

What is claimed is:

1. The method of producing an image electro-optically which comprises simultaneously producing a plurality of trains of light waves equal in number to the elemental areas of a field of view, an image of which is to be produced, each of said trains being modulated in accordance with the light tone values of the corresponding elemental area of the field of view and having a distinctive super-audio frequency characteristic.
2. The method of producing at a transmitting station and selectively controlling thereby corresponding elemental areas of a receiving field of view which comprises simultaneously producing a plurality of wave trains equal in number to the elemental areas of a field of view, an image of which is to be produced, each train being modulated in accordance with the light tone values of the corresponding elemental area of the field of view and having a distinctive super-audio frequency characteristic.
3. The method of producing an image electro-optically which comprises simultaneously producing a plurality of light wave trains equal in number to the elemental areas of a field of view, an image of which is to be produced, each train being modulated in accordance with the light tone values of the corresponding elemental area of the field of view and interrupted at a distinctive super-audio frequency.
4. A multiple channel electro-optical image producing system comprising means for producing a beam of light and means for periodically simultaneously modifying a large number of separate portions of said beam at a separate distinctive super-audio frequency for each portion.
5. A multiple channel electro-optical image producing system comprising means for illuminating each elemental area of a field of view with light interrupted at a frequency different for each area.
6. A multiple channel electro-optical image producing system comprising means for illuminating each elemental area of a field of view with light interrupting at a frequency different for each area, and translating means for generating photo-electric currents having frequencies corresponding to said frequencies of interruption and amplitudes cor-

responding to the light tone values of each of the elemental areas, respectively.

7. An electro-optical system for producing images of a field of view, a plurality of resonant light control elements having different resonant super-audio frequencies, respectively, and means for simultaneously electrically energizing said elements in accordance with the light tone values of corresponding elemental areas of a field of view.

8. In an electro-optical image producing system, means for producing an image including a light source comprising a bank of resonant light transmitting elements and means for actuating said elements simultaneously.

9. An electro-optical image producing system comprising a plurality of resonant light control elements at the transmitting and at the receiving stations equal in number at each station to the elemental areas of a field of view, and means whereby each of said elements at the transmitting station selectively controls one of said elements at the receiving station.

10. An electro-optical image producing system comprising a plurality of light controlling crystal elements equal in number to the number of elemental areas of a field of view and a corresponding number of transmission channels all simultaneously and continuously acting, each of said elements controlling the illumination of an elemental area of a field of view.

11. In an electro-optical system, light emitting means comprising a plurality of elements each resonant to a different frequency of impressed voltage, and means for actuating said elements simultaneously to produce an image.

12. In an electro-optical system, a source of light, a bank of piezo-electric crystals for controlling said light and means for causing all of said crystals to operate simultaneously.

13. In an electro-optical system, a source of light, a bank of piezo-electric crystals for controlling said light, and means for causing all of said crystals to vibrate simultaneously, each at a different frequency.

14. A bank of light valves arranged to embrace a portion of the surface of a sphere, a source of light at the center of said sphere, and means for applying image current to said valves.

In witness whereof, I hereunto subscribe my name this 27th day of August, 1928.

RALPH V. L. HARTLEY.