May 26, 1936. A. D. DOWD 2,041,822

ELECTROOPTICAL SYSTEM

Filed March 6, 1934

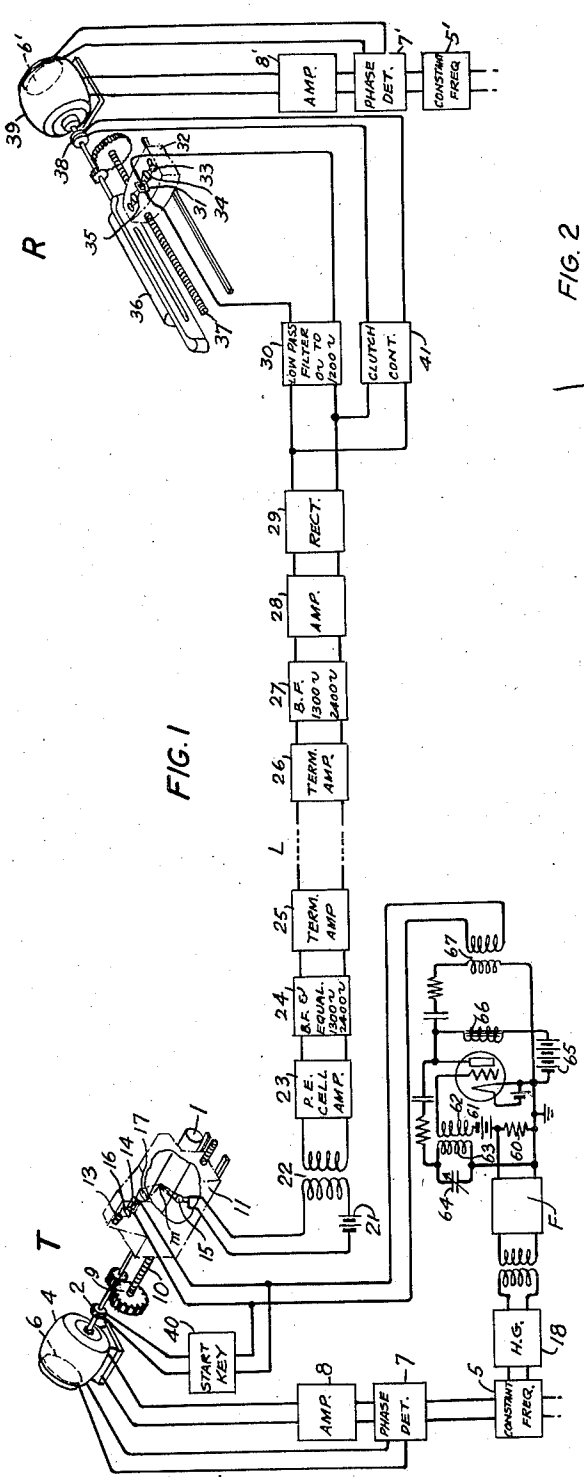

FIG. 1

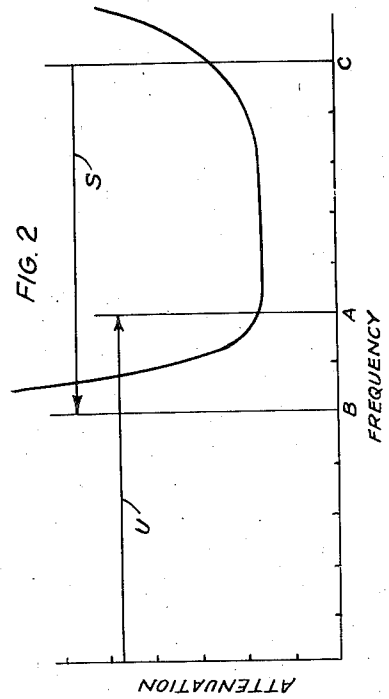

FIG. 2

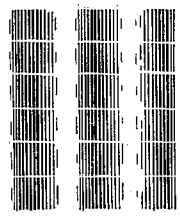

FIG. 4

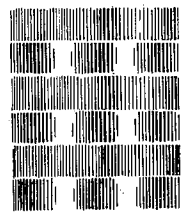

FIG. 3

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ELECTROOPTICAL SYSTEM

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3 Claims. (Cl. 178—5)

This invention relates to electro-optical transmission and more particularly to the production of a signal modulated carrier current suitable for transmission over telephone circuits.

Where a light beam after being modulated or caused to pulsate at a carrier frequency rate is used to scan a subject and hence its intensity is also modulated in accordance with the varying tone values of successive elemental areas of the subject and is then applied to a light sensitive electric means; the latter is activated by the received light to cause the production of a signal modulated carrier current consisting of an unmodulated current component of carrier frequency and two side bands, and in addition a unidirectional current varying as the tone values of successive elemental areas of the subject.

Transmission of the unidirectional or picture current is undesirable, for the reason that at the receiving station it causes distortion of the image or picture. This current consists of components of different frequencies represented by a Fourier series which extends from zero frequency to an upper limiting frequency, determined by the number of elemental areas into which the picture is divided and the rate of scanning. The picture current includes a band of current components extending from zero to some value, less than the said upper limiting frequency, which are essential to the production of a picture of good quality, as well as a series of components of relatively large amplitudes which are not essential for this purpose.

For efficient transmission of a picture current band over telephone lines it is desirable to restrict both the upper and lower frequencies of the band to be transmitted, in order to avoid high line attenuation and also difficulties in correcting the phase distortion of the line. As will be set forth below, the carrier frequency, which is placed near the upper limit of the transmitted band, should preferably be as high as possible to avoid the distortion introduced by the overlapping currents of different frequencies which result from scanning the picture and similar components included in the lower side band which results from modulating the carrier current with the picture currents. For this reason it is desirable to use a carrier having a frequency substantially equal to twice the limiting frequency of the essential picture band and to select the lower side band of the modulation products without seriously distorting any of the selected components, otherwise the received picture will be distorted. However, the lower side band and the picture current include a series of components having the same frequencies, i. e., certain current components of the picture band overlap their counterparts in the lower side band. This condition presents a serious operating difficulty, since it is impossible to provide selective means which, while freely passing the desired components of the lower side band, can at the same time suppress these overlapping components, the presence of which cause distortion of the picture.

The present invention relates to a system of the type described above, having a transmitting apparatus adapted to produce a picture or image modulated carrier current which may be efficiently transmitted over telephone circuits and includes means for substantially eliminating or so controlling the overlapping components that the receiver may operate to produce a high quality picture or image of the subject scanned at the transmitter.

An object of the invention is to control the rate of scanning of a subject and the frequency of modulation of the scanning beam in such a manner as to cause the production of a single side band picture modulated carrier, that may be efficiently transmitted over telephone circuits and used at the receiver to control the production of a substantially undistorted image or picture.

Another object is to control the production of a picture or image modulated carrier current which may be efficiently transmitted over telephone circuits and may be used to produce a substantially undistorted reproduction at the receiver by establishing and maintaining a fixed relation between the picture or field scanning rate and the frequency of modulation of the scanning beam at the transmitter.

An auxiliary object is to effect the above mentioned objects by controlling the speed of the scanning member and the rate of vibration of the light modulating element, respectively, by alternating currents of different frequencies, the frequencies of which are controlled by an alternating current of constant frequency.

One embodiment, selected for illustration, comprises a picture transmitting system in which the picture to be transmitted is mounted on a rotating cylinder having associated therewith an optical system, including a light source, means for concentrating the light supplied by this source into a beam, a two-ribbon light valve for modulating the beam of light at a carrier frequency

rate and a light sensitive electric device, such system being mounted on a carriage which is continuously moved at a uniform rate longitudinally of the cylinder; whereby, due to relative motions of the cylinder and optical system, the successive elemental areas of the picture are illuminated by the moving light beam and light reflected from the picture is directed to the light sensitive means which is thereby activated to cause the production of a picture modulated carrier current including an unmodulated component of carrier frequency and a unidirectional picture current. The light valve comprises a mounting provided with two fixed jaws extending transversely of the direction of travel of the picture and its two ribbons are mounted under tension in a magnetic field of constant intensity and supplied with alternating current of a carrier frequency, whereby they are caused to move bodily toward and away from each other in a direction transversely of the fixed jaws and hence transversely of the motion of the picture, i. e., the direction of scanning. This method of vibrating the ribbons results in the production of a unidirectional or picture current in which the frequency band width occupied by the current components essential to the production of a satisfactory picture at the receiver is materially narrowed and the amplitudes of the non-essential components are smaller than in a picture current produced when the ribbons vibrate in a direction lengthwise of the direction of scanning.

Filtering means are used to select the components of the lower side band of the modulation products which are essential to picture production, to suppress the upper side band and the unidirectional picture current. Because of the curved characteristic of the cut-off of the filter, certain components of the upper side band as well as certain components of the picture current and the selected side band, which are not essential to the production of a good quality picture at the receiver, will pass through the filter.

The motor driving the cylinder carrying the picture at the transmitter is controlled by an alternating current from a source which also supplies current to a harmonic generator, one harmonic component supplied by this generator is selected and used to control the frequency of current produced by a source, which supplies current of carrier frequency to the vibrating ribbons of the light valve included in the path of the scanning beam; whereby the rate of scanning the picture and the frequency of modulation or pulsation of the light beam are fixedly related, with the result that the distortion, caused by the non-essential components of the picture current and selected side band that are transmitted by the filter, is materially reduced and hence the quality of the picture produced at the receiver is greatly improved.

A detail description of the invention follows and is illustrated in the attached drawing in which,

Fig. 1 illustrates more or less diagrammatically a system involving the invention;

Fig. 2 illustrates the selective characteristic of the filter;

Figs. 3 and 4 are sketches of a pilot or guide strip which will be hereinafter referred to.

Referring to Fig. 1 there is shown a picture transmitter T connected to a receiver R by a telephone line L. The transmitter comprises a cylinder **1** driven through a clutch **2** by a constant speed direct current motor **4**, having associated therewith a sending control means supplied with alternating current from a constant frequency source **5**. The motor is designed to provide a uniform driving torque and within its housing and on the same shaft as its armature is an inductor type generator **6** which furnishes an alternating current of fixed frequency when driven at normal speed by the motor. For illustrative purposes the normal speed of the motor may be 100 revolutions per minute and the frequency of the alternating current supplied by the generator **6** when the speed of the motor is normal may be 300 cycles, which is the same as that supplied by the constant frequency source **5**. The difference in phase between the current supplied by the source **5** and that supplied by the generator **6** is used to maintain the speed of the motor **4** constant. The sending control unit, comprising a vacuum tube phase detector **7** and an amplifier **8** which is adapted to be controlled by the phase difference between these frequencies and operates to vary the armature current supplied to the motor. The phase detector **7** consists of two vacuum tubes, the grids of which are supplied with current from the constant frequency source **5**, while a voltage from the inductor generator **6** is applied to the plates of these tubes. The output current from the detector **7**, which will depend upon the phase relation between the two applied voltages, is supplied to the control grids of the amplifier **8**, consisting of four vacuum tubes connected in parallel, which is capable of supplying the total armature current of the motor. The fields of the motor and inductor generator are supplied from a battery (not shown), and the motor armature is supplied through the variable impedance of the plate circuits of amplifier **8**. For a complete disclosure of the motor control unit briefly described above, reference may be made to application Serial No. 670,261 of E. R. Morton, filed May 10, 1933.

Connected to the motor through a gearing **9** is a lead screw **10** for driving a carriage **11** provided with a housing enclosing an optical system comprising a source of light of constant intensity **13**, a light valve **14**, a small mirror *m* and a light sensitive electric means **15**. The lead screw **10** operates to move the carriage longitudinally of the rotating cylinder **1** at a uniform constant speed. The light valve **14** comprises two flat ribbon conductors stretched under tension and forming a loop circuit which is located in a magnetic field obtained from a permanent magnet. The direction of the magnetic field is at right angles to the plane containing the two largest dimensions of the ribbon, i. e., length and breadth, so that, when an alternating current passes through the ribbons, they will vibrate sidewise alternately increasing and decreasing the separation between them. These ribbons lie in a common plane and each is parallel to the direction of motion of the cylinder, and the inner edges of the respective ribbons cooperate with two fixed jaws which are carried by the light valve structure and which extend transversely to the ribbons to form an aperture. A beam of light from the source **13** is directed by a condensing lens **16** through the aperture of the light valve and an image of this aperture is focussed by a second lens system **17** to form an intense spot of light in the form of a square on the surface of the picture carried by the cylinder **1**. Alternating current of the desired frequency is supplied to and passes through the light valve ribbons whereby they are caused to vibrate and thereby modulate or vary

the light supplied by the source 13 at a carrier frequency rate.

In accordance with this invention, current from the constant frequency source 5 is supplied to a distorting device 18 which operates to produce current components the frequencies of which are harmonically related to that supplied by the source 5.

The output circuit of the harmonic generator includes a filter F which selects one of the harmonic components and suppresses the fundamental as well as the other harmonics. The selected harmonic is impressed across a resistance 60 included in the input circuit 61 of a vacuum tube oscillator, which comprises this input circuit connected between its grid or control element and filament and includes a winding 62 which is coupled with a similar winding 63, shunted by an adjustable condenser 64 included in the output circuit of the tube. The coil 63 and condenser 64 constitute a tuned circuit, included in one alternating current branch of the filament to plate or output circuit of the tube, which in general serves to determine the frequency of the oscillations generated and should be adjusted to the desired frequency, i. e. approximately the frequency of the harmonic. Space current is supplied from a source 65 through a choke coil 66 to the plate of the oscillating tube and oscillating current is supplied through the transformer 67 to the circuit including the ribbons of the light valve 14.

The harmonic component impressed across the resistance 60 coacts with the current generated by the oscillator and the effect of this coaction is to pull the oscillator into step with the frequency of the impressed harmonic and thereby cause the frequency of the oscillations and the harmonic current to become identical. In this case, the output current from the oscillator is supplied to and passes through the light valve ribbons which are thereby caused to vibrate at the frequency of the harmonic and in synchronism with the scanning operation.

Due to the relative motion of the drum or cylinder and the optical system, the spot of light, fluctuating at a carrier frequency rate scans successive elemental areas of the picture mounted on the drum and the doubly modulated light reflected from these areas is applied to the light sensitive electric device 15, which is thereby activated to cause the production of a unidirectional picture current and a picture modulated carrier current consisting of an unmodulated carrier component and two side bands. The unidirectional picture current comprises a continuous series of components having relatively large amplitudes, which constitute a frequency band, extending from zero frequency to an upper limiting frequency, which is largely determined by the number of elemental areas into which the picture is divided and the rate of scanning, and each side band of the modulated carrier current comprises a similar band extending in both directions in the frequency spectrum from the carrier frequency, which is determined by the rate of vibration of the light valve ribbons. The small mirror *m* diverts carrier modulated light directly to the light sensitive means 15, which is thereby activated to cause the production of current of carrier frequency in phase with the unmodulated component of the picture modulated carrier current, to provide carrier bias, whereby the energy level of the carrier current is raised at the transmitting terminal to minimize the effect of disturbances entering by way of the line.

By positioning the light valve ribbons so that they lie parallel to the direction of motion of the picture, i. e., parallel to the direction of scanning, and causing them to vibrate transversely thereto, the dimension of the aperture and hence of the spot of light illuminating the elemental areas of the picture along the length of the scanning line remains fixed, while its dimension transversely of the scanning direction varies in accordance with the wave shape of the alternating current flowing through the ribbons. This results in a material reduction in the frequency band width occupied by the current components of relatively large amplitude present in the unidirectional current and in the side bands and also in a reduction in the amplitudes of certain of the selected components. For a complete disclosure of this feature, reference may be made to application Serial No. 713,939, of F. W. Reynolds, filed March 3, 1934.

The light sensitive means 15 is supplied with current from a direct source 21, and the photoelectric current produced thereby is supplied by a transformer 22 to an amplifier 23. The output current from this amplifier is supplied to a band filter 24 adapted to select the lower side band of the picture modulated carrier current which is then amplified to the desired energy level by the amplifier 25 and supplied to the transmission line L.

The incoming picture modulated side band is amplified by amplifier 26, selected by the filter 27, amplified by the amplifier 28 and is rectified or demodulated by a full wave rectifier 29 to yield the picture current, which is selected by the filter 30 and supplied to the ribbon of the light valve 31 included in an optical system mounted on a carriage 32. The optical system comprises a light source of constant intensity 33, a lens 34 for concentrating light supplied by the source 33 on the light valve aperture and a lens system 35 adapted to image the aperture of the light valve on a photographic film mounted on a rotating cylinder 36.

Cylinder 36 of a lead screw 37, adapted to move the carriage 32 longitudinally of the cylinder at a uniform rate, are connected by means of an electromagnetically operated clutch 38 to a driving motor 39 which is controlled in the same manner as the motor 4 at the transmitter, i. e., by means of a phase detector 7' in cooperation with an inductor generator 6' on the motor shaft and a constant frequency source 5', and an amplifier 8' which serves to supply armature current, controlled by the phase relation of the currents supplied to the detector 7', to the motor 39.

Due to the displacement of the ribbon of the light valve 31 under control of the received picture current and the relative motions of the cylinder and carriage, varying amounts of light, corresponding to the varying tone value of successive elemental areas of the picture scanned at the transmitter, will be supplied to the film, and hence a picture of the subject scanned at the transmitter will be recorded, provided the transmitting and receiving cylinders are operated in synchronism and in phase with each other. Synchronous operation of the cylinders is assured by providing sources 5 and 5' which generate alternating currents of the same frequency which do not vary by more than about one part in five hundred thousand and by causing the cylinders to be

simultaneously started by a control switch at one of the cooperating stations.

Starting is effected by actuating the start key 40 at the transmitting station, which operates to simultaneously control the supply of current to the electromagnet controlling the clutch at the transmitter and to a similar electromagnet at the receiver through the clutch control 41. Starting may be controlled equally well by the receiving operator, in which event, the start key could be placed at the receiving station.

Since transmission of the low frequency picture currents over the line is impossible, because of the line characteristics, it is necessary to combine these low frequency variations with a carrier in order that they may be transmitted over the line. The filter 24 is used to select, from one of the side bands, resulting from this modulation, a series of components essential to the production of a satisfactory picture at the receiver. The selected components constitute a band extending from the unmodulated carrier component to a lower limiting frequency. Since it is necessary to pass freely all of the side band components essential to satisfactory picture reproduction, the cut-off of filter 24 must be such that it does not attenuate any of the desired components, otherwise distortion will result.

In order to obtain satisfactory definition in the received picture while remaining within limits prescribed by the transmission characteristics of the telephone circuits, the carrier frequency was made slightly greater than twice the frequency of the picture modulated current band essential for satisfactory reproduction, or, in other words, twice the frequency of the band passed without attenuation by the filter, and the ribbons of the light valve were supplied with oscillations of this frequency.

Fig. 2 illustrates the selective characteristic curve of filter 24 and lines U and S respectively indicate the frequency range of the picture current band and lower side band which include components of appreciable amplitudes. As therein indicated these bands overlap and the filter transmits a frequency band extending from the carrier frequency to a point A in the frequency spectrum and a further band extending from A to B which includes the overlapping components of the picture band and of the side band, as well as a limited number of the upper side band components. The filter is designed in accordance with the disclosure in Nyquist Patent 1,748,168, issued February 25, 1930 and hence operates to cause the selected components of the upper side band to be in phase with components of corresponding frequencies in the lower side band which would otherwise be subject to distortion.

Although the overlapping components of the unidirectional current and the lower side band passed by the filter are materially attenuated, they may cause appreciable distortion of the picture produced at the receiver.

Distortion due to the two groups of overlapping components was particularly noticeable when the ribbons of the light valve 14 were supplied with oscillations of the desired constant frequency from an independent source, i. e., from a source which was not synchronized with the picture scanning rate. The character of the distortion thereby produced is shown in Fig. 3, which is a draftman's reproduction of an enlargement of a portion of a pilot or guide strip consisting of a series of straight and slightly converging black lines on a white background. This strip was applied to the picture surface at the transmitter and formed a part of the field which was scanned for transmission. As shown in this figure, the reproduced lines are neither straight nor uniformly black, but rather wavy and the successive elemental areas are not of the same tone value, thereby indicating that certain of the elemental areas are not properly aligned with respect to others and the tone values of some of them are modified. In effect the pattern produced looks like a checkerboard or basket weave in which different colored strands are used. Distortion of the type illustrated is caused by the interaction of the two groups of overlapping components, one group belonging to the picture current resulting from the scanning operation and the other to the lower side band resulting from the modulation process in the photoelectric cell. Such interaction results in distortion of the tone value, and the change in tone value will occur in varying positions in each successive revolution of the picture wrapped around the cylinder, because of the changing relation of the two overlapping groups of frequencies resulting from the unsynchronized state of the carrier frequency and the frequency of rotation of the cylinder. This effect is further aggravated by some unavoidable phase distortion in the transformers and filters of the system causing certain frequencies to be transmitted faster or slower than is demanded by distortionless transmission.

A still further cause of the irregular pattern is the fact that the time of opening and closing of the light valve is not negligible in comparison with the speed of rotation of the cylinder. This results in the displacement of tones during successive revolutions of the picture cylinder when the opening and closing of the transmitting light valve is not synchronized with the rotation of the cylinder. Synchronization of the carrier frequency and the rotation of the cylinder does not eliminate distortion of tone values referred to above, but it controls the location of distorted picture elements and hence makes them less obvious in the received picture. The improvement in the received picture resulting from the synchronizing operation is illustrated in Fig. 4. This is a draftsman's reproduction of an enlargement of the received pilot strip and comprises a series of straight black lines converging slightly, as in the original scanned at the transmitter. While the edges of the black lines are not sharply defined but somewhat fuzzy, it is clearly apparent that synchronizing the picture scanning means and the light modulating means has improved the appearance of the received picture by preventing the irregular distribution of the picture elements.

What is claimed is:

1. An electro-optical system comprising means for producing a beam of light, an alternating current source for varying the amount of light of said beam in accordance with a definite law, a field of view to be scanned by said light beam, means for causing relative motion of said scanning beam and said field, means controlled by light received from said field of view to produce a picture current and a picture modulated carrier current which respectively include current components of the same frequencies, means for selecting a picture modulated sideband which also selects at least some of said components of said picture current, and means for producing a definite relation between the frequency of said

alternating current and the relative motion of said field and said scanning beam.

2. In an electro-optical scanning system comprising an image field, a source of steady light supplying a beam of light, a light valve controlled by an alternating current for cyclically modulating said light beam, means for producing relative movement between said light beam and said field to cause the former to scan successive elemental areas of the latter, means controlled by light received from said field of view to produce a picture current and a picture modulated carrier current which respectively include current components of the same frequencies, means for selecting a picture modulated sideband which also selects at least some of said components of said picture current, means for generating two electric currents having frequencies bearing definite frequency relationship to each other, and means for applying these currents to control respectively the alternating current supplied to said light valve and to the means for producing relative movement between the image field and the scanning beam.

3. An electro-optical system comprising means for producing a carrier modulated light beam, means for effecting relative movement of said beam and a field of view, means controlled by light received from said subject to produce a picture current and a picture modulated carrier current which respectively includes current components of the same frequencies, means for selecting a picture modulated side band which also selects at least some of said components of said picture current, and a common source for respectively controlling the operation of the beam modulating means, and the means for effecting its motion relative to said field.

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