Nov. 29, 1938. A. G. COOLEY 2,138,398

ELECTRO-OPTICAL TRANSMISSION METHOD AND APPARATUS

Filed Oct. 26, 1936 2 Sheets-Sheet 1

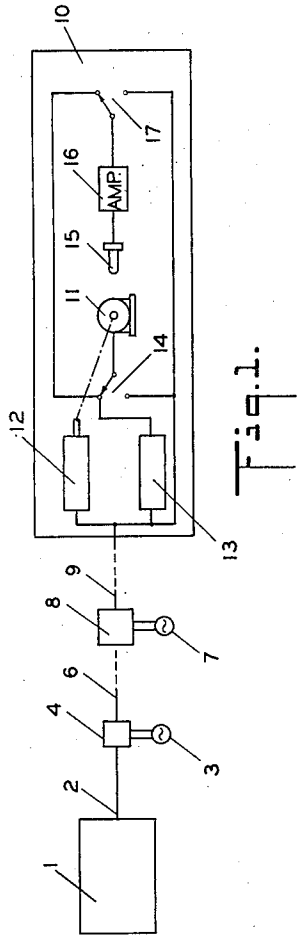


Fig. 1.

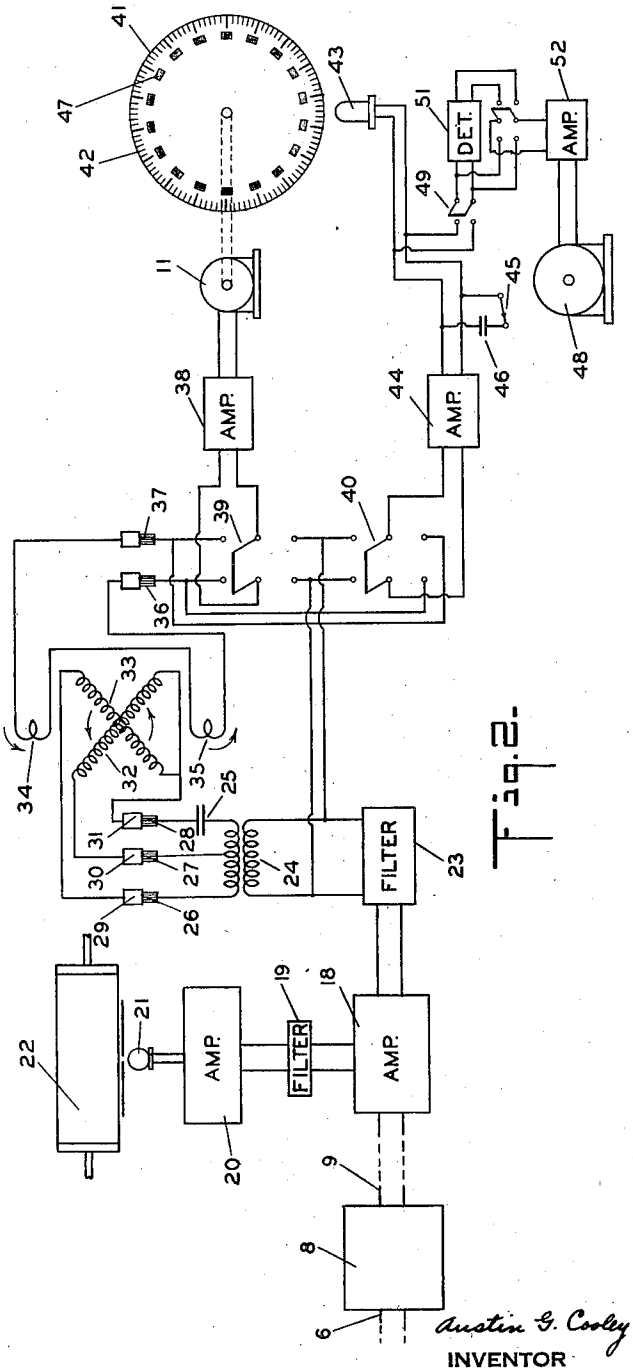


Fig. 2.

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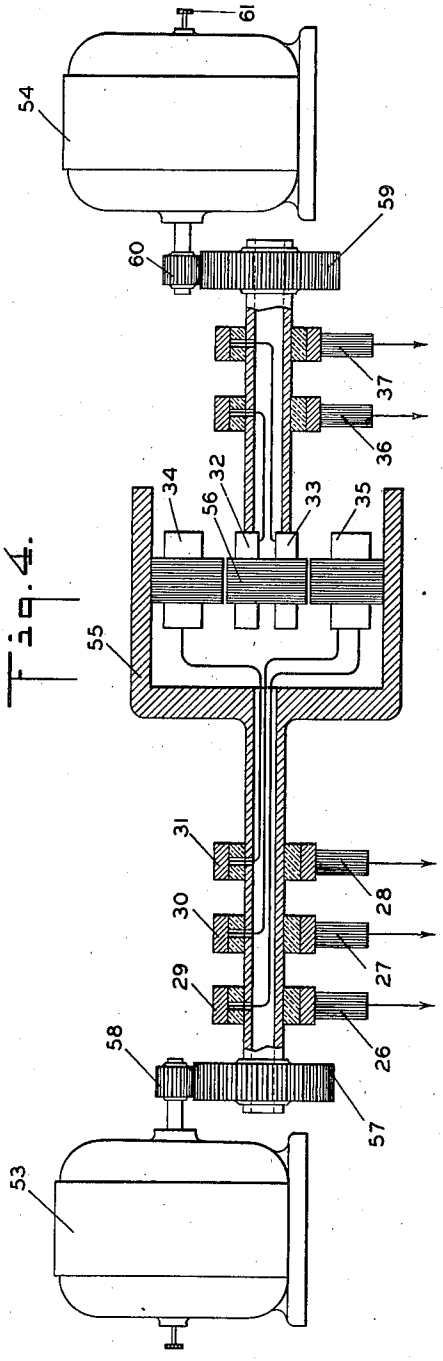


Fig. 4.



Fig. 7.

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ELECTRO-OPTICAL TRANSMISSION METHOD AND APPARATUS

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18 Claims. (Cl. 178—69.5)

This invention relates to electro-optical transmission and more particularly to systems of reproducing visual representations at a distance through the intermediary of electric waves.

A principal object of the invention is to provide an improved method and apparatus for effecting synchronization of the movable analyzing and synthesizing apparatus at the transmitter and receiver of an electro-optical system e. g., a facsimile or photo-transmission system and the like.

Another object is to provide an improved system of electro-optical transmission of the type wherein the picture current, or a selected frequency component thereof, is used for synchronizing; in conjunction with novel means to compensate for "frequency drift" introduced during transmission.

A feature of the invention relates to an improved form of compensating device to compensate for frequency drift in a carrier current transmitting and receiving system.

Another feature relates to an improved organzation of apparatus for maintaining synchronism in a photo-telegraphic, facsimile or similar system.

A further feature relates to the novel organization, arrangement and connection of parts which constitute an improved synchronizing monitoring system for systems employing a carrier wave link between a transmitting station and a receiving station.

Other features and advantages not specifically enumerated will be apparent after a consideration of the following detailed descriptions and the appended claims.

While the invention will be disclosed herein as embodied in one known type of signal transmission system, it will be understood that this is done merely for explanatory purposes and not by way of limitation. Furthermore only those parts of the system are shown as are necessary to a complete understanding of the inventive concept. Accordingly in the drawings,

Fig. 1 is a schematic diagram of an electro-optical transmission system embodying features of the invention.

Fig. 2 is a detailed wiring diagram, partly schematic, of the system outlined in Fig. 1.

Fig. 3 is a characteristic representation of a typical wave-train used at one stage of the synchronizing process according to the invention.

Fig. 4 is a detailed view, partly sectional, of the improved frequency drift compensator according to the invention.

Referring for the present to Fig. 1, the numeral 1 represents generally any well-known form of apparatus for translating the shade variations of a visual representation into so-called picture currents. Preferably, although not necessarily, this apparatus is of the type disclosed in Patent No. 2,015,742, granted October 1, 1935, wherein the picture currents are produced in the form of a variable amplitude wave having an inherent frequency component or fundamental definitely related to the speed of the movable analyzing mechanism. In general there are two methods of transmitting the picture currents to a receiving station, namely by transmitting the currents directly over a metallic circuit, or by employing them to modulate a carrier wave which may be transmitted either over a metallic circuit or by means of radio channels or the like. When the picture signals are transmitted directly over a metallic line, such for example as the usual telephone service line, satisfactory synchronization can be achieved. On the other hand, I have found that when these picture currents are transmitted over the usual carrier telephone channels, there may be introduced into the reproduced picture a noticeable distortion. This distortion is due to the fact that the frequency of the modulating and demodulating oscillators of the carrier telephone channels are not always synchronized, resulting in what may be termed "frequency drift." While this frequency drift is not objectionable in ordinary telephonic or sound wave communication, it is at times very objectionable in picture transmission. In accordance with the present invention means are provided to compensate for this frequency drift so that its effect on the picture reproduction is reduced to a substantially negligible amount. Thus as indicated in Fig. 1 of the drawings, the output of the picture transmitter 1 is applied to the usual telephone service line 2, and at the telephone central office terminal equipment, the picture currents are transformed into a correspondingly modulated carrier wave. Merely for purposes of illustration this carrier equipment is represented schematically in Fig. 1 by the carrier oscillator 3 and the modulator 4. The modulated carrier wave is then transmitted over a suitable carrier channel 6, either wire or wireless, to a carrier telephone receiving station at which is located any well-known form of demodulator. As is generally the case these demodulators employ some form of local receiving oscillator 7 and demodulating equipment by means of which the original picture signals are

capable of being demodulated or detected and impressed on the local telephone link 9 leading to the picture receiving equipment 10. For purposes of ordinary sound wave communication it is not necessary to maintain the frequency stability of the oscillator 7 above a predetermined amount with the result that from time to time there may be produced a frequency drift of as much as ten cycles per second in the demodulated wave. Under these circumstances, any system of picture transmission which employs the original picture signals as a medium of synchronization will be subjected to variations resulting in lack of synchronism between the picture transmitter and the picture reproducer. To remedy this condition, the synchronous motor 11 which drives the picture reproducing drum or carrier 12 is controlled by the signals from the line 9, after they have been acted upon by suitable drift compensating mechanism represented by the numeral 13 and shown in detail in Figs. 2 and 4.

In general the drift compensator comprises a rotary transformer having a two phase primary supplied by the incoming picture signal, and a single phase secondary which feeds the circuits which supply the synchronous motor 11. By varying the relative speed of rotation between the primary and secondary windings, the fundamental frequency of the received picture signals may be increased or decreased in the proper amount to render them synchronous with the signals as originally generated at the device 1. In order that the equipment may be used on ordinary non-carrier telephone transmission lines, a switch 14 is provided to disconnect the drift compensator 13. When the drift compensator is in circuit it is necessary to provide some indication to the attendant when the device 12 is in synchronism with the corresponding device at the transmitter 1. For this purpose the synchronous motor 11 may drive a stroboscopic chart and the drift compensated signals are used to light the lamp 15 which illuminates the disc. When the drift compensator is not in circuit, the stroboscopic lamp 15 is energized directly through a suitable amplifier by means of switch 17.

Referring to Fig. 2 a detailed description will now be given of a typical picture reproducing equipment such as is indicated in Fig. 1 by the numeral 10, it being assumed for the present that the transmission is to take place from the picture transmitter over a carrier telephone channel 6, through the intermediary of the usual telephone carrier demodulating or detecting equipment 8. Merely for purposes of reference it will be assumed that the original picture signals, before application to the carrier channel, possess a fundamental frequency of 1800 cycles per second, and with amplitude variations corresponding to the shade values of the picture being transmitted. The picture signals after demodulation in the device 8 are preferably amplified in a suitable amplifier 18, and part of the amplified signals pass through the filter 19 to the amplifier 20, the output of which is impressed upon the recording lamp 21. Lamp 21 acts on the picture receiving surface mounted on the drum to reproduce the picture thereon in successive elemental areas, as disclosed for example in Patent No. 2,015,742, it being understood that the drum 22 is rotated by a suitable synchronous motor 11. Another part of the output of amplifier 18 passes through the filter 23 and thence to the transformer primary winding 24, the secondary winding being split as shown and one section of the secondary being provided with a condenser so as to produce a two-phase 90 degree displaced current at the brushes 26, 27, 28. These brushes contact with corresponding slip rings 29, 30, 31 connected to the two-phase primary of the rotary transformer. As shown this primary consists of two windings 32, 33 mounted for rotation as a unit by a suitable motor. The secondary of the rotary transformer comprises the series connected single phase windings 34, 35 which are mounted for rotation as a unit around the primary winding, it being understood that suitable rotating means are provided for that purpose. Preferably although not necessarily, the primary and secondary windings of the rotary transformer are rotated in the same direction as indicated by the arrows. The current at the brushes 36, 37 will therefore be a single phase alternating current whose frequency is a function of the relative rotational speeds of the primary and secondary windings. By varying the speed of rotation of either or both of the windings, the frequency of the current at brushes 36, 37 may be correspondingly increased or decreased. If as assumed above there is no frequency drift, the picture currents received over the line 9 have a frequency of 1800 cycles, and if the windings of the drift compensator are rotated in the same direction at the same speed, the current at the brushes 36, 37 will also be at a frequency of 1800 cycles. This latter current may, if desired be amplified in a suitable amplifier 38 and then applied to the synchronous motor 11, and for this purpose the switch 39 is closed on its upper contact set, and switch 40 on its lower contact set. In order that the attendant may ascertain whether the motor 11 is operating in synchronism with the signals from the output of amplifier 18, said motor drives a stroboscopic disc having a series of equally spaced spots 42 which are illuminated by the stroboscopic lamp 43. When the switch 40 is closed on its upper contact set, the lamp 43 which is preferably of the glow discharge type, is excited by the 1800 cycle current supplied from the output of amplifiers 18 and 44. If the spots 42 appear to be stationary then the attendant knows that the motor 11 is operating at 1800 cycle speed. Under these conditions assuming that there is no "frequency drift" introduced at the demodulator 8, and assuming that the windings of the drift regulator are rotating at the same speed, then the closure of switch 39 on either its upper or lower contact set should not result in any apparent movement of the spots 42.

If it is known or suspected that the signals are being transmitted through phone circuits involving carrier equipment, the sending operator will cause the 1800 cycle carrier to be modulated at a low frequency, say 90 cycles per second. The stroboscope lamp 43 will then illuminate the target 41 in such a way that the spots 47 will appear prominent. If there is a frequency drift these spots will appear to slowly move with or against the rotation of the target. This is an indication to the attendant that it is necessary to adjust the drift compensator to add or subtract the necessary number of cycles to cause the target to appear to stand still. Accordingly the attendant causes a relative change in speed between the primary 32—33 and secondary 35.

While the above description gives the general method of operation for maintaining synchro-

nism, it is preferred to employ the following procedure so that before starting the actual transmission and reproduction of a picture the operator at the transmitter and the operator at the receiver may be assured that the proper synchronous conditions exist. The transmitting operator transmits an unmodulated 1800 cycle signal which is amplified by amplifier 18. The receiving operator closes switch 39 on its lower contact set, and switch 40 on its upper contact set and stroboscopically synchronizes motor 11 on the 1800 cycle signal by means of the lamp 43 and the disc 41. The transmitting operator then transmits an 1800 cycle signal modulated with a 90 cycle signal, as represented by the curve of Fig. 3. Under this condition the receiving operator closes switch 45 to connect the condenser 46 in shunt to lamp 43. The combination of lamp 43 and condenser 46 acts similar to a detector of the 90 cycle signal, and as indicated the disc 41 is provided with a series of larger more widely spaced spots 47 for stroboscopic synchronizing on 90 cycles. If the spots 47 appear to move one way or the other the receiving operator is thereby warned that a frequency drift is being introduced in the transmission channel, whereupon he may adjust the speed of either or both windings of the drift compensator until the spots again appear stationary. After this adjustment the 90 cycle modulated wave is disconnected at the transmitter and the system is ready for the regular picture transmission. If during transmission the receiving operator notices that the spots 41 appear to move, he may switch in the dritf compensator by closing switch 39 on its upper contact set and switch 40 on its lower contact set. Preferably however, after the initial synchronization on the 1800 cycle carrier has been effected, the drift compensator is switched into circuit, so that the actual picture transmission and reproduction is effected with the drift compensator in circuit at all times.

Under certain conditions it may be desirable instead of employing a relatively high speed synchronous motor such as the 1800 cycle motor 11, to employ a lower speed for example, 90 cycles. I have found that with such lower speeds the frequency drift effect may be avoided by transmitting the 90 cycles as a modulation of a higher frequency carrier wave, for example a 400 cycle wave. In other words at the transmitter there will be provided means for producing the usual 1800 cycle picture signal as described in Patent No. 2,015,742, and in addition there will be provided a source of 400 cycle carrier current modulated by a 90 cycle signal. When the receiver is to be driven from a 90 cycle motor such as motor 48 (in place of motor 11), switch 40 is closed on its upper contact set; switch 39 on its lower contact set; and switches 45 and 49 are closed. Switch 50 may be closed on either its left-hand contact set or on its right-hand contact set. In the latter position the 90 cycle detector 51 is connected in circuit with amplifier 52 and motor 48. In certain cases however reliance may be placed entirely on the combination of condenser 46 and glow lamp 43 as the detecting mechanism, in which case switch 50 is closed on its left-hand contact set. In either case the detected 90 cycle signal will not be affected by any "frequency drift" of the carrier demodulating equipment 8, so that the motor 48 may be operated without the drift compensator. It will be understood of course that when the motor 48 is being used, that the filter 19 is properly designed so as to exclude the 400 cycle carrier from the picture reproducing lamp 21, and if desired the filter 23 may be adjusted to keep the picture frequency of 1800 cycles from reaching the motor 48.

Referring to Fig. 4 a description will now be given of a structure of drift compensator that has been found to produce the desired results. Two universal variable speed motors 53, 54 with suitable speed governors (not shown) drive respectively the frame 55 and frame 56. Frame 55 carries the primary windings 34, 35 (Fig. 4), and frame 56 carries the secondary windings 32, 33. These frames are rotated in the same direction but at different speeds depending upon the amount of frequency drift to be compensated, as described in connection with Fig. 2. The primary frame 55 is driven through gears 57, 58, and the secondary frame is driven through gears 59, 60. A thumb screw adjustment 61 is preferably provided for the governor on motor 54, and this screw may be provided with a calibrated dial to indicate the speed of motor 54. If the speed of the secondary frame is greater than the primary frame one cycle will be added to the output of the compensator for each revolution gained by the secondary. If the secondary runs lower than the primary, one cycle will be subtracted for each revolution lost by the secondary. Instead of using two variable speed motors, one of the motors may be a synchronous motor and the other a variable speed motor. However, it is preferred to employ two variable speed motors of the same matched design since ordinarily variable speed governor-controlled motors tend to gain or lose in speed after they are warmed up. By using two matched variable speed motors, the resultant speed differential is reduced to a minimum. Instead of using one synchronous motor and one variable speed motor, two synchronous motors may be employed, one driven from the 60 cycle mains and the other driven from a suitable source of variable frequency, such as an adjustable oscillator.

While certain specific arrangements and types of parts have been disclosed, it will be understood that various changes and modifications may be made therein without departing from the spirit and scope of the invention by the expression "carrier channel" as employed in the claims is meant a communication channel where signals are transmitted by means of carrier waves generated at a distant transmitting point and wherein the modulations are demodulated by an oscillator or similar device which is intended to be in synchronism with a similar oscillator at the transmitting point.

What I claim is:

1. In a system for transmitting a visual representation between two points employing an oscillator-modulator at the transmitting point and an oscillator-demodulator at the receiving point, the combination of a picture reproducing means at the receiving point, a synchronous motor driving said reproducing means, means to receive synchronizing signals over the carrier channel, means to indicate frequency drift in said synchronizing signals after demodulation at the receiving terminal of the carrier channel, frequency changing means to act on the received synchronizing signals to compensate for any frequency drift between the oscillators at the terminals of the carrier channel to produce a current of constant frequency for operating said synchronous motor.

2. In a system for transmitting a visual representation between stations linked by a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, the combination of means to analyze the representation into corresponding signal currents, means to apply said signal currents to a carrier transmission channel, means to reproduce a picture under control of said signals, means to indicate frequency drift in said signals and frequency changing means acting on the signals received from said carrier channel to compensate continuously for the frequency drift introduced into said signals by reason of their transmission over said carrier channel.

3. In a system for transmitting a visual representation between stations linked by a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, the combination of means to translate a picture into picture current signals having an inherent frequency component related to the speed of the picture analyzing mechanism, means to impress said signals on a carrier transmission channel, means to reproduce the picture under control of said signals, the last-mentioned means including movable synthesizing means whose speed of operation is controlled by said frequency component, and frequency changing means acting on the signals received from said carrier channel to compensate for frequency drift introduced into said frequency component by reason of the transmission over said carrier channel.

4. In a system for transmitting a visual representation between stations linked by a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, the combination of means to analyze a picture into corresponding signal currents having the characteristics of a modulated carrier wave, means to apply said signal currents to a carrier transmission channel, means to reproduce the picture under control of said signal currents and to synchronize the reproducing mechanism with the analyzing mechanism, the last-mentioned means including a synchronous motor, and a frequency converter whose output is applied to drive said motor.

5. In a system for transmitting a visual representation between stations linked by a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, the combination of means to analyze a picture into corresponding signal currents having the characteristics of a modulated wave of a frequency corresponding to the analyzing frequency, a carrier transmission channel having means to modulate a carrier wave by said signal currents and means to demodulate said carrier wave to derive therefrom said currents, a picture reproducing mechanism including synthesizing means and a synchronous motor therefor, a frequency converter on which said derived signals are impressed, and means to operate said synchronous motor by the output of said converter to compensate for frequency drift introduced by said carrier channel.

6. In a system for transmitting a picture over a carrier channel of the type having modulating and demodulating oscillators at the terminals thereof, the method which comprises generating at a transmitter a sustained wave modulated by another wave the latter wave having a frequency determined by the speed at which the picture transmitter and picture reproducer are to operate, applying said modulated wave to a carrier transmission channel to transmit said modulated wave as a modulation of a carrier wave over said channel, receiving the first-mentioned modulated wave after demodulation from said carrier, stroboscopically synchronizing a device at the receiver under control of the modulations in said modulated wave, then transmitting from the transmitter to the receiver over said channel a sustained wave modulated in accordance with picture characteristics, applying the last-mentioned wave to synchronize the transmitter and receiver, and acting on said last-mentioned wave to compensate for any frequency drift in the last-mentioned wave by reason of its transmission over said carrier channel.

7. In a system of the character described the combination of means to receive from a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, picture currents in the form of a sustained wave having amplitude modulations corresponding to the shade characteristics of a picture to be reproduced, picture reproducing mechanism, a synchronous motor for driving said mechanism, stroboscopic means to indicate the operation of said motor at a known frequency, and a frequency converter having its output connected to said motor and its input controlled by a portion of said picture currents.

8. In a system of the character described, the combination of means to receive from a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, a current having a frequency for determining the speed at which the picture reproducing mechanism is to operate, picture synthesizing means, means including a synchronous motor to synchronize said synthesizing means at said frequency, and frequency converting means whose output is applied to said synchronous motor to control the speed of operation of said synthesizing means, and means for applying said current to the input of said converting means.

9. In a system of the character wherein picture currents are transmitted to a receiving station over a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, the combination of a picture scanning mechanism, a synchronous motor for actuating said mechanism, means to receive a synchronizing alternating current, and a rotary transformer for converting the frequency of said current prior to application to said motor to compensate for frequency drift introduced in said channel, and means to apply the converted currents to said synchronous motor.

10. A system according to claim 9 in which the transformer is provided with a polyphase winding, and means are provided to convert the said current into a corresponding polyphase current prior to application to said transformer.

11. A frequency converter for use in receiving pictures transmitted over a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof, comprising a rotatable primary winding and a rotatable secondary winding, a pair of matched variable speed motors for driving said windings, means to receive picture synchronizing signals, means to apply said signals to the primary of said converter, means to apply the signals in the secondary of said converter to said synchronous

motor, and stroboscopic means to determine whether one or both of said variable speed motors are operating at the required speed.

12. In a system of the character described, the combination of means to transmit a synchronizing signal over a carrier transmission channel of the type having modulating and demodulating oscillators at the terminals thereof, means associated with said channel to demodulate the carrier to derive the synchronizing signal therefrom, the last-mentioned means including a demodulating oscillator, and means to convert the frequency of said demodulated signal to compensate for the frequency drift of said oscillator.

13. The method of transmitting a picture over a carrier telephone channel of the type having modulating and demodulating oscillators at the terminals thereof which includes the steps of scanning the picture to produce a synchronizing frequency, modulating said synchronizing frequency by a lower drift checking frequency, applying said modulated frequency to the carrier telephone channel, receiving said modulated frequency from said channel, detecting the drift checking frequency and the synchronizing frequency, driving a scanning device under control of the synchronizing frequency, and applying said lower modulating frequency to detect stroboscopically whether any frequency drift is introduced into the synchronizing frequency by said carrier telephone channel.

14. The method according to claim 13 in which the received modulated synchronizing frequency is applied to a frequency changer to compensate for frequency drift introduced by the carrier telephone channel.

15. In a system for transmitting pictures from a transmitting point to a receiving point over a carrier telephone channel of the type having carrier frequency oscillators at the terminals thereof, means at the transmitting point to generate a voice frequency synchronizing carrier, means to modulate said synchronizing carrier by a lower frequency drift checking signal, means to apply said modulated carrier to said telephone channel, means to receive at the receiving point a signal which is the resultant of the transmitted synchronizing frequency and any frequency drift introduced in the carrier channel, means to detect said lower frequency modulation, and stroboscopic means controlled jointly by said rerultant and said detected modulations.

16. A system according to claim 15 in which a motor is provided for driving the stroboscope target, said motor being controlled by said resultant and said detected modulation being applied to a stroboscope lamp for illuminating said target.

17. A system according to claim 15 in which means are provided for applying the said resultant to an adjustable frequency converter, the output of which drives the stroboscope target.

18. A frequency transformer having primary and secondary windings rotatable in the same direction, each winding having its own driving motor and each motor having its own individual speed control.

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