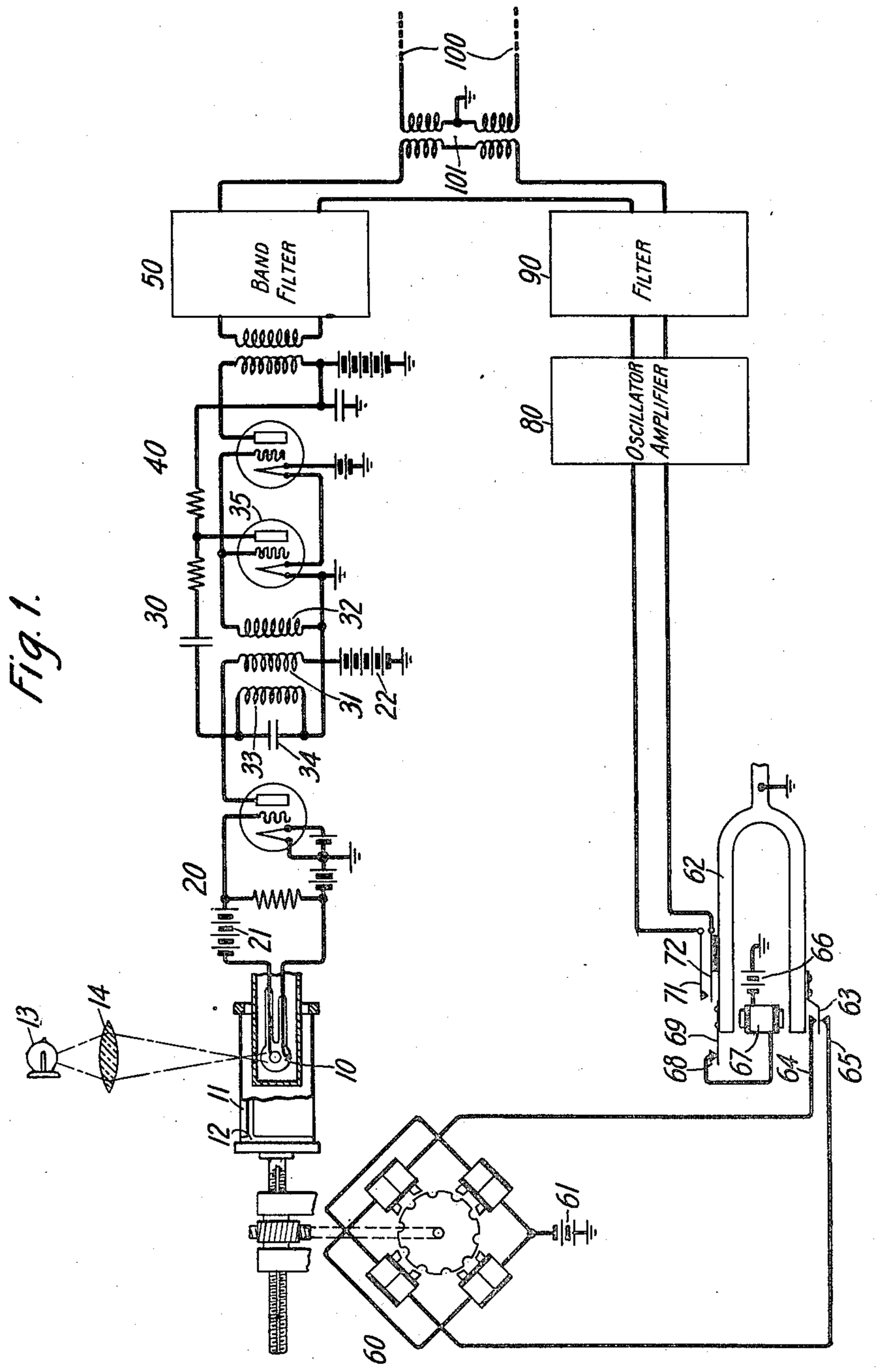
Nov. 1, 1932. W. H. T. HOLDEN ET AL 1,885,826

SYSTEM OF PHOTOGRAPHY EMPLOYING FREQUENCY MODULATION

Filed Dec. 8, 1926 2 Sheets-Sheet 1

Fig. 1.



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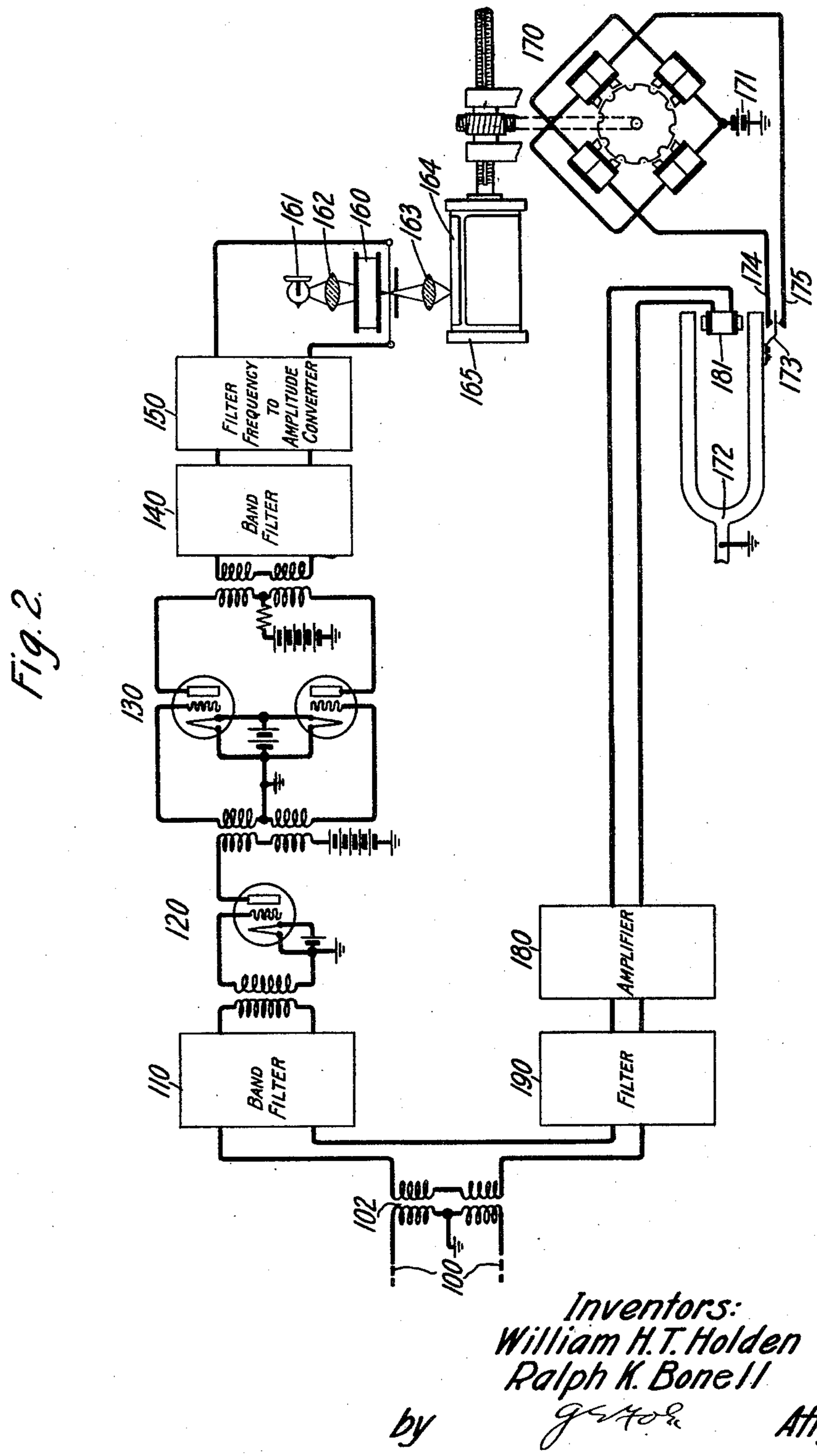

Fig. 2.

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UNITED STATES PATENT OFFICE

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SYSTEM OF PHOTOGRAPHY EMPLOYING FREQUENCY MODULATION

Application filed December 8, 1926. Serial No. 153,408.

This invention relates to alternating current signaling systems, and more particularly to electro-optical transmission systems.

An object of this invention is the maintenance, in an alternating current signal transmission system, of a substantially constant signaling current level at the receiving station irrespective of transmission level variations.

In a preferred embodiment of this invention the signal to be transmitted modulates the frequency of a carrier current rather than the amplitude of the carrier current, and at the receiving terminal the incoming frequency modulated wave is amplified to a value above a given minimum, taking due account of normal variations in the transmission line, and then kept at a substantially constant value by a current limiting device which is always acting, thereby producing beyond the current limiting device a signal wave of substantially constant amplitude having its frequency modulated in accordance with a signal such as the tone values of a picture. This wave of substantially constant amplitude and varying frequency is then converted into a wave having both amplitude and frequency variations, the amplitude being a linear function of the frequency, and thereby made capable of operating a light valve or other device which is sensitive only to the amplitude and substantially independent of the frequency of the operating current.

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

Figure 1 is a general schematic arrangement of the transmitting apparatus of a preferred embodiment of this invention.

Fig. 2 is a general schematic arrangement of the receiving apparatus for use with the equipment of Fig. 1.

The embodiment of this invention as herein shown relates to a picture transmitting and receiving system. At the transmitting station the tone values of the picture whose image is to be transmitted cause a frequency modulation of a carrier current. In Fig. 1 a photoelectric cell 10 is exposed to light variations modulated in accordance with the tone value of the transparent picture or negative 11. The transparent picture is fixed upon a transparent drum 12 which is given a motion of rotation and of translation. A small elemental area of the picture is illuminated by a source of intense light 13 and a lens system 14 focuses the light on a small elemental area of the picture. Upon passing through the picture, the light impinges upon a photoelectric cell 10, thereby causing it to pass current in proportion to the amount of light transmitted through an elemental area of the picture. The movement of the picture is such that its elemental areas are successively scanned by the beam of light. The terminals of the photoelectric cell 10 are connected through a source of electric current 21 with a substantially distortionless amplifier 20 which, in turn, connects with the frequency modulating apparatus 30.

The output circuit of the amplifier is energized by the battery 22 and the circuit is connected to the winding 31 of the input transformer of the frequency modulating apparatus 30. The input transformer of the frequency modulating apparatus has three windings, 31, 32 and 33, the latter two windings being so connected to the vacuum tube 35 as to cause it to set up sustained oscillations and provide a carrier current. The oscillating circuit is tuned by the winding 33 and the condenser 34 and a carrier current of the desired frequency is generated. The input transformer is so constructed and the circuits are so adjusted that the inductance of the winding 33 which determines the frequency of the oscillator will vary as the inverse square of the current in the winding 31 which results in the frequency of the oscillations generated by the vacuum tube 35 being a linear function of the input current traversing the winding 31. This current is a linear function of the illumination of the photoelectric cell 10 and by this modulation of the frequency of the oscillator, its frequency output is a linear function of the light density of the picture

through which the photoelectric cell receives its light. The frequency modulator oscillator apparatus 30 connects with the vacuum tube amplifier 40 which, in turn, connects with the high pass band filter 50. The output circuit of the transmitting apparatus just described connects with the transmission line 100 through the repeating coil 101.

In picture transmission systems of the type described, elemental areas are successively scanned, and it is therefore necessary that the transmitting apparatus and the receiving apparatus be operated in synchronism. A suitable means for maintaining such synchronism is disclosed in the patent to Maurice B. Long, No. 1,706,032, March 19, 1929, filed December 18, 1923. A LaCour motor whose speed is controlled by a tuning fork is used for driving the apparatus at the transmitting and at the receiving stations. At the transmitting station the LaCour motor 60 is geared to the picture drum 12 which is so mounted that it receives a motion of both rotation and translation by any suitable arrangement such as a gear connection to cause rotation and a threaded shaft and fixed nut to cause lateral movement. The LaCour motor is supplied with an electric current from any suitable source, such as the battery 61. The speed of operation of this motor is controlled by the tuning fork 62 which, at the end of one of its tines, carries a contact 63 which alternately connects with the contacts 64 and 65 connected with the two sets of windings on the motor. The frequency of vibration of the tuning fork controls the speed of the motor. The tuning fork is operated by the battery 66, the magnet 67 and the contacts 68 and 69 associated with one of the tines of the fork.

A synchronizing circuit is controlled by the contacts 71 and 72 operated by the tuning fork 62. Synchronizing current of suitable frequency and strength is generated by the oscillator and amplifying apparatus 80, and after passing through the filter 90 it is impressed upon the transmission line 100 through the repeating coil 101. Both the modulated picture current and the synchronizing current are simultaneously transmitted over the transmission line 100.

The arrangement of the apparatus at the receiving station is shown in Fig. 2. The incoming frequency modulated carrier current from the transmission line 100 passes through the repeating coil 102 to the band filter 110 which allows only the picture currents to pass to the input amplifier 120. The picture currents are next impressed upon the push-pull current limiting device 130, such as the vacuum tube arrangement shown on page 374 in the first edition of a book by van der Bijl entitled "Thermionic Vacuum Tubes", published by McGraw-Hill Book Company, which is so adjusted that it limits the amplitude of the output current so that it is always of constant value even when the amplitude of the incoming modulated carrier current is a minimum due to normal causes, such as increased attenuation of the line or low gain in the repeaters. The output of the current limiting device is next passed through a band filter 140 to suppress harmonics of the picture carrier current which may be produced in the current limiting device. The output of this filter is a variable frequency picture carrier current of substantially uniform amplitude.

The output of the band filter 140 is transmitted to the filter frequency to amplitude converter 150 which has a sloping characteristic over the range of the frequencies transmitted such that there is a linear relation between attenuation and frequency. An arrangement for converting frequency variations to amplitude variations is disclosed in a co-pending patent application of Maurice B. Long, Serial No. 110,910, filed May 22, 1926. The function of this second filter is to convert the output of the first mentioned filter from a uniform amplitude variable frequency current to a current having both amplitude and frequency variation, the amplitude being a linear function of the frequency. In this connection it is important that the filter frequency to amplitude converter be supplied with a current of substantially constant amplitude. If, however, the output of the signal modulating apparatus is such that the relation between frequency and signal strength, the latter in the embodiment here shown being proportional to the illumination of the photoelectric cell, is non-linear, it is still possible to compensate for this non-linearity by the use of filter circuits having non-linear frequency-transmission characteristics such that the resultant current impressed on the light valve is still a linear function of the illumination of the photoelectric cell. The output now varies in both frequency and amplitude in accordance with the light variations or tone values of the picture at the transmitting station and can be employed to operate a receiving device such as a light valve which is sensitive to this amplitude but substantially independent of the frequency of the operating current.

The receiving apparatus here shown employs a light valve 160 electrically connected with the output circuit of the high pass filter 150. The light valve varies the intensity of a beam of light from the light source 161 transmitted through it and through any suitable lens system such as the lenses 162 and 163 to properly focus the light beam on the photo-sensitive receiving film 164.

The film 164 is fixed on the surface of the drum 165 which is given a motion of rotation and translation in synchronism with that of

the drum 12 at the transmitting station. Small elemental areas of the photo-sensitive film are successively illuminated in accordance with the illumination of similar elemental areas of the picture at the transmitting station and cause a reproduction of the picture in accordance with well-known principles. The drum 165 is driven by the LaCour motor 170 supplied by a source of power 171. The speed of operation of this motor is controlled by the tuning fork 172 which has a frequency identical to that of the tuning fork 62 at the transmitting station. A contact 173 is attached at the end of one of the tines of the fork and this contact alternately connects with the contacts 174 and 175, thereby energizing one or the other of the sets of coils on the LaCour motor.

The incoming synchronizing current passes from the transmission line 100 through the repeating coil 102, the filter 190, the amplifier 180 and to the magnet 181 which drives the tuning fork 172. The LaCour motor 170 is thereby caused to operate in synchronism with the LaCour motor 60 at the transmitting station, in accordance with principles well known in the art, and the picture carrying drums 12 and 165 at the transmitting and receiving stations, respectively, are given synchronous motions of rotation and translation.

While the apparatus above described embodying the principles of this invention shows a picture transmission system, it is obvious that this invention is applicable to other signal transmitting systems.

What is claimed is:

1. In a frequency modulated carrier current signaling system, means at a receiving station for reducing distortion due to fluctuations in amplitude of the transmitted current resulting from variable attenuation properties of the transmission medium, said means comprising a current limiting device of the push-pull type, an amplifier for amplifying the received modulated current of varying frequency and fluctuating amplitude, and means for impressing the amplified current upon said current limiting device, said amplifier amplifying the impressed current by such an amount that the amplified current is always limited by said current limiting device whatever the amplitude of received current.

2. In a frequency modulated carrier current signaling system, means at a receiving station for reducing distortion due to fluctuations in amplitude of the transmitted current resulting from variable attenuation properties of the transmission medium, a current limiting device of the push-pull type, an amplifier for amplifying the received modulated current of varying frequency and fluctuating amplitude, and means for impressing the amplified current upon said current limiting device, said amplifier amplifying the impressed current by such an amount that the amplified current is always limited by said current limiting device whatever the amplitude of received current.

3. In a frequency modulated carrier current signaling system, means at a receiving station for reducing distortion due to fluctuations in amplitude of the transmitted current resulting from variable attenuation properties of the transmission medium, said means comprising a current limiting device of the push-pull type, an amplifier for amplifying the received modulated current of varying frequency and fluctuating amplitude, means for impressing the amplified current upon said current limiting device, said amplifier amplifying the impressed current by such an amount that the amplified current is always limited by said current limiting device whatever the amplitude of received current, and means for eliminating harmonics caused by said current limiting device.

4. A carrier current system comprising means for producing a frequency modulated carrier current whose frequency varies over a considerable range, a transmission line for transmitting said current to a receiving station, said line having varying attenuation properties which introduce fluctuations in said current, an amplifier at a receiving station for amplifying the received current of varying frequency, and a space discharge current-limiting device of the push-pull type upon which said amplified current is impressed, said amplifier amplifying the impressed current by such an amount that the amplified current is limited by said current limiting device whatever the amplitude of received current.

5. An electro-optical transmission system comprising means for generating an oscillating carrier current the frequency of which is modulated in accordance with the light tone values of successively scanned elemental areas of a field of view, means at a receiving station for reducing distortion due to fluctuations in amplitude of the transmitted current resulting from variable attenuation properties of the transmission medium, said means comprising a current limiter, an amplifier for amplifying the received modulated current of varying frequency and fluctuating amplitude, means for impressing the amplified current upon said current limiter, said amplifier amplifying the impressed current by such an amount that the amplified current is always limited by said current limiter whatever the amplitude of received current, means for eliminating harmonics produced by said current limiter, means controlled by said current of limited amplitude for producing amplitude modulations corresponding to the frequency modulations of the transmitted cur-

rent, and means controlled by said last mentioned modulations for producing an image of the distant field of view.

6. A signaling system comprising means for receiving carrier waves the frequency of which is modulated in accordance with a signal, a current limiting device of the push-pull type, means for impressing said waves upon said current limiting device to produce a corresponding wave of limited and constant amplitude, and means for utilizing said last mentioned wave in the reproduction of the signal.

7. A signaling system comprising means for receiving a carrier current wave the frequency of which is modulated in accordance with signals, a wave amplitude limiting device of the push-pull type means for impressing said wave upon said limiting device to produce a corresponding wave of limited and constant amplitude, means for eliminating from said last mentioned wave harmonic components caused by said current limiting device, and means for utilizing the resultant wave in the reproduction of the signal.

In testimony whereof, we have signed our names to this specification this 7th day of December, 1926.

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