

July 8, 1930.

F. GRAY

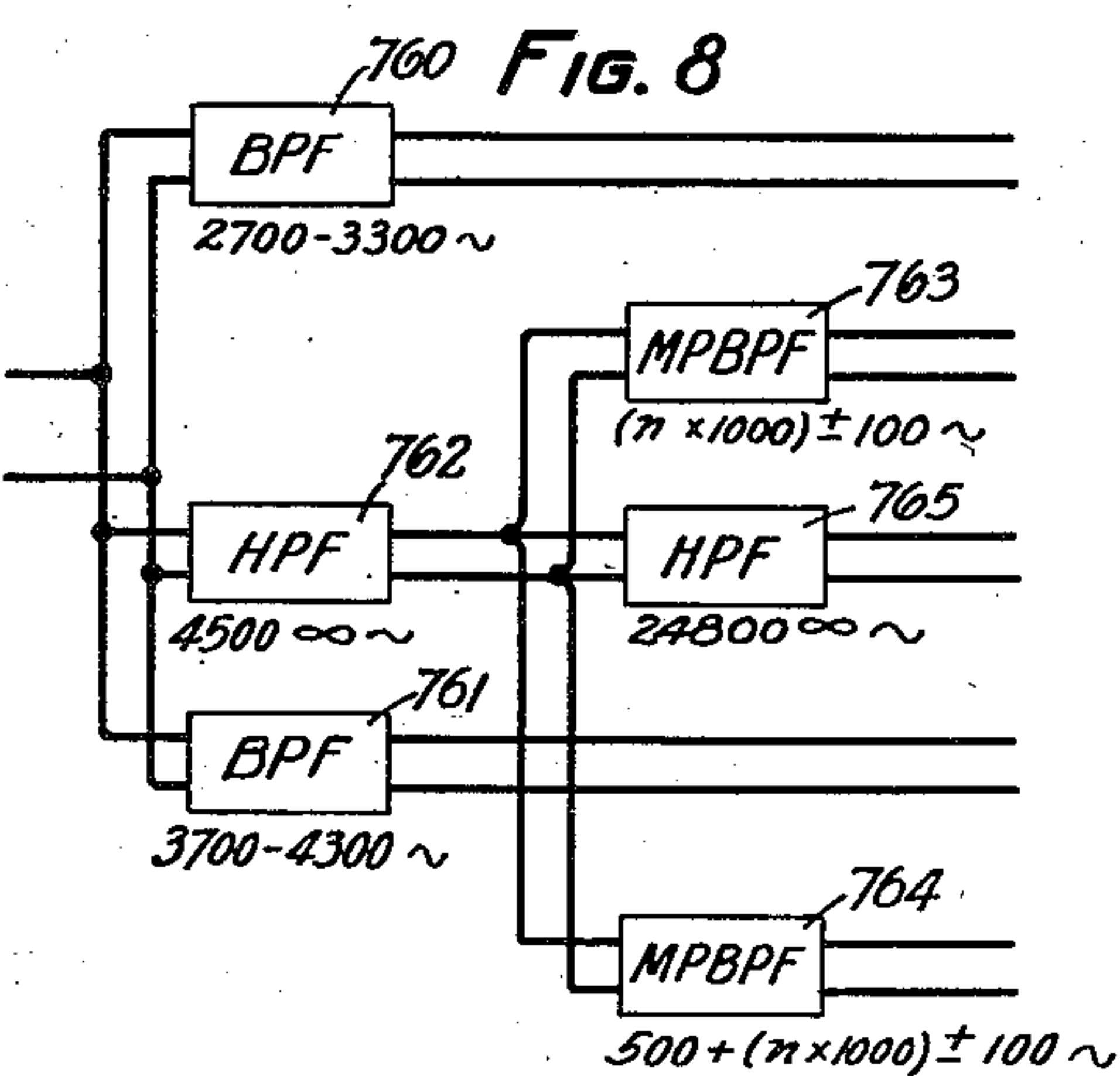
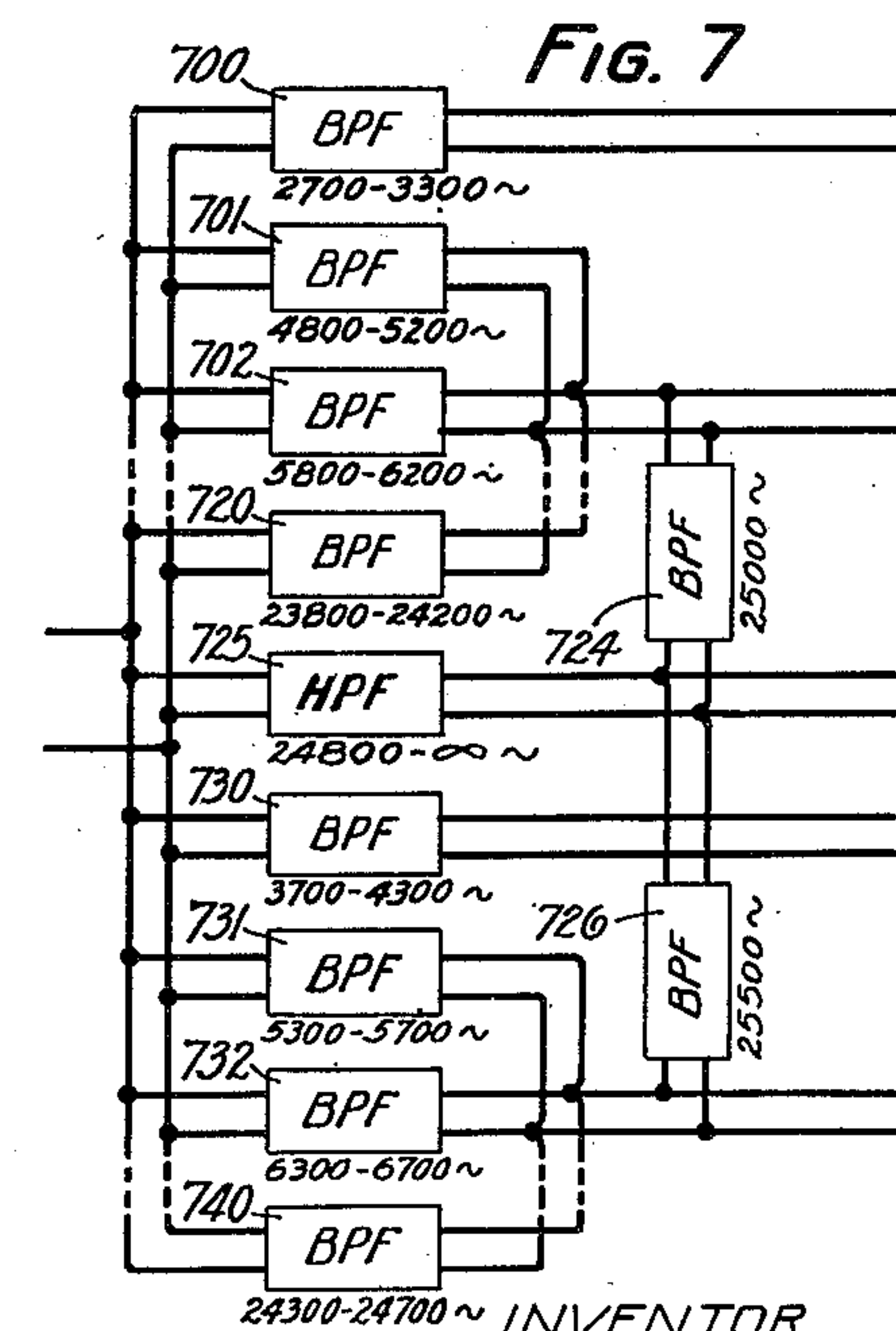
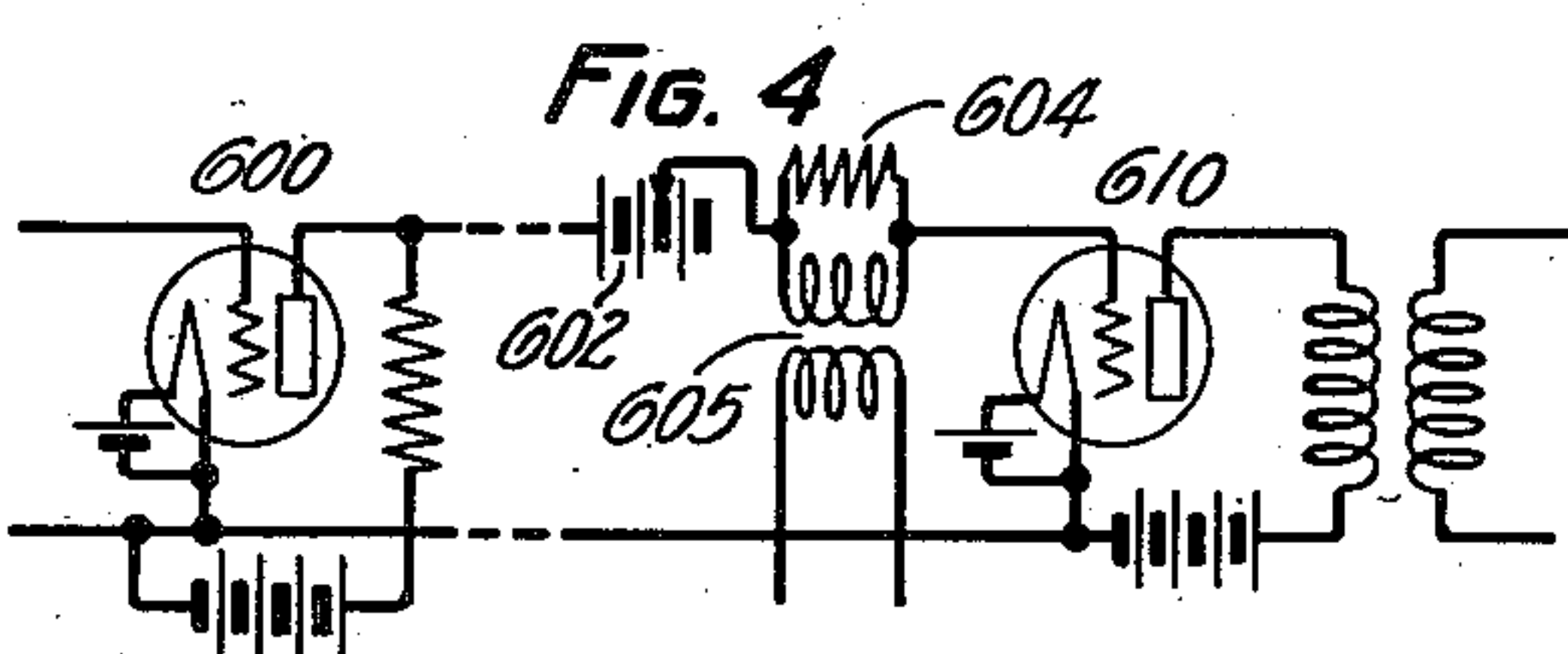
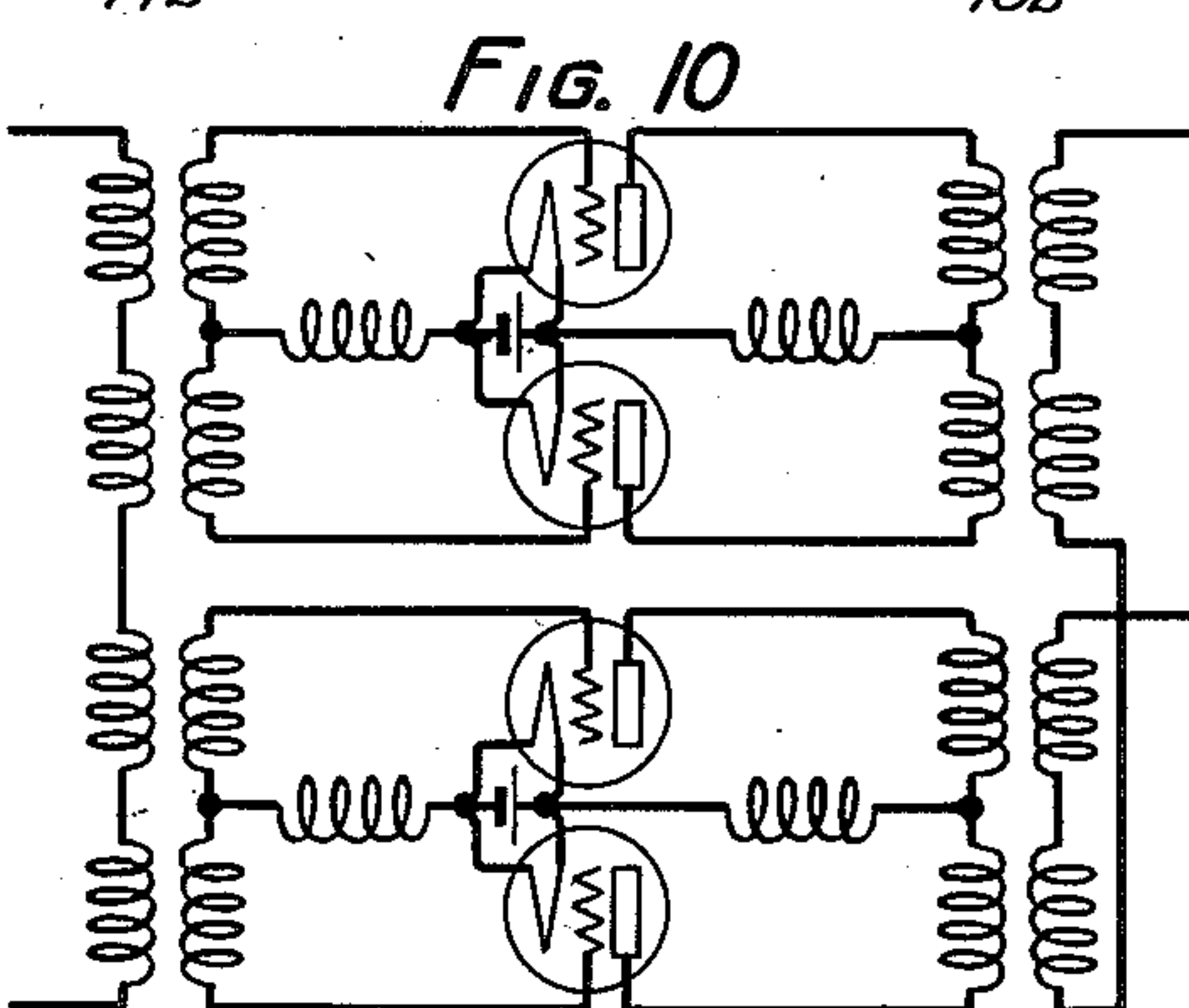
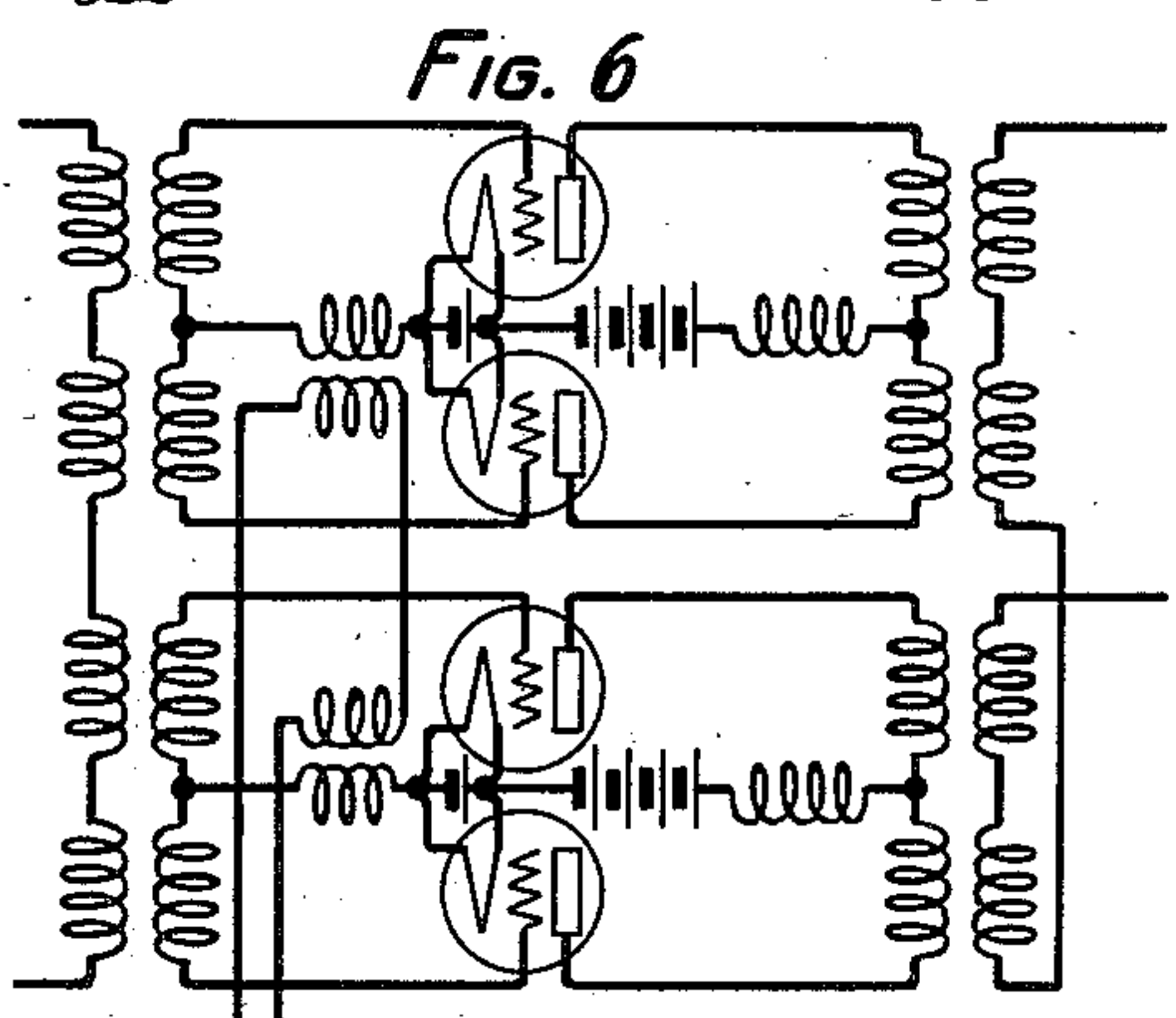
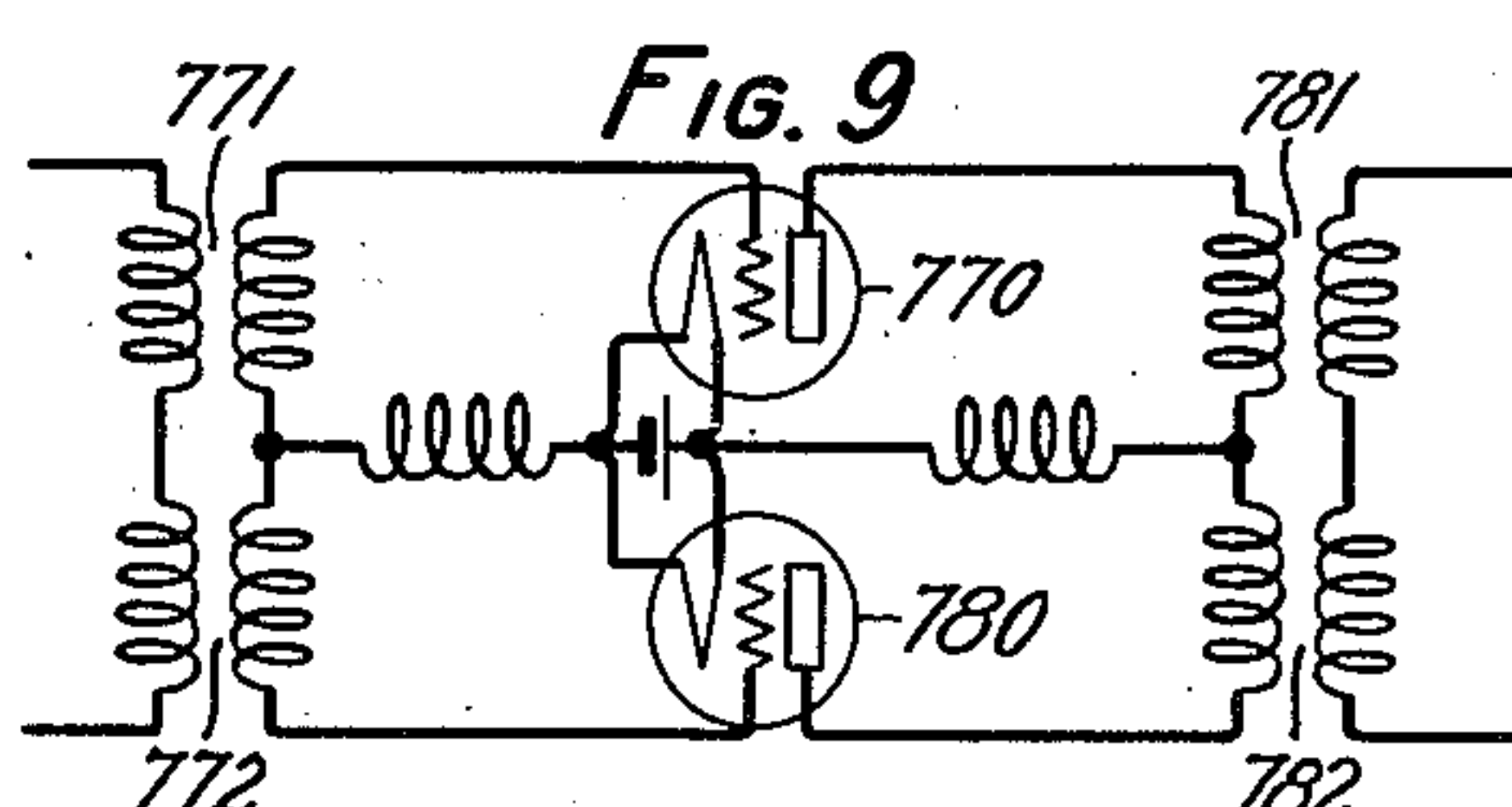
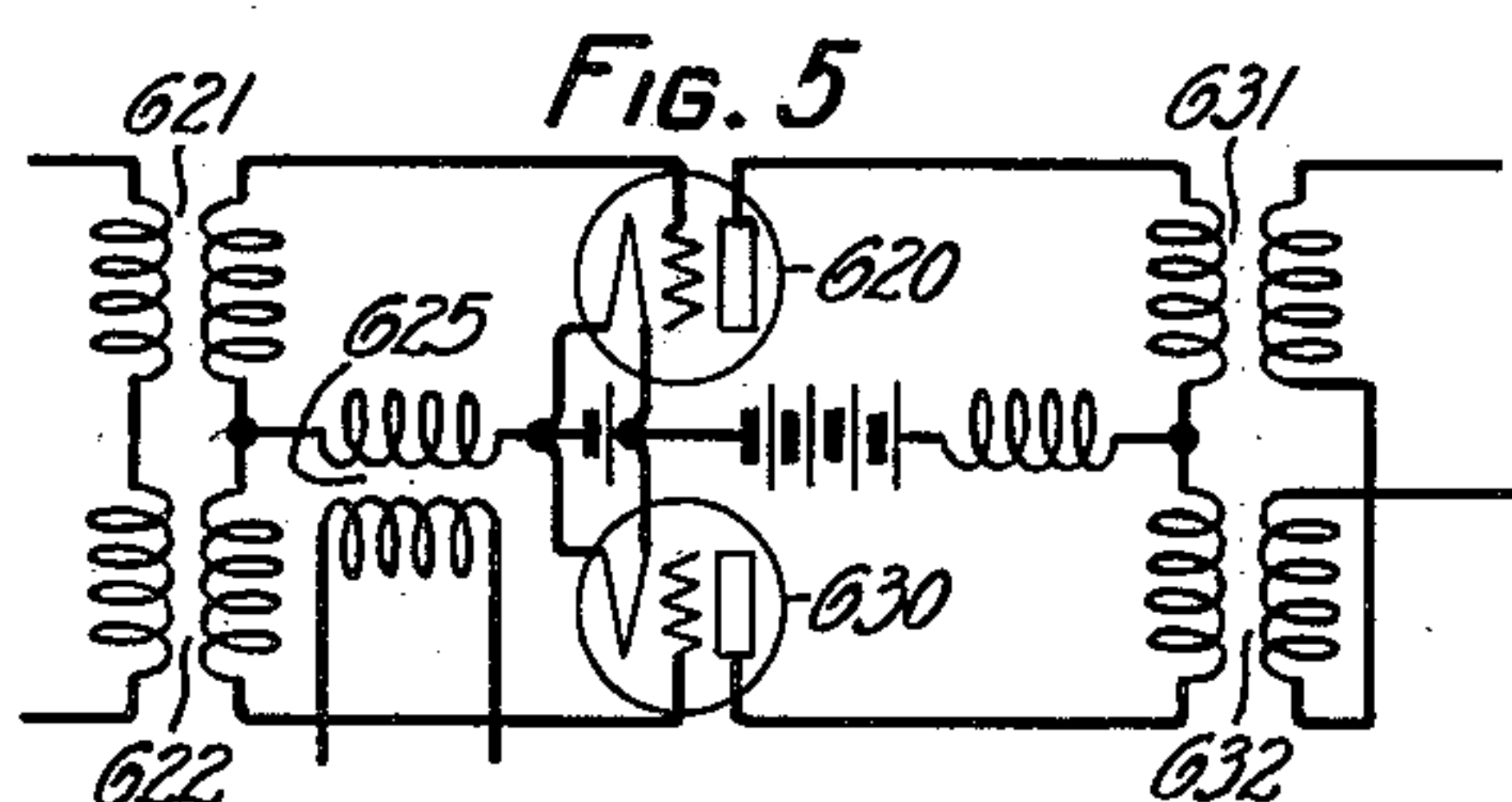
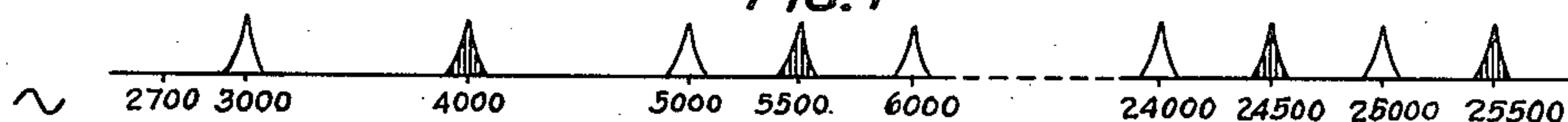
1,769,920

ELECTROOPTICAL TRANSMISSION SYSTEM

Filed April 30, 1929

3 Sheets-Sheet 1

FIG. 1



INVENTOR
F. GRAY
BY *C. E. Sprague*
ATTORNEY

July 8, 1930.

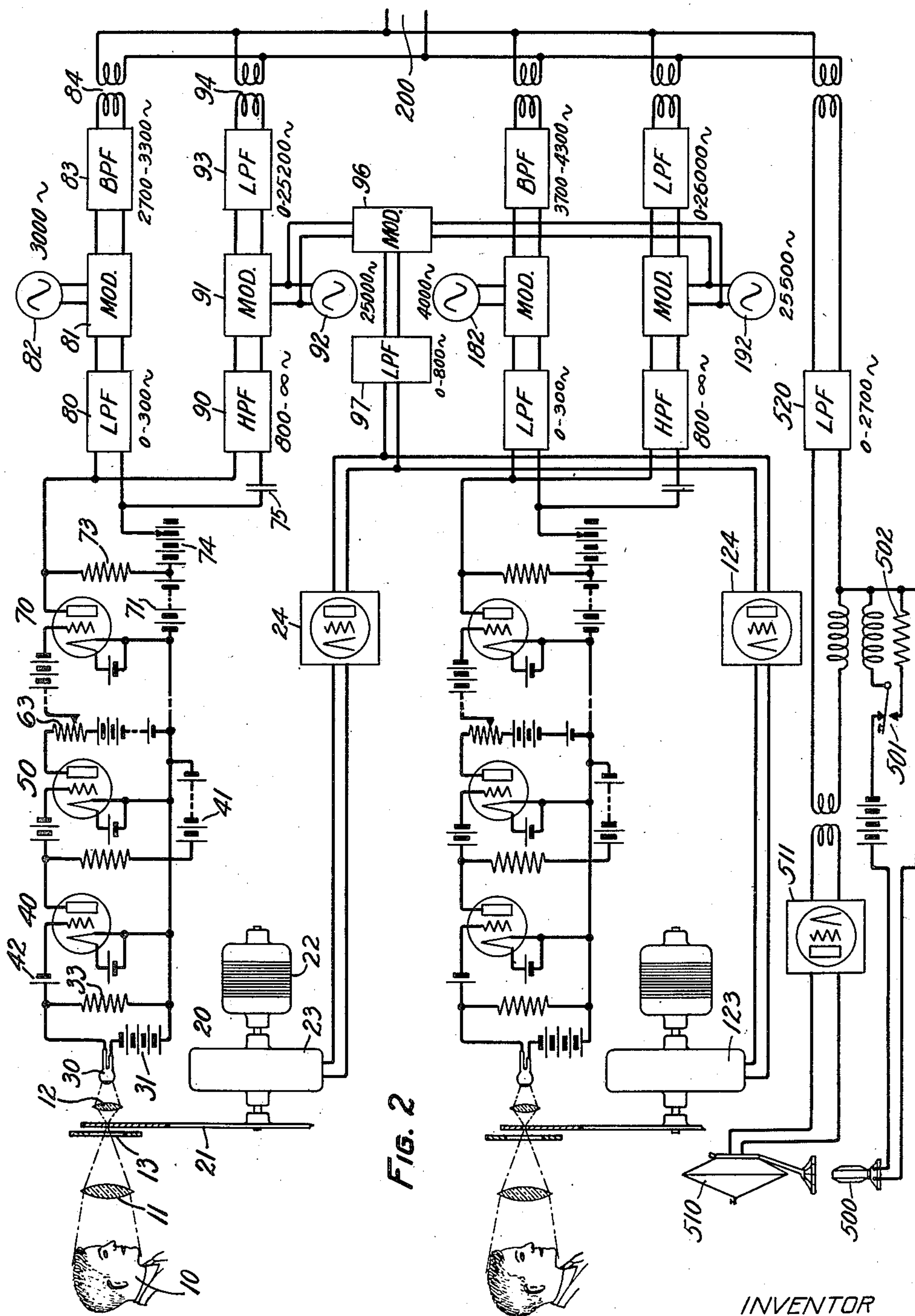
F. GRAY

1,769,920

ELECTROOPTICAL TRANSMISSION SYSTEM

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3 Sheets-Sheet 2



INVENTOR
F. GRAY

BY

C. C. Sprague
ATTORNEY

July 8, 1930.

F. GRAY

1,769,920

ELECTROOPTICAL TRANSMISSION SYSTEM

Filed April 30, 1929

3 Sheets-Sheet 3

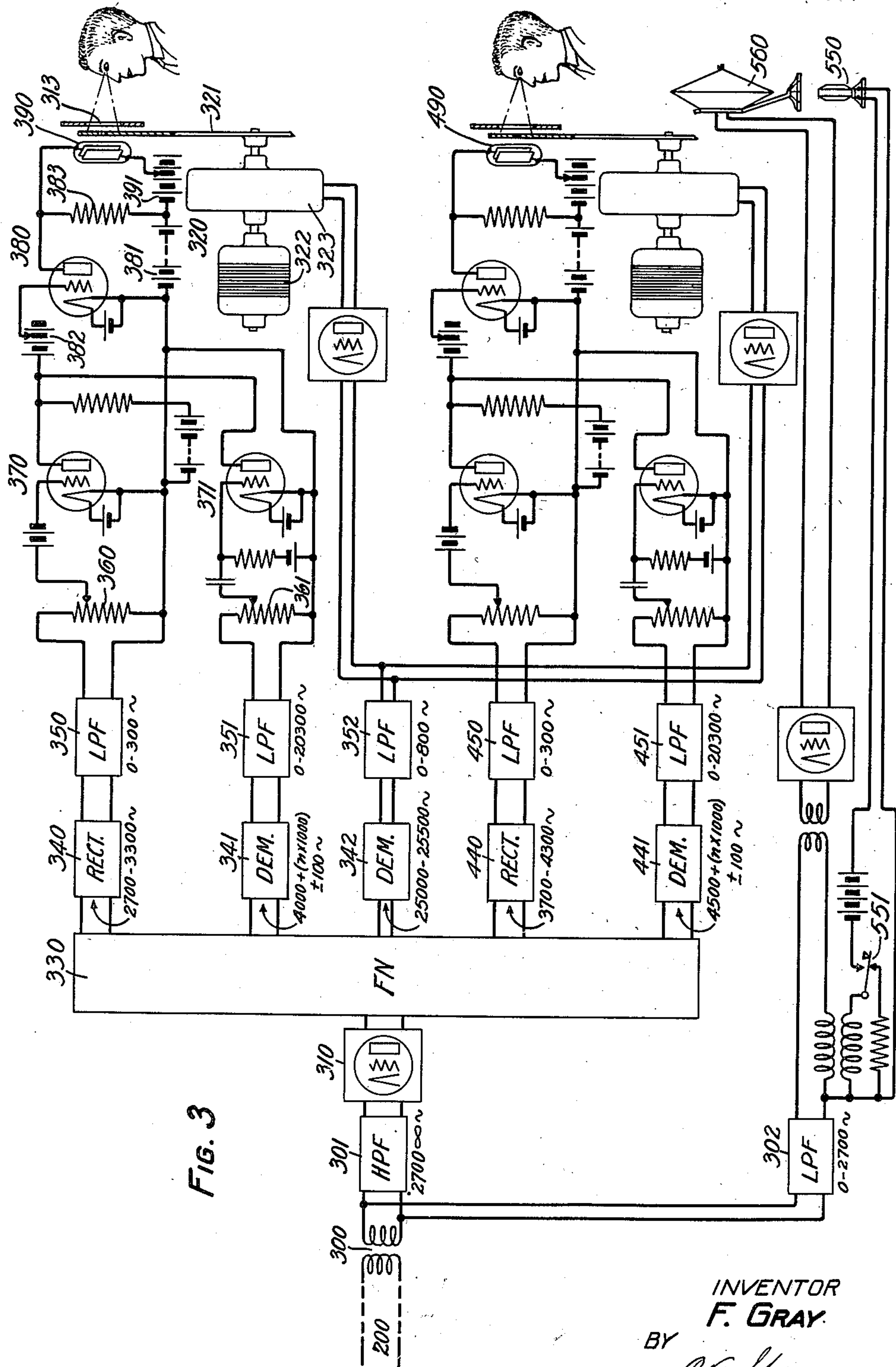


FIG. 3

INVENTOR
F. GRAY
BY
O. G. Sprague
ATTORNEY

UNITED STATES PATENT OFFICE

FRANK GRAY, OF NEW YORK, N. Y., ASSIGNOR TO BELL TELEPHONE LABORATORIES,
INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

ELECTROOPTICAL TRANSMISSION SYSTEM

Application filed April 30, 1929. Serial No. 359,212.

This invention relates to signaling and more particularly to television and high speed picture transmission and composite signal transmission.

5 An object of the invention is to improve the utilization of the frequency transmission band involved in signaling for such types of transmission as television and high speed picture transmission.

10 This invention is the result of the discovery that when an object or field of view is periodically scanned in a series of parallel lines and the light tone values of elemental areas are translated into electric current variations, the energy is largely concentrated in a number of distinct bands of frequencies between which there is very little useful energy, and the position of the bands in the frequency spectrum is dependent upon the field scanning frequency and upon the line scanning frequency. The energy concentrations resulting from scanning an ordinary field occur in the regions of the field scanning frequency and some of the lower harmonics thereof and in the regions of the line scanning frequency and the lower harmonics thereof. These latter bands are made up of a plurality of frequencies the prominent ones of which differ by approximately the field scanning frequency. The bands may, for example, have a band width of approximately 20% of the line scanning frequency in which case the low energy intervening gaps or valleys have a frequency band width of approximately 80% of the line scanning frequency.

This invention provides means for utilizing the above mentioned gaps or valleys for other purposes such as, for example, for the transmission of the direct current and very low frequency components by shifting them by combining them with a current of constant frequency to produce combination frequencies which will fit into the low energy gaps or for the shifting of the higher frequency bands of the photoelectric current to lower frequency bands by similarly obtaining combination frequencies to fit into the gaps between the low frequency bands or vice versa to reduce the width of the total

frequency band and for the transmission of a plurality of similar photoelectric currents by shifting the bands of one or more of the currents to fit in the gaps of the other or others, etc.

In accordance with one form of this invention as herein shown for multiple channel electro-optical transmission over a single circuit incapable of transmitting very low or very high frequencies means are provided for interweaving the respective energy concentration bands of a plurality of photoelectric currents, for shifting the direct current and very low frequency components of each photoelectric current upward into gaps in the main frequency bands, for inserting the synchronizing current in one of the gaps and for generating and transmitting communicating currents having frequency bands also occupying gaps in the photoelectric currents. Such a system is applicable to either one-way or two-way operation over a single transmission circuit or medium and the different photoelectric channels may obviously be arranged for stereoscopic operation, color transmission, transmission of a plurality of different scenes or different parts of the same scene or picture, etc.

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

Fig. 1 is a typical current-frequency diagram of the energy concentrations resulting from interweaving the energy concentrations of frequencies generated from scanning two ordinary objects in a series of parallel lines each at a line scanning rate of approximately 1000 cycles per second and combining the photoelectric currents so generated with currents of constant frequency to produce combination frequencies which are shifted so that the energy concentrations of one photoelectric current fit into the low energy gaps or valleys of the other photoelectric current and also of synchronizing or other signal currents having frequencies different from those of the energy concentration bands of the photoelectric signal currents.

Fig. 2 is a general schematic representa-

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tion of the transmitting terminal apparatus of a television system arranged in accordance with the invention for simultaneously generating and transmitting a plurality of television currents.

Fig. 3 is a general schematic representation of the receiving terminal apparatus of a television system arranged in accordance with the invention for simultaneously receiving and translating a plurality of television currents into images.

Fig. 4 is a schematic arrangement of the circuits of a modulator for modulating an alternating current with direct current and with low frequency alternating current.

Fig. 5 is a schematic arrangement of the circuits of a simple modulator, such as may be employed in the television transmitting apparatus.

Fig. 6 is a schematic arrangement of the circuits of a double-balanced modulator.

Fig. 7 is a general schematic representation of a filter network for connecting the apparatus at the receiving station with the transmission line.

Fig. 8 is an alternative arrangement of a filter network for that shown in Fig. 7.

Fig. 9 is a schematic arrangement of the circuits of a simple demodulator such as may be employed in the receiving apparatus.

Fig. 10 is a schematic arrangement of the circuits of a double-balanced demodulator.

The typical current-frequency diagram shown in Fig. 1 is similar in its general characteristics as to energy concentrations to those shown in the joint copending application of Frank Gray and J. R. Hefele, Serial No. 337,132, filed Feb. 2, 1929, showing typical current-frequency curves of a number of different objects both at rest and in motion. The current-frequency diagram shown herein indicates the position of the energy concentrations of the different signals at different frequencies in the frequency band or spectrum over a range up to approximately 26000 cycles per second of different photoelectric currents and other signals. Current strength is indicated in the direction of the ordinate and frequencies along the abscissa. The first band of frequencies up to approximately 2700 cycles is assigned to speech or sound transmission; the bands in the regions of 3000 and the 4000 cycles are assigned to the transmission, by means of carrier currents, of the direct current components and the low frequency components of the two television signals; the range from approximately 5000 to 24500 cycles is assigned to the transmission of television signal bands which are multiples of the line scanning frequencies; and the 25000 and the 25500 cycle bands are assigned to synchronization. Both of the television signals are generated by the same line scanning rate, namely 1000 cycles per second. The 1000, 2000, etc. to 20000 cycle

bands of each are combined with carrier currents to produce a frequency displacement to clear the frequency band or spectrum between approximately 300 to 5000 cycles and also for the purpose of relatively displacing the television frequency bands which are multiples of the line scanning frequencies to produce combination frequencies which may be interwoven into the low energy gaps or valleys of each other. A carrier frequency of 25000 cycles and another of 25500 cycles may be modulated by the two respective television currents to produce the desired displacement of their frequency bands. Synchronization is secured by combining the 25000 and the 25500 cycle carrier current to produce a 500 cycle synchronizing current. The 1000 cycle harmonic thereof might also be used for synchronizing. To clear the frequency region below approximately 300 cycles the direct current components and the low frequency components in the region of the picture scanning frequency are combined with a 3000 cycle and a 4000 cycle carrier current, respectively, for transmitting these components of the two photoelectric currents which results in comparatively narrow frequency bands in the regions of these carrier frequencies.

The television transmitting station shown in Fig. 2 in general comprises terminal apparatus consisting of television scanning apparatus, current amplifying apparatus, filter networks, carrier current generators, and modulating apparatus for two complete photoelectric transmitting units, arranged for each to operate at the same scanning rate; and also terminal apparatus for two-way telephone communication. The photoelectric currents generated by the transmitting units are transmitted by means of carrier currents, which properly displace and interweave the photoelectric energy concentration bands for transmission without interference over a single circuit or medium. The frequency distribution of the energy concentrations are arranged as already described and shown in the current-frequency diagram, Fig. 1. An object 10 whose image is to be transmitted is periodically scanned in a series of parallel lines by the scanning apparatus 20. An image of the object is focused upon the viewing field of the scanning apparatus by means of a suitable objective lens system 11 and light from elemental areas of the image formed is directed by means of the lens system 12 upon the light sensitive cell 30. The scanning arrangement may comprise any suitable device such as a rotating scanning disc 21 having a row of apertures spirally arranged. An opaque member having an aperture 13 is positioned between the lens 11 and the scanning disc and limits the size of the image field upon the scanning disc so that just one aperture in the scanning disc is exposed

at any instant, the angular width of the aperture 13 being equal to the angular pitch of the apertures in the scanning disc. The scanning disc is driven at suitable speed by means of a driving motor 22. A synchronous alternator 23 mounted on the same shaft with the scanning disc 21 and the driving motor 22 is employed to maintain synchronism between the transmitting and the receiving scanning apparatus. The photoelectric current generated in the light sensitive element 30 is amplified by suitable vacuum tube amplifiers 40, 50, and 70. The arrangement here shown amplifies both the direct and the alternating current components. The output circuit of the light sensitive cell 30 contains a battery 31 and a resistance 33. The battery causes a current to flow through the resistance 33 which is varied by the changing excitation of the light sensitive cell. This results in a varying potential across the resistance 33, one side of which is connected through the biasing battery 42 to the grid and the other to the filament of the vacuum tube of the amplifier 40. The output of amplifier 40 is impressed on the intermediate amplifier 50 whose output is in turn impressed upon succeeding amplifiers. Battery 41 supplies space current for amplifier 40. Any suitable number of stages of amplification may be employed. The amplified photoelectric current, whose intensity is controlled by any suitable arrangement such as the potentiometer 63, on passing through the last amplifier stage 70 which is supplied with space current by the battery 71 is impressed across the resistance 73. A circuit containing the adjusting battery 74, taken from the terminals of the resistance 73, leads to the low-pass filter 80 and the high-pass filter 90. A condenser 75 in series with the circuit carrying the high frequency currents to the high-pass filter 90 blocks the passage of the direct current to this filter. The direct current and low frequency components up to about 300 cycles are transmitted by the low-pass filter 80 and are combined in the modulator 81 with a carrier current of about 3000 cycles generated by the oscillator 82. The carrier current and the upper and lower side bands of the modulated signal current are passed by the band-pass filter 83 having cut-off frequencies of 2700 and 3300 cycles to the repeating coil 84 and therethrough to the transmission line 200. The higher frequencies of the signal current above 800 cycles are passed by the high-pass filter 90 and combined in the modulator 91 with a carrier current of 25000 cycles generated by the oscillator 92. The carrier and the modulated signal current above 800 cycles are passed by the low-pass filter 93 having a cut-off frequency of 25200 cycles to the repeating coil 94 and therethrough to the transmission line 200. By means of these carrier currents the low fre-

quency photoelectric currents below 300 cycles are positioned for transmission in the frequency band between 2700 and 3300 cycles, while the energy concentration bands in the photoelectric signal spectrum above 800 cycles are positioned for transmission in frequency bands in the regions of 5000 cycles, 6000 cycles, etc. up to 24000 cycles. The 24000 cycle signal band results from modulation of the 25000 cycle carrier current by the 1000 cycle photoelectric signal band, while the 5000 cycle signal band results from modulation by the 20000 cycle signal band. The total photoelectric energy concentrations spaced about 1000 cycles apart in the regions of multiples of 1000 cycles may thus be transmitted by a carrier current and the signal bands positioned in the frequency spectrum beginning at 24000 cycles and ending at 5000 cycles when, for example, 20 bands are considered.

The second television transmitting unit shown in the lower half of Fig. 2 is a duplicate of that shown in the upper half of this figure and just described with the exception that the frequency of the two carrier currents is different from that used in the first transmitting unit so as to interweave the energy concentration bands of the two television currents when they are impressed upon the common transmission line 200. The oscillator 182 generates a carrier current of 4000 cycles. This carrier current is modulated by the low frequency components of the second television current below 300 cycles and the upper and lower side bands thereof fall between 3700 and 4300 cycles, while the low frequency components of the first television transmitting unit fall between 2700 and 3300 cycles. The photo-electric current above 800 cycles modulates a 25500 cycle carrier current generated by oscillator 192. As the energy concentrations band of the photoelectric current occur in the regions of 1000 cycles and multiples thereof, the modulated bands are also spaced 1000 cycles apart but at positions which are odd multiples of 500, thus separating the second set of television current bands from the bands of the first set by 500 cycles, the former being positioned at multiples of 500. The energy concentration bands of the two television signal currents are thus interwoven before being impressed upon the common transmission line 200. The transmission line or circuit 200 may contain suitable amplifying apparatus and repeaters though they are not shown in the drawing.

A synchronizing current may be produced by combining the 25000 and the 25500 cycle carrier currents in modulator 96 to produce a current of 500 cycles. The low-pass filter 97 having a cut-off frequency of 800 cycles transmits the synchronizing current of 500 cycles through each of the amplifiers 24 and 124

to each of the alternators 23 and 123 associated with the scanning device of each of the two transmitting television units. As heretofore stated, the 25000 and the 25500 cycle carrier currents are impressed upon and transmitted by the transmission line 200, so that they are available for generating a 500 cycle synchronizing current at each of the receiving television units.

A two-way communication channel is provided in the form of a telephone system. A telephone transmitter 500 and a telephone receiver, such as a loud speaker 510, may be connected through suitable terminal circuits to the transmission circuit 200. A low-pass filter 520 having a cut-off frequency of 2700 cycles is connected in circuit between the telephone terminal apparatus and the transmission line. A frequency range from 0 to 2700 cycles has been chosen as it is sufficient for transmitting conversations. A switch 501 may be placed in the telephone transmitting local circuit so that the microphone may be disconnected. When such disconnection is made the switch connects the balancing resistance 502 in the local circuit so as to maintain unchanged the circuit characteristics and thus avoid any disturbance of the operation of the receiver. Suitable amplifying apparatus 511 may be employed in the local telephone circuit.

The television receiving station shown in Fig. 3 in general comprises terminal apparatus consisting of filtering networks for separating and routing the several received signal currents, remodulating apparatus, current amplifying apparatus and synchronously operated television receiving apparatus for two complete receiving units arranged for each to operate at the same scanning rate; and also terminal apparatus for two-way telephone communication. The two receiving units are connected with the transmission line 200 by the repeating coil 300. The television signal and the carrier currents are passed by the high-pass filter 301 having a cut-off frequency of 2700 cycles to the two television receiving units, while the communication current below 2700 cycles is passed by the low-pass filter 302 also having a cut-off frequency of about 2700 cycles to the telephone terminal apparatus. Suitable amplifying apparatus 310 is employed in the television circuit. The incoming television signals are separated and routed to the proper receiving apparatus by means of the filter network 330. The direct current and low frequency television components transmitted by carrier current having a modulated frequency range between 2700 and 3300 cycles are passed by the filter network 330 to the rectifier 340 which demodulates the carrier current and restores the direct current and low frequency components of the original signal and the resulting signal current thus has a frequency

band between zero and 300 cycles. This current is next passed through a low-pass filter 350 having a cut-off of 300 cycles and then through suitable amplifying and control circuits to the television receiving lamp 390. The television energy concentration signal bands spaced 1000 cycles apart and occurring at even multiples of 500 cycles, commencing at 5000 cycles and extending to 24000 cycles, or in other words $4000 + (n \times 1000) \pm 100$ cycles, n being any whole number from one to twenty, and also the 25000 cycle carrier current is transmitted by the filter network 330 to the demodulator 341 which restores this part of the television signal to its original frequencies. The demodulated signal is next passed through the low-pass filter 351 having a cut-off frequency of about 20300 cycles and through suitable amplifying and control apparatus to the television receiving lamp 390. By means of the filter network and these two local receiving circuits all of the signal components of the television current transmitted on the 3000 and the 25000 cycle carrier currents are combined and impressed upon the common receiving lamp 390. Part of the 25000 cycle and the 25500 cycle carrier currents are transmitted by the filter network 342 to the demodulator 352, wherein these currents are combined and a 500 cycle local synchronizing current produced. This 500 cycle current is transmitted through the low-pass filter 352 having a cut-off frequency of 800 cycles and through suitable amplifiers to the synchronous motor of each television receiving unit.

The television receiving unit in the lower half of Fig. 3 is arranged for receiving the second television signal. It is substantially the same as that in the upper half of this figure with the exception that the circuits are arranged for television current transmitted by a 4000 and a 25500 cycle carrier current. The direct current and low frequency television components transmitted by carrier current having a modulated frequency range between 3700 and 4300 cycles are passed by the filter network 330 to the rectifier 440 which demodulates the carrier current and restores the direct current and low frequency components of the original signal and the resulting signal current thus has a frequency band between zero and 300 cycles. This current is next passed through the low-pass filter 450 having a cut-off frequency of 300 cycles and then through suitable amplifying and control circuits to the television receiving lamp 490. The television energy concentration bands spaced 1000 cycles apart and occurring above 1000 cycles at the odd multiples of 500 cycles, commencing at 5500 cycles and extending to 24500 cycles, or in other words $4500 + (n \times 1000) \pm 100$ cycles, n being any whole number from one to twenty, and also the 25500 cycle carrier current is trans-

mitted by the filter network 330 to the demodulator 441, which restores this part of the television signal to its original frequencies. The demodulated signal is next passed through the low-pass filter 451 having a cut-off frequency of 20300 cycles and through suitable amplifying and control apparatus to the television receiving lamp 490. By means of the filter network and these two local receiving circuits all of the signal components of the television current transmitted on the 4000 and the 25500 cycle carrier currents are combined and impressed upon the common receiving lamp 490 of the second television receiving unit, the same as with the first television receiving unit shown in the top half of this Fig. 3. The two sets of local circuits transmitting the demodulated or restored television signal currents to the respective receiving lamps contain certain control devices which will now be described. Referring to the television receiving unit in the upper half of Fig. 3 the direct current and the low frequency components of the television signal are impressed upon the circuit connecting with the translating apparatus through the potentiometer 360 arranged for regulating the intensity of this part of the television signal. This signal current is amplified by the amplifier 370. The television signal current in which the energy concentrations occur in the regions of 1000 cycles and multiples thereof is impressed upon the circuit connecting with the translating apparatus through the potentiometer 361 arranged for regulating the intensity of this part of the television signal. This signal current is amplified by the amplifier 371. Both the lower frequency and the higher frequency signal components are next impressed upon the control amplifier 380 and network connecting with the receiving lamp 390. The current through the glow discharge receiving lamp should at all times be proportional to the illumination at the transmitting station since a well established linear relation exists between the intensity of the illumination resulting from the glow discharge and the current. The circuit of the amplifier 380 provides means for making necessary adjustments. The incoming photoelectric or television signal current whose intensity is generally adjusted by means of the potentiometers 360 and 361 is impressed upon the vacuum tube of the amplifier 380. The space current which is provided by the battery 381 is adjusted by the grid biasing voltage of the battery 382 and by means of this adjustment the current flowing through the glow discharge receiving lamp is so adjusted that practically no light is emitted for black portions of the object. Instead of connecting the glow discharge lamp and the vacuum tube directly in series a resistance 383 is shunted across the output of the circuit of

the vacuum tube across which is set up a potential proportional to the current through the resistance. The receiving lamp 390 is shunted across this resistance. In order to confine the operation of the vacuum tube of the amplifier 370 to the linear part of its characteristic the biasing battery 391 is connected in series with the lamp so that current through the lamp will go to substantially zero even when a finite current is flowing through the vacuum tube of the amplifier 380 and it is still on the linear part of its characteristic.

The viewing field in front of the receiving lamp is defined by the aperture 313 in an opaque plate positioned in front of the scanning disc 321 and in line with the receiving lamp 390. The annular width of the aperture 313 is such that the area of just one aperture in the scanning disc appears at any instant, the annular width of this aperture being equal to the annular pitch of the apertures in the scanning disc. The scanning disc at the transmitting and the receiving stations are driven by direct current motors and held in synchronism and in phase by synchronous motors controlled by a synchronizing current in accordance with well established practice. A typical synchronizing arrangement is shown in the patent of H. M. Stoller et al., No. 1,763,909, issued June 17, 1930. The synchronizing current of 500 cycles is produced by combining the incoming 25000 and 25500 cycle carrier currents and it is impressed upon the synchronous motor 323 associated with the receiving apparatus 320. The energy for driving the scanning disc is applied by the driving motor 322. The terminal circuits for amplifying and controlling the television current impressed upon the receiving lamp 490 of the second television receiving unit shown in the lower half of Fig. 3 are identical with those just described for the first television receiving unit in the upper half of this figure and further description is unnecessary.

The communication apparatus shown in Fig. 3 is similar to that shown at the other terminal in Fig. 2. The transmitter 550 may be cut into and out of circuit by means of the switch 551. The receiver 560 is shown as the loud speaker. The low-pass filter 302 transmits frequencies up to 2700 cycles.

In Figs. 4 to 10 further details of the modulators, demodulators, and filter networks used in the terminal apparatus just described are shown.

A simple circuit for the modulator 81 of Fig. 2 is shown in Fig. 4. This is a modulator for the direct current and the low frequency components of the photoelectric current. It comprises vacuum tube elements 600 and 610. The carrier current supplied by the oscillator 82 is impressed upon the modulator through the transformer 605. A suitable polarizing potential is applied to the vacuum tube 610

by means of the grid biasing battery 602. The resistance 604 may be connected across this transformer to more nearly match the impedances of the modulator tube and the oscillator circuit.

Details of a modulator, for the higher frequency photoelectric current which is combined with a carrier current having a frequency of the order of 25000 cycles, suitable for the modulator 91 shown in Fig. 2 may be a simple modulator such as shown in Fig. 5 or a double-balanced modulator such as shown in Fig. 6. The simple modulator shown in Fig. 5 comprises the vacuum tube elements 620 and 630 connected in push-pull arrangement. The incoming photoelectric signal current is impressed upon the grids of these tubes by means of the transformers 621 and 622 while the carrier current is impressed through the transformer 625. The modulated outgoing current is transmitted through the transformers 631 and 632. The double-balanced modulator shown in Fig. 6 comprises two units similar to those shown in Fig. 5 connected in parallel. Either type of modulator may be used but the double-balanced modulator has the advantage of cutting out more of the extraneous frequencies produced in modulation.

The filter network 330 employed in the receiving terminal of Fig. 3 is shown more in detail in Fig. 7 and an alternative arrangement is shown in Fig. 8. The filter network shown in Fig. 7 consists of a set of filters all connected in multiple with the incoming signal circuit. Band-pass filter 700 having cut-off frequencies of 2700 and 3300 cycles transmits the 3000 cycle carrier current and the upper and lower sidebands thereof resulting from its modulation at the transmitting station by the direct current and low frequency components of the television current below 300 cycles generated by the first transmitting unit shown in Fig. 2. Band-pass filter 701 having cut-off frequencies of 4800 and 5200 cycles transmits the signal energy concentration band as modulated in the region of 5000 cycles. Band-pass filter 702 having cut-off frequencies of 5800 and 6200 cycles transmits the signal current concentration band as modulated in the region of 6000 cycles. Similar band-pass filters are employed for each signal energy concentration band as modulated up to that in the region of 24000 cycles which is transmitted by band-pass filter 720 having cut-off frequencies of 23800 and 24200 cycles. The output circuits of all of these filters are connected in multiple to the demodulator 341 shown in Fig. 3. The high-pass filter 725 transmits frequencies above 24800 cycles. This filter passes the carrier currents of 25000 and 25500 cycles. The 25000 cycle carrier current is transmitted by the band-pass filter 724 to the demodulator 341 thus providing

carrier current for demodulating the television signal current impressed upon this demodulator. Band-pass filter 730 having cut-off frequencies of 3700 and 4300 cycles transmits the 4000 cycle carrier current and the upper and lower sidebands thereof resulting from its modulation at the transmitting station by the direct current and the low frequency components below 300 cycles generated by the second transmitting unit shown in Fig. 2. These currents are impressed upon the rectifier 440. Band-pass filter 731 having cut-off frequencies of 5300 and 5700 cycles transmits the signal energy concentration band as modulated in the region of 5500 cycles. Band-pass filter 732 having cut-off frequencies of 6300 and 6700 cycles transmits the signal energy concentration band as modulated in the region of 6500 cycles. Similar band-pass filters are employed for each signal energy concentration band as modulated up to that in the region of 24500 cycles which is transmitted by band-pass filter 740 having cut-off frequencies of 24300 and 24700 cycles. As many such band-pass filters as there are energy concentrations in the television signal are employed and all are connected in multiple to the demodulator 441 shown in Fig. 3. The 25500 cycle carrier current is transmitted through the band-pass filter 726 to the demodulator 441 thus providing carrier current for demodulating the television signal current impressed upon this demodulator.

An alternative filter network is shown in Fig. 8. The band-pass filter 760 having cut-off frequencies of 2700 and 3300 cycles transmits the 3000 cycle carrier current and sidebands resulting from modulation by the direct current and the low frequency components of the first television signal current to the rectifier 340. Band-pass filter 761 having cut-off frequencies 3700 and 4300 cycles transmits the 4000 cycle carrier current and the sidebands resulting from modulation by the direct current and low frequency components of the second television signal current to the rectifier 440. High-pass filter 762 having a cut-off frequency of 4500 cycles transmits all signal currents above this frequency to multiple-pass band-pass filters 763 and 764. Multiple-pass band-pass filter 763 transmits all signal energy concentration bands having a band width of about 200 cycles in the region of 1000 cycles and in multiples of 1000 cycles, $(n \times 1000) \pm 100$, or in other words in the regions of the even multiples of 500 cycles, to the demodulator 341. Multiple-pass band-pass filter 764 transmits all signal energy concentration bands having a band width of about 200 cycles in the region of 1500 cycles and above in multiples of 1000 cycles plus 500 cycles, $500 + (n \times 1000) \pm 100$, or in other words in the regions of the odd multiples of 500 cycles, to the demodulator 441. High-

pass filter 765 having a cut-off frequency of 24800 cycles transmits a part of the 25000 and 25500 cycle carrier currents to the demodulator 342.

5 The circuit arrangements of a simple demodulator and a double-balanced demodulator for use in the receiving circuits shown in Fig. 3 are shown in Fig. 9 and Fig. 10, respectively. In Fig. 3 demodulator 342 may be a simple demodulator and demodulators 341 and 441 are preferably the double-balanced type. The single demodulator comprises the vacuum tube elements 770 and 780 connected in push-pull arrangement. The input circuit is connected through the transformers 771 and 772 and the output circuit through the transformers 781 and 782. The double-balanced demodulator comprises two units similar to those shown in Fig. 9 connected in parallel. An advantage of the double-balanced demodulator is that it eliminates more of the extraneous frequencies than the simple demodulator and it is therefore preferable in circuits demodulating television currents.

25 The different frequencies used in describing this system as arranged for simultaneous transmission of two television signals are typical and are used primarily to facilitate the description. Obviously different scanning rates may be selected which would cause the energy concentrations to occur at different frequency positions in the television current spectrum. For example, the field of view might be scanned in 50 lines at the rate of 40 times a second which would produce picture scanning frequencies of 40 cycles and line scanning frequencies of 2000 cycles and resulting energy concentrations at multiples thereof. The same line scanning frequency, 2000 cycles, and the same positioning of the energy concentrations occurring at multiples of the line scanning frequency would result if the field of view were scanned in 100 lines at the rate of 20 times a second, but the picture scanning frequency would be one half or 20 cycles. Various other combinations of picture and line scanning rates and the different frequency positioning of the resultant energy concentrations are obvious. Other systems of scanning than those employing a scanning disc may be used to generate equivalent photoelectric currents. Also the range of the frequency band of the television spectrum is not limited to approximately 20,000 cycles, the figure used in the description of the apparatus. Different frequencies from those mentioned may also be used for synchronization and for communication. Further, different carrier current frequencies may be used for transmitting the various signals. Preferably only one side band of the resultant modulations produced by the energy concentrations of each photoelectric current is transmitted in order that

the frequency width of the total currents transmitted may be held as narrow as possible. A plurality of television signals greater than the two mentioned in describing the system may be used thus increasing the number of television signals which may be transmitted over the same circuit, the number of such signals being primarily limited by the number of the energy concentration bands which may be interwoven and at the same time sufficiently separated to permit separation of the other television signal currents at the receiving station. In other words, the energy concentrations of the different transmitted signal currents must occur at substantially mutually exclusive frequency positions.

The operation of each of the principal elements of the system has been described in more or less detail in the foregoing description of the apparatus. In the general operation of the system as a whole, the light tone values of line series of elemental areas of the objects or fields of view are translated into different and distinct photoelectric currents, each having energy concentrations in narrow frequency bands at predetermined separated frequency positions in the photoelectric current spectrum. A plurality of such photoelectric currents have their energy concentration bands displaced by combining with carrier currents of such frequency that the energy concentrations of the different signal currents resulting from modulation occur at mutually exclusive frequency positions for each photoelectric current and the several resulting photoelectric television signal currents may thus be transmitted over a single circuit without interference. A television signal current may have its frequency spectrum compressed or narrowed by transposing its energy concentration bands into closer positions to each other by means of carrier currents. Other signals than television, such as communication and synchronization may also be transmitted over the same transmission circuit without interference. All of the different signals at the transmitting station are impressed upon a common transmission circuit. These signals are separated at the receiving station by filter networks and directed to their respective translating devices with the result that each energy concentration band of each signal acts as if it had been kept separate throughout its transmission. In the system illustrated herein the direct current and very low frequency components are combined with a carrier current for transmission the same as the higher frequency components.

This invention in general utilizes the low energy gaps or valleys in the photoelectric signal current and makes possible the utilization of the transmission medium to the fullest possible extent and also makes possible the transmission of all signal currents necessary

for the operation of a plurality of photoelectric current transmissions over a single transmission circuit. As heretofore mentioned the television transmission may be from a plurality of scanings of different objects or different portions of the same object at the same station or from different objects from different stations and the transmission may be in the same direction or in opposite directions all over the same transmission circuit. Obviously stereoscopic transmission, multiple channel transmission or color transmission where suitable filters or selective elements are used with a plurality of channels at both the transmitting and receiving stations may be accomplished with this system.

Simultaneous two-way operation over the same transmission medium for both television and communication may be carried on by modifying the arrangement shown in Fig. 2 and Fig. 3 for television transmission of two images in opposite directions. It is obvious that one of the transmitting units in Fig. 2 might be interchanged with one of the receiving units including the necessary filtering network in Fig. 3 and simultaneous two-way television transmission carried on between each terminal station at the same time that two-way telephonic communication is in progress. This invention, making possible simultaneous two-way television and telephony over a single circuit, may be adapted to a combined television and telephone central office exchange system operating between subscribers' stations. In such a system the television frequency spectrums may be both compressed and interwoven by using suitable carrier currents so as to occupy as narrow a total frequency range as possible thus making the total frequency band fall within the comparatively narrow frequency limitations of intercommunicating circuits. A combined intercommunicating telephone and television system operating through a central office exchange is disclosed in the patent application of H. E. Ives, Serial No. 138,845, filed October 1, 1926, which requires several circuits for interconnecting subscribers' stations, while the arrangement disclosed in this invention requires only one circuit.

What is claimed is:

1. The method of transmission which comprises generating and transmitting a plurality of image currents each representing the tone values of elemental areas of a picture or other object and having spaced energy concentrations occurring at mutually exclusive frequency positions, and concurrently transmitting said currents over the same transmission medium all within a frequency range of substantially the same width as that of one of the said image currents.

2. A method of transmission which comprises successively scanning a plurality of fields of view having different tone values,

producing from said scanings a corresponding plurality of composite electric currents containing one or more groups of frequency components of large amplitude, combining said currents with carrier currents of such frequencies that the essential frequency components in the resultant currents occupy substantially mutually exclusive frequency positions with respect to each other, utilizing a frequency range outside of said resultant currents for the transmission of separately generated currents, and transmitting all of said currents over the same transmission medium.

3. A transmission system comprising means for generating a plurality of image currents each corresponding to the tone values of elemental areas of a field of view and having spaced energy concentrations occurring at mutually exclusive frequency positions the essential frequency components of each of said currents being distributed over a wide band, means for impressing upon a transmitting medium said essential frequency components of all of said image currents, and means for separately and concurrently impressing upon said transmitting medium current having components different from said essential frequencies.

4. A transmission receiving system comprising means for concurrently receiving a plurality of image currents each having spaced energy concentrations occurring at mutually exclusive frequency positions and representing the tone values of elemental areas of a picture or other object and occupying a wide band of frequencies, and non-image currents having frequency components different from those of said image currents, means for separating said image currents from each other and from said non-image currents, and means for separately utilizing said currents.

5. A television receiving system comprising means for concurrently receiving a plurality of television image currents having mutually exclusive energy components and extending over a wide band of frequencies, and synchronizing current having frequency different from that of said components, means for separating said image currents from each other and from said synchronizing current, image producing means for utilizing said image currents in the production of television images, and means for utilizing said synchronizing current to control said image producing apparatus.

6. A transmission receiving system comprising means for concurrently receiving a plurality of image currents each having spaced energy concentrations occurring at mutually exclusive frequency positions and representing the tone value of elemental areas of a picture or other object and extending over a wide band of frequencies and non-image currents respectively occupying ex-

clusive frequency bands within a frequency range having a width of the order of said wide band of image currents, and means for selecting and directing each of said currents into a separate channel.

7. The combination with a scanning field of means for simultaneously and repeatedly scanning a plurality of line series of elemental areas of said field in substantially parallel lines, light sensitive means for separately receiving light from each scanning of said field as it is scanned and a source of current for said light sensitive means whereby a plurality of photoelectric currents are generated each having a plurality of frequency components, means for electrically shifting the frequency of said components, filtering means for selecting frequency components from within the range of frequencies thus generated, and image producing means for utilizing the said currents.

8. The method of transmission which comprises scanning a plurality of fields of view having different tone values, producing from said scanings a corresponding plurality of electric signaling currents containing one or more groups of frequency components of large amplitude, positioning the essential frequency components of said currents in substantially non-interfering frequency positions, generating synchronizing current of a frequency outside of said groups, generating a telephone current having a frequency range outside of said groups and of said synchronizing current, and simultaneously transmitting all of said signaling currents over the same transmission medium.

9. The method of signaling which comprises successively scanning a field of view having different tone values, producing from said scanning a composite electric signaling current containing one or more groups of frequency components of large amplitude, separately generating a second composite signaling current, and electrically shifting the frequencies of the components of one of said signaling currents to fit its components in between the components of the other of said signals.

10. The method of signaling which comprises successively scanning a field of view having different tone values, producing from said scanning a composite electric signaling current containing one or more groups of frequency components of large amplitude, separately generating a similar composite signaling current the frequency components of which substantially coincide in position with those of the first said composite electric signaling current, and electrically shifting the frequencies of the components of one of said signaling currents to fit its components in between the components of the other of said signals.

11. The method of signaling which comprises successively scanning a portion of a field of view having different tone values, producing from said scanning a composite electric signaling current containing one or more groups of frequency components of large amplitude, separately generating a second composite signaling current by scanning another portion of said field, and electrically shifting the frequencies of the components of one of said signaling currents to fit its components into frequency positions in between the components of the other of said signaling currents.

12. The method of signaling which comprises successively scanning a portion of a field of view having different tone values, producing from said scanning a composite electric signaling current containing one or more groups of frequency components of large amplitude, separately generating a similar composite signaling current by scanning another portion of said field the frequency components of which substantially coincide in position with those of the first said composite electric signaling current, and electrically shifting the frequencies of the components of one of said signaling currents to fit its components into frequency positions in between the components of the other of said signaling current.

13. The method of signaling which comprises successively scanning for a given color a field of view having different tone values, producing from said scanning a composite electric signaling current having one or more groups of frequency components of large amplitude, separately generating a second composite signaling current by successively scanning for another color the said field, and electrically shifting the frequency components of one of said signaling currents to fit its components into frequency positions in between the components of the other of said signaling current.

14. The method of signaling which comprises successively scanning for a given color a field of view having different tone values, producing from said scanning a composite electric signaling current having one or more groups of frequency components of large amplitude, separately generating a similar composite signaling current by successively scanning for another color the said field the frequency components of which substantially coincide in position with those of the first said composite electric signaling current, and electrically shifting the frequency components of one of said signaling currents to fit its components into the frequency positions in between the components of the other of said signaling current.

15. The method of signaling which comprises a plurality of simultaneous successive scanings of line series of elemental areas

of a field of view having different tone values, producing from said scannings a corresponding plurality of composite electric signaling currents each containing one or more groups of frequency components of large amplitude, and electrically shifting the frequencies of the components of the said plurality of signaling currents so as to fit the components of each one of the said signaling currents into frequency positions in between the components of each of the other of the said signals.

16. In an electro-optical system, the method of increasing the signal capacity of the transmission medium which comprises generating a plurality of energy concentrations separated by substantially empty frequency regions, and displacing said energy concentrations of each of said signals by combining with carrier currents of suitable frequency to produce combination frequency bands for all of said signals which occupy substantially mutually exclusive frequency positions in the combined frequency spectrum of all signals.

17. In an electro-optical system, the method of substantially removing the electrical energy from certain frequency regions which comprises generating a plurality of fundamental signal frequencies having a plurality of energy concentrations at substantially uniformly spaced frequency positions, displacing said energy concentrations of each of said signals by combining with carrier currents of suitable frequency to produce combination frequency bands for all of said signals, and employing the substantially vacated frequency regions for the transmission of other signals.

18. In combination, means for scanning a plurality of fields of view and generating a plurality of different photoelectric currents having energy concentrations occurring at the scanning frequency and multiples thereof, means for generating carrier currents, means for combining said photoelectric currents with the said carrier currents having frequencies arranged for displacing the energy concentrations of the different signals after modulation of the said carrier currents to substantially mutually exclusive frequency positions in the combined spectrum of all of the said modulated signals, and means for impressing the modulated currents upon a single transmission circuit.

19. In combination, means for scanning a plurality of fields of view and generating a plurality of different television currents having energy concentrations occurring at the scanning frequency and multiples thereof, means for generating carrier currents, means for modulating with said television currents the said carrier currents having frequencies arranged for displacing the energy concentrations of the different signals to substan-

tially mutually exclusive frequency positions in the combined spectrum of all of the resultant modulated signals, means for impressing the resultant modulated currents upon a single transmission circuit, means for transmitting said modulated currents, means for separating and demodulating each of said modulated signal currents, and scanning means for translating each of said demodulated television signal currents into images.

20. In combination, a television and a telephone system simultaneously transmitting both television signals and telephonic signals in mutually exclusive frequency positions over a single transmission medium, comprising means for scanning a plurality of fields of view and generating a corresponding plurality of television currents having energy concentrations occurring at scanning frequencies and multiples thereof, means for generating carrier currents, means for combining said television currents with said carrier currents having frequencies arranged for displacing the energy concentrations of the different signals, after modulation of said carrier currents, to substantially mutually exclusive frequency positions in the combined spectrum of all of the resultant modulated signals, and means for generating telephonic signals having a frequency range occupying a frequency position different from that occupied by the television signals, means for impressing said telephonic signals upon the said transmission medium over which the television signals are transmitted, and image and sound producing means for utilizing the said currents.

In witness whereof, I hereunto subscribe my name this 18th day of April, 1929.

FRANK GRAY. 105

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