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Oct. 12, 1937. P. MERTZ 2,095,341

ELECTROOPTICAL TRANSMISSION SYSTEM

Filed June 2, 1934

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FIG. 1

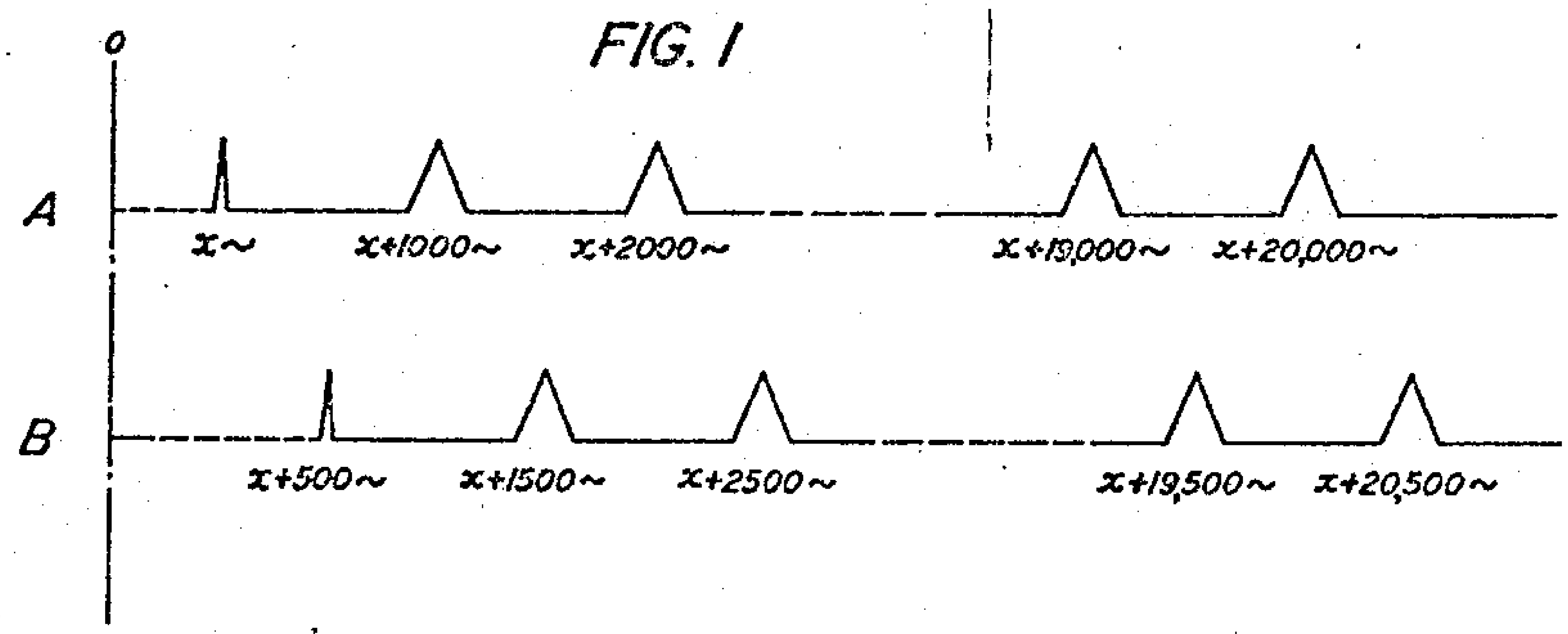


FIG. 2

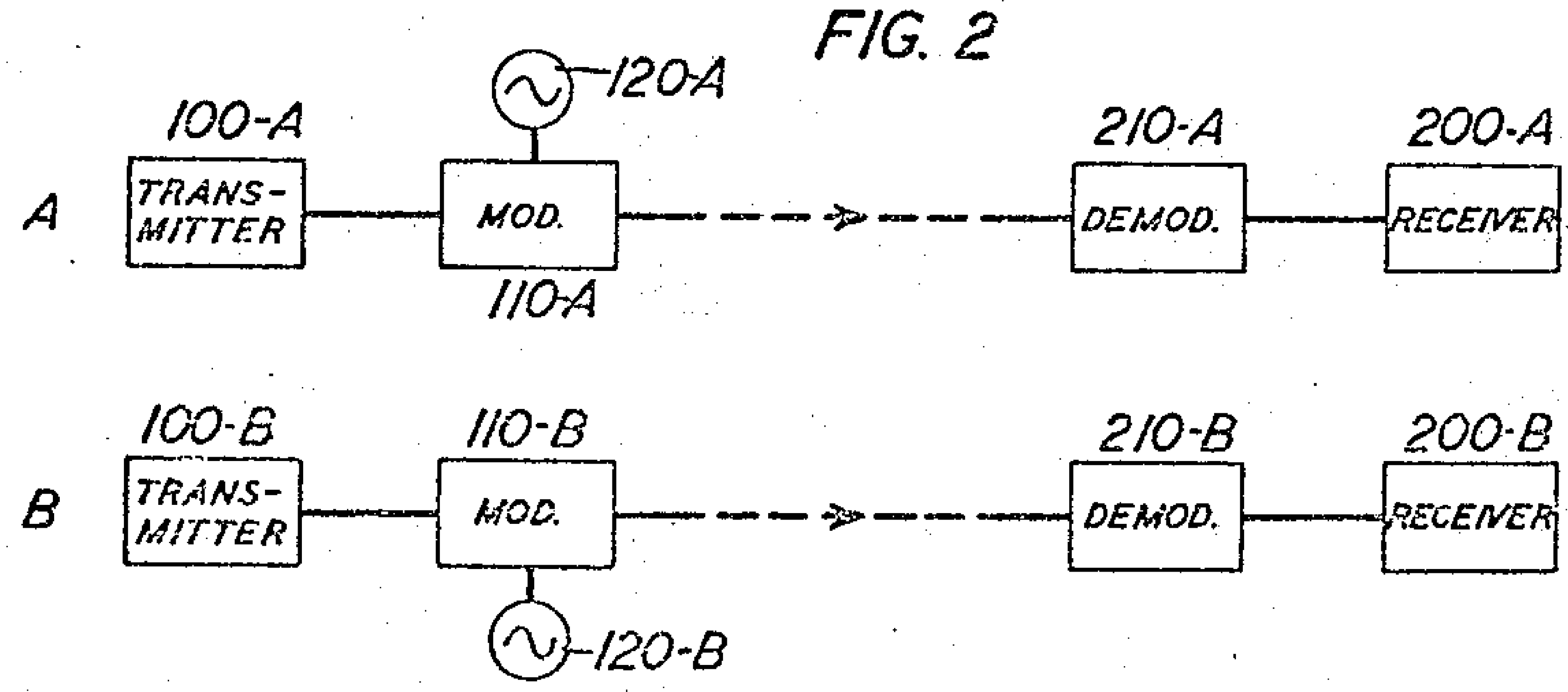


FIG. 3

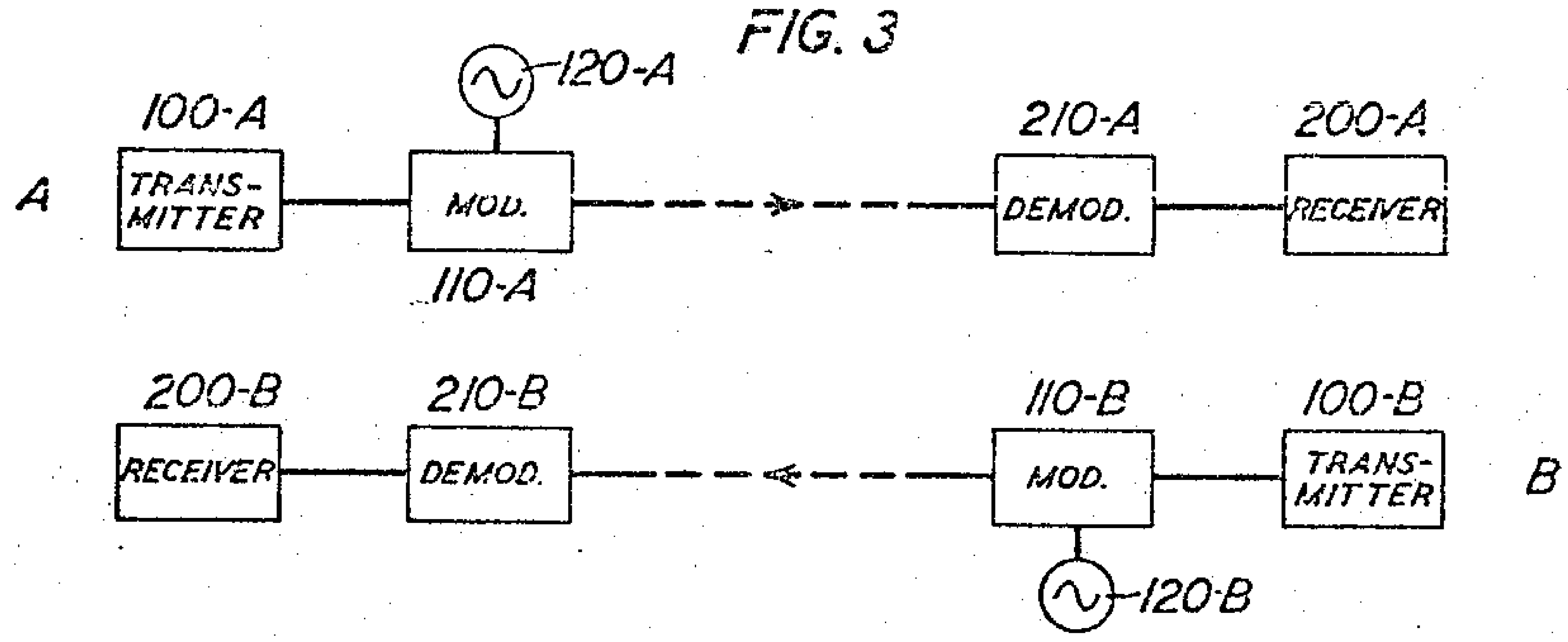
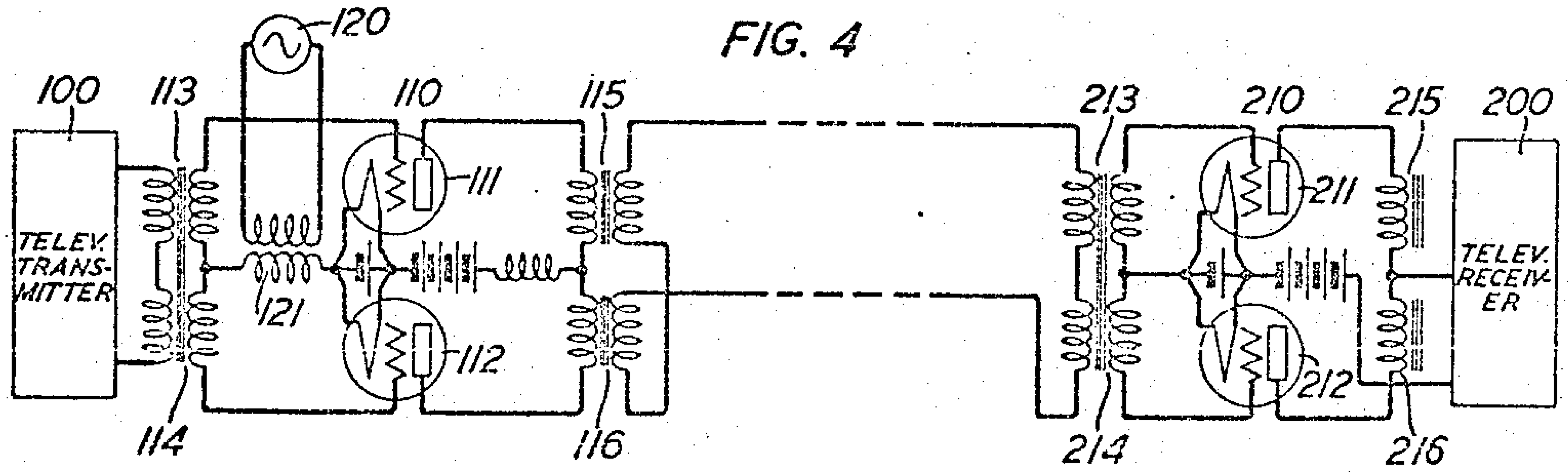


FIG. 4



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UNITED STATES PATENT OFFICE

2,095,341

ELECTROOPTICAL TRANSMISSION SYSTEM

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1 Claim. (Cl. 178—5)

This invention relates to electro-optical transmission and more particularly to a method and means for reducing mutual interference between television signals transmitted respectively over different adjacent or nearby circuits. This interference is ordinarily referred to as "cross-talk", a term borrowed from the telephone art.

An object of this invention is to reduce the mutual interference or cross-talk between two or more electro-optical systems operating either in the same or opposite direction.

When an object or field of view is periodically scanned in a series of adjacent 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 ordinary fields 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 having a difference of approximately that of the picture scanning frequency and ordinarily may have, for example, a band width of approximately 20 per cent of the line scanning frequency in which case the low energy intermediate gaps or valleys have a frequency band width of approximately 80 per cent of the line scanning frequency. In other cases, the band width of the energy concentrations may be much wider, particularly in telephotography. The width of these bands are governed more or less by the filtering action of the scanning aperture and by the characteristics of the object or field being scanned.

This invention provides means for utilizing the above mentioned low energy gaps or valleys for reducing mutual cross-talk between two or more systems simultaneously operating by introducing a relative shift in the frequencies of the several signals so that the energy peaks of each system come in the low energy regions of each of the other systems and vice versa.

In accordance with the form of this invention herein shown as illustrative of the invention, means are provided for simultaneously operating with the same resolution two electro-optical transmission channels either in the same or in opposite directions. Two separate parallel television systems are shown each employing carrier currents for the transmission of the electro-optical signal. The carrier currents differ in frequency by one-half the line scanning frequency or an odd multiple thereof, so that the signals sent out have a relative shift in frequency by this amount. More than two signals may be simultaneously transmitted in which case the carrier currents are such as to produce relative frequency shifts in the signals to cause their energy concentration to occupy mutually exclusive frequency positions.

By this arrangement, the far end cross-talk requirement between several systems operating over circuits of a pole line or cable may be made much more lenient than in the ordinary arrangement where the carrier currents have the same frequency.

This invention is applicable to telephotography as well as to television but in the case of the former the practical details of the application are more difficult because of the very close spacing of the practically idle and the utilized frequency bands.

In this arrangement the over-all range of the frequency band width of the several signals concurrently transmitted in each case is substantially the same as if only one signal were transmitted. The relative shifting of the energy concentrations of the signals in accordance with this invention is quite different from that of utilizing the low energy gaps of a given signal for the transmission of additional signals over the same circuit for the purpose of making greater use of the available frequency band of limited width over a given transmission circuit. The present arrangement employing a transmission circuit for each signal is concerned primarily with the reduction of interference or cross-talk between the different circuits, while the latter arrangement is concerned primarily with reducing the total frequency band width required for transmitting a plurality of signals to within substantially that ordinarily required for only one signal and transmitting all of the signals over a common circuit.

A more detailed description of the invention follows and is illustrated in the accompanying drawing:

Figure 1 is a typical current-frequency diagram of the energy concentrations of two photoelectric signal currents 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 one or both of the photoelectric currents so generated with a carrier current or currents, respectively, of constant frequency to produce a combination frequency or combination frequencies, respectively, which are shifted so that the energy concentrations of the two photoelectric signal currents are relatively shifted by one-half the line scanning frequency;

Fig. 2 is a general schematic representation of two separate electro-optical systems transmitting in the same direction and so arranged that the energy peaks in one system come in the regions of the energy valleys of the other system and vice versa;

Fig. 3 is a general schematic representation similar to that shown in Fig. 2 but arranged for transmitting in opposite directions; and

Fig. 4 diagrammatically shows the essential apparatus elements and their interconnections for a single circuit one-way transmission television system adaptable to this system employing a plurality of circuits.

The typical current-frequency diagrams A and B shown in Fig. 1 show the signal energy concentrations for two photoelectric currents relatively displaced by one-half the line scanning frequency. This invention is concerned primarily with the relative displacement of the energy concentrations and one of the signals need not have its energy concentrations shifted. However, it may be desirable to displace the energy concentrations of all signals somewhat to better adapt the frequency bands of the signals to the transmission characteristics of the available circuits. Certain circuits are not adapted to transmit direct current or the lower frequency components and therefore a frequency displacement of all signals upwardly so that the lower frequencies thereof are high enough to avoid transmission difficulties may be desirable thus placing all of the signals in substantially equally favorable positions with respect to the transmission characteristics of the several circuits. Considering the signals as having a line scanning frequency of 1000 cycles per second and a total band frequency width of 20,000 cycles, two signals may be displaced relatively to each other 500 cycles, namely, one-half the line scanning frequency by combining one of the signals with a carrier current of 500 cycles per second and using the upper sideband thereof or, preferably, by combining with a carrier current of 20,500 cycles and using the lower sideband thereof. This would place the displaced signal energy concentrations of one of the signals of the signal frequency spectrum in the regions of the odd multiples of 500 cycles, namely, at 500, 1500, 2500, etc. to 20,500, while the energy concentrations of the other signal would remain in the region of the even multiples of 500, namely, zero, 1000, 2000, etc. to 20,000. If it is desirable to effect frequency displacements of respectively x and x plus one-half the line scanning frequency, as indicated in Fig. 1, in the signals, respectively, to better adapt them for transmission over the available circuits, the other signal would be similarly combined with a carrier current of 1000 or of 21,000 cycles per second and either the upper or the lower sideband used for transmission. The displaced energy concentrations of both signals would still occur around the position of the odd and the even multiples of 500, respectively, but would commence in the region of 500 and 1000 cycles per second, respectively. Where three signals are employed, the energy concentration of one signal would be displaced one-third the line scanning frequency from the corresponding concentrations of the other signals.

The frequency band positions of the several signals with reference to the useful frequency band of the transmission media may be such as to clear any desired portion of the latter for the transmission of other signals. For example, the television signals might all have an upward displacement x of at least 3,000 cycles and all be transmitted above 3,000 cycles, thus permitting this cleared low frequency range to be used for sound transmission, synchronizing, monitoring, etc.

The above described plan of symmetrically positioning the energy concentration of the different signal currents in more or less mutually exclusive frequency positions is limited to a comparatively small number of relative displacements owing to the fact that the energy concentrations have a substantial frequency band width and if this plan were carried on to the point where appreciable overlapping occurred, its effectiveness would be decidedly decreased. However, even for the simultaneous transmission of a larger number of signals a real advantage in cutting down cross-talk may be obtained by relatively displacing the energy concentrations as between different groups of circuits. For example, considering twelve circuits between which cross-talk may occur, six of them may transmit a signal without relative frequency displacement of the energy concentrations of the signals with respect to each other, and a second group of six circuits may be so operated but with a frequency displacement as between the two groups, the displacement of the energy concentrations of one group with respect to those of the other group being one-half the line scanning frequency. This group arrangement might be carried somewhat further and the twelve circuits placed in three different groups of four circuits each with the relative frequency displacement as between the several groups equal to one-third the line scanning frequency. When two circuits or two groups of circuits have relative frequency displacement of their signal energy concentrations, the arrangement is somewhat more effective in the case when half of the circuits are transmitting in one direction and half in the opposite direction in which case near end cross-talk occurs as between the groups and far end cross-talk occurs within each group. Where all are transmitting in one direction, the cross-talk obviously occurs at the far end. When the transmission is in opposite directions, cross-talk is more acute owing to the fact that the energy level of the signals being transmitted is higher than that of the signals being received.

Fig. 2 schematically shows two television transmitting systems A and B, respectively, arranged for the energy concentrations of the signal current of one system to occupy the regions of the energy valleys of the signal current of the other system. The transmitters 100—A and 100—B generate the respective signal currents which, by means of modulators 110—A and 110—B are combined with suitable carrier currents generated by oscillators 120—A and 120—B, respectively. The respective modulated carrier current signals are transmitted over suitable individual transmission circuits and demodulated by demodulators 210—A and 210—B at the respective receiving stations. Television receivers 200—A and 200—B operating in synchronism with transmitters 100—A and 100—B, respectively, reproduce the images in the usual manner. The carrier current frequency generated by the oscillators 120—A and 120—B, respectively, differ in frequency by one-half the line scanning frequency, or perhaps by a different fraction thereof if more than two circuits are considered.

While Fig. 2 shows an arrangement for both circuits to transmit in the same direction, the transmission may be concurrently in opposite directions as schematically shown in Fig. 3. The description of Fig. 2 is applicable to Fig. 3 as the apparatus elements are similar and the corresponding reference characters are identical.

Fig. 4 diagrammatically shows the essential apparatus elements and their interconnection for a television system transmitting over one transmission circuit in one direction adaptable to this system employing a plurality of circuits. The television transmitter 100 including the usual current amplifying apparatus generates the photoelectric signal current by scanning the field of view in successive line series of elemental areas. The amplified signal is impressed upon the circuits of the modulator 110 through any suitable coupling such as transformers 113 and 114. The modulator may be a simple modulator of the push-pull type as here shown or a double-balanced modulator comprising two units similar to those of the simple modulator suitably interconnected. The simple modulator 110 comprises vacuum tube elements 111 and 112 connected in push-pull arrangement. The incoming photoelectric signal current is impressed upon the grids of these tubes by means of transformers 113 and 114 while the carrier current generated by the oscillator 120 is supplied through the transformer 121. The modulated outgoing signal current is transmitted through the transformers 115 and 116 to the transmission circuit. The output transformers should have separate cores while the input transformers may have either separate or combined cores. If a double-balanced modulator which introduces further refinement is desired, it may be formed, as stated above, by using two units similar to those shown for modulator 110 connected in parallel. The double-balanced modulator has the advantage over the simple modulator of cutting out more of the extraneous frequencies produced in modulation. It may be desirable to insert a low pass filter between the output transformers of the modulator and the transmission line to eliminate the undesirable high frequency components passed by the modulator but usually this will be unnecessary since the output side of each modulator is connected to an individual transmission line which will largely prevent undesirable high frequency components reaching the receiving station. At the receiving end, the incoming signal including its carrier is impressed upon the demodulator 210. Any suitable amplifying apparatus, though not shown in the drawing, may be employed to amplify the incoming signal. The demodulator may be either a simple demodulator as here shown or a double-balanced demodulator. The simple demodulator 210 comprises vacuum tube elements 211 and 212 connected in push-pull arrangement. The input circuit is connected with the incoming transmission line through transformers 213 and 214 and the output circuit of the demodulator is obtained by using inductances 215 and 216 and connecting one side of the output circuit with the cathodes of the vacuum tubes and the other at the midpoint between the two inductances. Transformers may be used instead of inductances. In either case, the two output coupling units should have separate cores, while the input coupling units may have a common core or separate cores. If double-balanced demodulators are used, they would comprise two units similar to those shown forming the simple demodulator 210 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. The television receiver 200, including the usual current amplifying apparatus, may be of the usual type operated in synchronism and in phase with the television transmitter 100.

The apparatus and its interconnections for a plurality of television transmission circuits arranged for operation in accordance with this invention is similar for each circuit to that shown in Fig. 4. However, in the operation of different circuits such carrier frequencies are chosen as will produce the desired relative displacement of the energy concentration in the several signals or groups thereof. The different frequency stated in describing this system for simultaneous transmission of a plurality of television signals are typical and are mentioned primarily to facilitate the description. Obviously, different scanning rates may be selected which would cause energy concentrations to occur at different frequency positions in the television signal current spectrum. The energy concentrations of the signal current as transmitted over the different respective circuits may not only be staggered or displaced but may be positioned within any desired over-all frequency band so as to permit the use of certain frequency bands for the transmission of other signals which it may be desirable to have accompany the television transmission. Preferably only one side band of the carrier signal currents would be transmitted in order that the total frequency width of the signals transmitted may be as narrow as possible. The carrier current may be transmitted as is obvious from the arrangement shown in Fig. 4 or it may be suppressed and supplied at the receiving station from a local source. All of these variations are, in general, well known to the art and this invention relates primarily to the operation of a number of television systems in a manner to reduce cross-talk between their respective circuits to a minimum.

What is claimed is:

Means for image current transmission comprising a plurality of systems having individual physical transmission paths, said paths being so closely associated that energy transmission sufficient to produce cross-talk may take place, means including scanning devices for generating image currents in a group of such paths so that corresponding energy concentrations have similar positions in the frequency spectrum in each image current within the group, means including scanning devices for generating image currents in a second group of said paths so that corresponding energy concentrations have similar positions in the frequency spectrum in the image currents transmitted over the second group of paths but different positions as between the first and second groups of image currents, and means for simultaneously transmitting the generated currents over the transmission paths of one group in one direction and the other group in the opposite direction.

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