Aug. 4, 1925. 1,548,260

L. ESPENSCHIED

MULTIPLEX SYSTEM

Filed Sept. 19, 1919 2 Sheets-Sheet 1

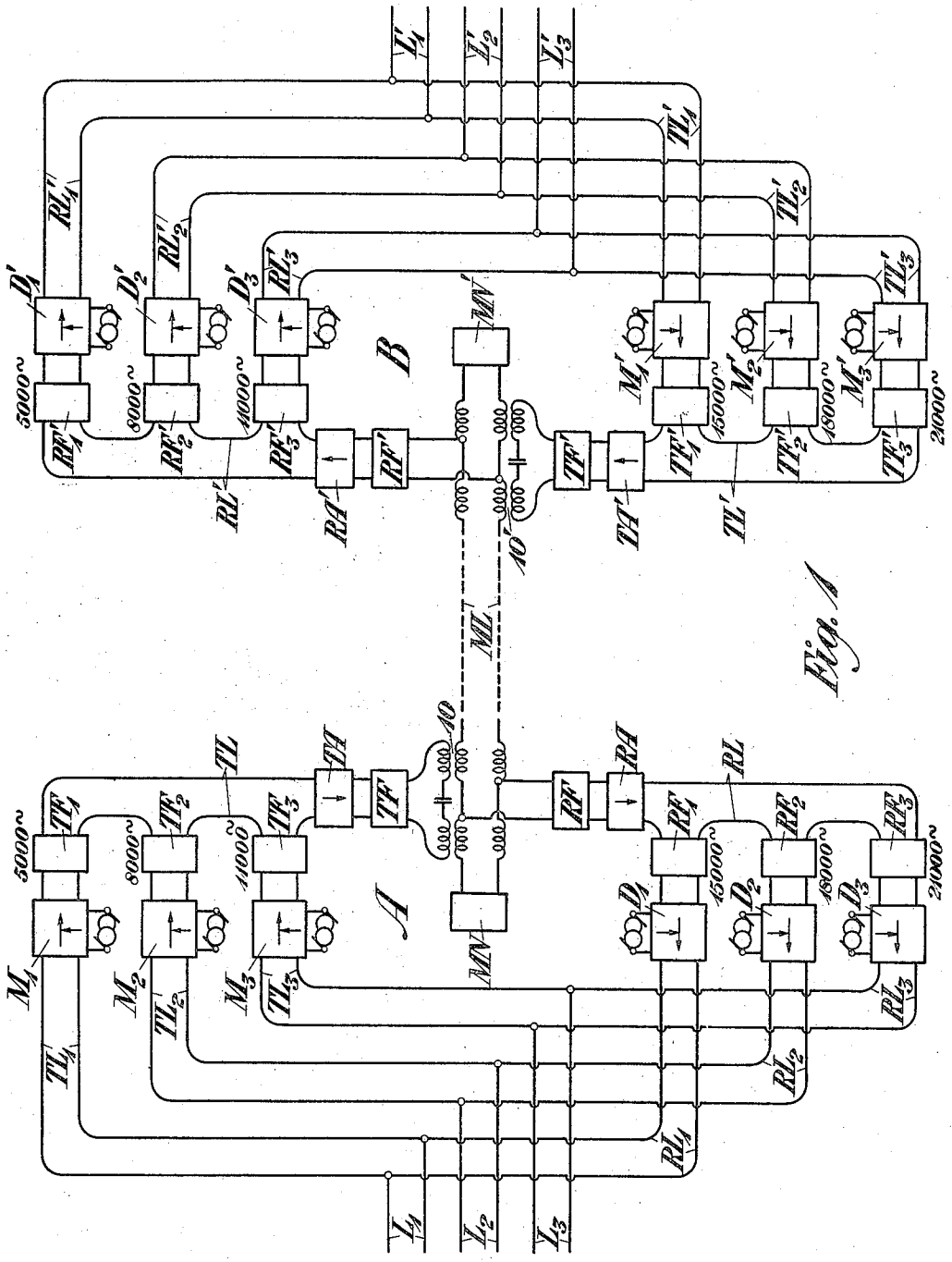


Fig. A

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2 Sheets-Sheet 2

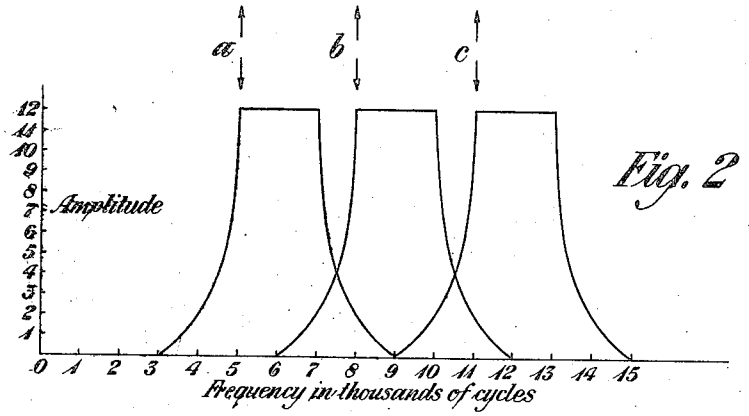


Fig. 2

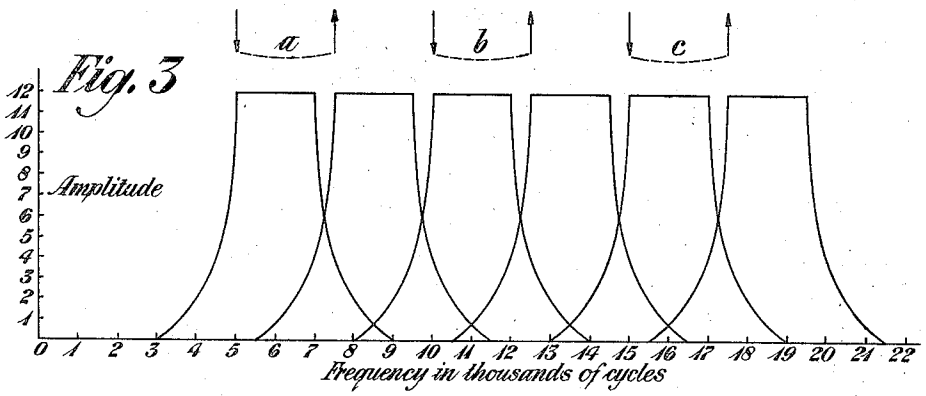


Fig. 3

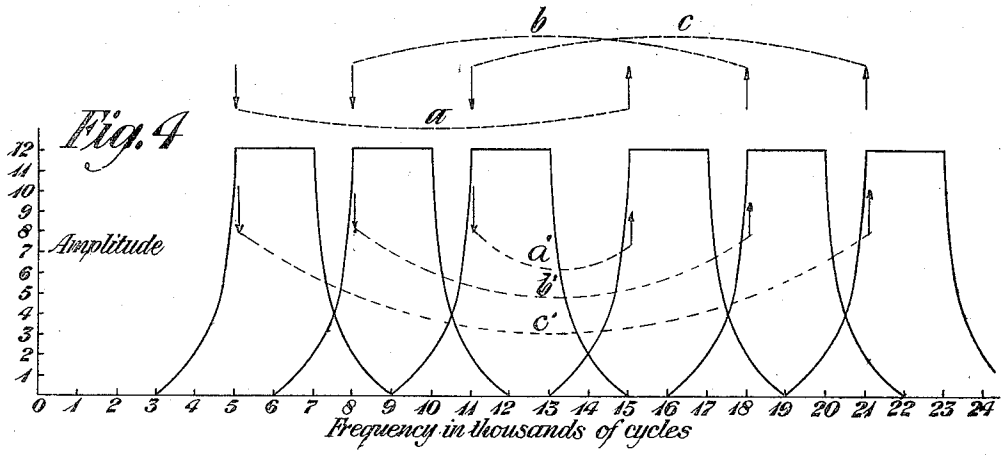


Fig. 4

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Patented Aug. 4, 1925. 1,548,260

UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF HOLLIS, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MULTIPLEX SYSTEM.

Application filed September 19, 1919. Serial No. 324,851.

To all whom it may concern:

Be it known that I, LLOYD ESPENCHIED, residing at Hollis, in the county of Queens and State of New York, have invented certain Improvements in Multiplex Systems, of which the following is a specification.

This invention relates to multiplex signaling systems and more particularly to radio and wire transmission systems in which carrier currents are employed for the transmission of signals.

One of the objects of this invention is to reduce interference between a plurality of signal channels over which simultaneous transmissions are taking place either in the same or opposite directions. Another object of the invention is to reduce the interference between transmissions over one or more channels employing the same transmission medium and similar channels employing a similar but different medium. Still another object of the invention is to provide a multiplex system in which oppositely directed transmissions may be readily separated at repeater points for separate amplification.

The above objects, as well as other aims of the invention, more fully appearing hereinafter, are realized in a multiplex signaling system in which a plurality of individual signals may be simultaneously transmitted over a common medium of communication through the agency of carrier currents of different frequencies, the frequencies of each channel being so chosen that oppositely directed transmissions will be separted from each other in frequency by an amount equal to or greater than the frequency separation between transmissions in the same direction.

Heretofore in multiplex systems employing carrier currents, it has been possible to both receive and transmit over each channel at the same channel frequency, provided an extremely good condition of balance is attainable by the outgoing and incoming transmissions. If, however, as is frequently the case, the condition of balance is so poor that the outgoing transmission from a particular channel reacts upon the local receiving circuit to too great an extent, it is no longer possible to both receive and transmit at the same frequency. Accordingly it has been proposed to "stagger" the frequencies of the outgoing and incoming transmissions pertaining to the several channels so that for a given channel the carrier frequency employed for transmission in one direction will lie between the frequencies employed for transmission in the opposite direction by that channel and the nearest adjacent channel.

With the arrangement just described, the interference between oppositely directed transmissions is reduced not only by selectivity due to the frequency difference, but is further reduced by the partial balance between oppositely directed transmission. Its efficiency, however, decreases as the degree of unbalance becomes greater, thereby necessitating a wider frequency separation so that the total frequency range necessary for a given number of channels becomes excessive. If the balance is extremely poor, a condition may arise where a greater frequency separation becomes necessary between oppositely directed transmission than that necessary for transmissions of the same direction. This arises from the fact that the amount of energy transmitted over the outgoing channel of a particular station is greatly in excess of the energy received from the incoming channel, the latter having been greatly attenuated during transmission from a distant point. Consequently even though the outgoing and incoming channels be partially balanced and partially separated in frequency, the total amount of outgoing energy which may react on the incoming channel may exceed the amount of interfering energy from an adjacent channel over which transmission is taking place in the same direction and the frequency of which differs from that of the channel in question by the same amount as the frequency separation between the outgoing and incoming transmissions.

It is, therefore, necessary, under these conditions of unbalance, to provide a greater frequency separation between oppositely directed transmissions than that provided between transmissions in the same direction. This result is secured in accordance with the present invention by grouping the frequencies utilized for transmission in one range of frequencies, the frequencies, employed for transmission in the opposite direction being included within another

range. Preferably, the several frequences in each range corresponding to the several channels will be separated from each other by an amount just sufficient to prevent undue interference between transmissions in the same direction. Since for any given channel the frequency employed for outgoing transmission will lie in an entirely different range from that employed for incoming transmission, the frequency separation between oppositely directed transmissions may be so great that no balance at all is necessary between the outgoing and incoming transmissions.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawings, in which Figure 1 is a schematic diagram showing one circuit arrangement in which the invention may be embodied, while Figs. 2, 3, and 4 show curves illustrating the principles of the invention.

Referring to Fig. 1, ML designates a main transmission line over which a plurality of signals may be simultaneously transmitted. The line ML and the carrier apparatus associated therewith is herein illustrated with reference to a telephone system, but it will be understood that the principles of the invention are equally applicable to the transmission of telegraphic and other types of signals. At station A the line ML is associated by means of a transformer 10 with a common carrier transmitting circuit TL and a common carrier receiving circuit RL. In order to render the circuits TL and RL conjugate with respect to each other, so that electrical disturbances arising in the one circuit will be without effect upon the other, the main line ML is balanced by an artificial line or network MN. Similarly at station B the line ML is associated through a transformer 10′ with common carrier transmitting circuit TL′ and common carrier receiving circuit RL′, said circuits being rendered conjugate by the provision of a balancing network MN′ for balancing the line ML.

L_1, L_2 and L_3 respectively designate low frequency signaling circuits, such as telephone circuits, which are so related to the main line ML that signals from said circuits may be simultaneously transmitted over said main line. For this purpose the line L_1 is connected to the common transmitting circuit TL through a transmitting channel TL_1 and to the common receiving circuit RL, through the receiving channel RL_1. In a similar manner lines L_2 and L_3 are associated with TL through transmitting channels TL_2 and TL_3, respectively, and with receiving circuit RL through receiving channels RL_2 and RL_3 respectively.

In order to translate the low frequency signals from the line L_1 into high frequency current for transmission over the line ML, the modulating arrangement M_1 is included in the transmitting channel TL_1. This modulating arrangement which is merely indicated schematically, may be any organization whereby high frequency oscillations from any suitable source are modulated in accordance with low frequency signals, but is preferably a duplex vacuum tube modulating arrangement such as is disclosed in the application of John R. Carson, Serial No. 157,413, filed March 26, 1917. Similar modulating arrangements M_2 and M_3 are provided for the transmitting channels TL_2 and TL_3, the modulators M_1, M_2 and M_3 differing from each other only in the frequency of the carrier currents supplied thereto. As indicated, the carrier frequencies supplied to these modulators may be 5,000, 8,000 and 11,000 cycles respectively, but it will be understood that these frequencies are given only for purposes of illustration.

In order to provide the desired frequency separation between the three transmitting channels, filters TF_1, TF_2 and TF_3 are included in the channels TL_1, TL_2 and TL_3 respectively. Where the low frequency signaling range is quite narrow, as in the case of telegraph transmission, these filtering arrangements may be simple tuned circuits, but where, as in the case of telephony, the low frequency signal range is of considerable width, the filters should preferably be of the broad band type disclosed in the United States patents to George A. Campbell, Nos. 1,227,113, and 1,227,114, dated May 22, 1917. Where it is desired to suppress one of the side bands resulting from modulation of the carrier current by a signaling current, each filter should be so designed as to transmit a band of frequencies extending either above or below the carrier frequency assigned to the channel by an amount equal to the low frequency signaling range. Thus in the case of channel TL_1, assuming that the range of telephonic transmission is from zero to about 2,000 cycles, the filter TF_1 should be designed to transmit a band extending either from 5,000 cycles to about 7,000 cycles, or from 5,000 cycles down to about 3,000 cycles. Similarly the filter TF_2 should transmit from 8,000 to 10,000 cycles or from 6,000 to 8,000 cycles, while the filter TF_3 should transmit from 11,000 to 13,000 cycles, or from 9,000 to 11,000 cycles, depending upon whether the lower or the upper side band is to be eliminated.

In order to amplify the modulated high frequency currents impressed upon the common circuit TL from the transmitting channels TL_1, TL_2 and TL_3 an amplifier TA may be included in the circuit TL. This amplifier may be of any well known type, but is

preferably a vacuum tube amplifier of the well known push and pull type. A filter TF is also provided in the circuit TL. This filter is likewise of the general type disclosed in the patents to Campbell above referred to and should be so designed as to transmit a band of frequencies sufficiently wide to include all of the frequencies arising in the several transmitting channels. In the case illustrated, assuming that the lower side band should be eliminated, the filter TF should transmit a range of frequencies extending from 5,000 cycles to 13,000 cycles.

Inasmuch as, in accordance with the present invention, the carrier frequencies used for receiving should lie within an entirely different range from those used for transmitting, the common receiving circuit RL is provided with a filter RF similar to the filter TF but so designed as to transmit a band of frequencies extending from the lowest frequency employed by any receiving channel to the highest frequency employed by any receiving channel. Assuming that the three receiving channels have assigned to them basic carrier frequencies of 15,000, 18,000 and 21,000 cycles respectively, and that the lower side band in each case is eliminated, the filter RF should pass frequencies from 15,000 to 23,000 cycles. A common amplifier RA similar to amplifier TA is also provided in the common receiving circuit RL in order to amplify all received frequencies.

In order to separate into the proper receiving channels the various received frequencies, filters RF_1, RF_2 and RF_3 are included in the receiving channels RL_1, RL_2 and RL_3 respectively. These filters are in general similar to the filters TF_1, TF_2 and TF_3, but are each designed to pass a band of frequencies extending either above or below the carrier frequency individual to the channel an amount equal to the range of frequencies employed for low frequency signals. If, for instance, the frequencies assigned to the receiving channels RL_1, RL_2 and RL_3 are 15,000 18,000 and 21,000 cycles, respectively, and the lower side band in each case is eliminated, filter RF_1 would be arranged to pass a band of frequencies from 15,000 to about 17,000 cycles, in the case of telephonic signaling. Similarly filter RF_2 would pass a band from 18,000 to 20,000 cycles and filter RF_3 a band from 21,000 to 23,000 cycles.

In order that the modulated carrier currents received in the different receiving channels may be translated into the low frequency signals, in accordance with which they were modulated at the distant transmitting station, the receiving channels are provided with detecting arrangements, D_1, D_2 and D_3 indicated schematically in the drawing. These detecting arrangements may be of any well known type but are preferably duplex vacuum tube detectors of the type illustrated in the application of J. R. Carson, Serial No. 157,414, filed March 26, 1917. The detecting or demodulating arrangement of the said application of J. R. Carson employs the so-called homodyne method of detecting, thereby necessitating that the carrier frequency of that particular channel be supplied to the demodulating arrangement at the same time that the received modulated carrier waves are applied thereto. Accordingly, the demodulating arrangements are illustrated as being supplied with oscillations from local homodyne sources having frequencies of 15,000, 18,000 and 21,000 cycles respectively. It will, of course, be understood that these frequencies are given merely for purposes of illustration and that in actual practice frequencies other than those indicated may be employed.

The arrangement at station B is quite similar to that at station A and similar parts are designated by the same reference characters as at station A, except that in the case of station B the reference characters are primed. Owing to the similarity of arrangements at the two stations, it is unnecessary to describe the apparatus at station B in detail. It should be noted, however, that as the system is organized so that two-way transmission takes place between L_1, L_2, and L_3 at station A, and lines L_1', L_2' and L_3' at station B, respectively, the frequencies assigned to the transmitting and receiving channels are different. Thus the frequencies of the receiving channels RL_1', RL_2' and RL_3' are indicated at being 5,000, 8,000 and 11,000 cycles respectively, these frequencies corresponding to the transmitting frequencies at station A. On the other hand the transmitting frequencies of the transmitting channels TL_1', TL_2' and TL_3' at station B are indicated as being 15,000, 18,000 and 21,000 cycles respectively, these frequencies corresponding to the frequencies assigned to the receiving channels at station A. The bands to be transmitted by the filters at station B are therefore modified accordingly.

The operation is as follows: Telephone currents incoming from the line L_1 are transmitted over the transmitting channel TL_1 to the modulator M_1 where they are impressed upon a carrier frequency of 5,000 cycles. After being modulated the resultant band of frequencies is passed through the filter TF_1 to the common transmitting circuit TL. At the same time other telephone waves from lines L_2 and L_3 are translated into carrier frequencies and pass through the filters TF_2 and TF_3 to the common transmitting circuit TL. After being amplified by the amplifier TA the several bands of frequencies are passed through the filter TF and are then

transmitted through the transformer 10 to the main line ML. However inefficient the balancing arrangement of the line ML may be, the frequencies passing through the filter TF to the line ML cannot enter the common receiving circuit RL since the band of frequencies passed by the filter RF is different from that passed by the filter TF. Furthermore, even assuming that the filter RF was sufficiently inefficient to pass some energy of the frequency of one of the transmitting channels such as, for instance, 5,000 cycles, to the transmitting channel TL_1, this frequency could not enter the receiving channel RL_1 to any appreciable extent because the band passed by the filter RF_1 is in the neighborhood of 15,000 cycles and therefore quite remote from a frequency in the neighborhood of 5,000 cycles.

The several carrier frequencies impressed upon the line ML from the transmitting circuit TL, upon being transmitted to station B, are passed by the filter RF′ into the common receiving circuit RL′, but are not permitted to enter the common transmitting circuit TL_1 since they do not lie within the range of the filter TF′. Upon passing the filter RF′ these frequencies are amplified by the amplifier RA′ and are then distributed into the proper receiving channels through the filters $RF_{1'}$, $RF_{2'}$ and $RF_{3'}$ respectively. The carrier frequencies then beat with frequencies of 5,000, 8,000 and 11,000 cycles respectively in the detecting arrangements $D_{1'}$, $D_{2'}$ and $D_{3'}$ so that the low frequency signals are transmitted from the output sides of the demodulating arrangements to the lines $L_{1'}$, $L_{2'}$ and $L_{3'}$.

Signals incoming from the lines $L_{1'}$, $L_{2'}$ and $L_{3'}$ pass into the corresponding transmitting channels at station B and modulate frequencies of 15,000, 18,000 and 21,000 cycles respectively. The resultant frequency bands are transmitted through the filters $TF_{1'}$, $TF_{2'}$ and $TF_{3'}$ to the amplifier TA′ where they are amplified, then passing through the filter TF′ and the transformer 10′ to the main line ML, being excluded from the common receiving circuit RL′ by the filter RF′. After being transmitted over the main line ML they pass through the filter RF to the amplifier RA of the common receiving circuit RL, being excluded from the common transmitting circuit by means of the filter TF. Upon being amplified the frequency bands are separated into the proper receiving channels through the filters RF_1, RF_2 and RF_3 where they beat with frequencies of 15,000, 18,000 and 21,000 cycles, respectively, in the demodulating arrangements D_1, D_2 and D_3. The resulting low frequency signals are then transmitted to the lines L_1, L_2 and L_3 respectively.

In order to obtain a clear understanding of the principles underlying the present invention and its advantages over arrangements previously proposed, attention is called to the curves of Figs. 2, 3 and 4. The curves of Fig. 2 represent the variation with frequency of the amplitude of the waves passed through the filters of the transmitting and receiving channels corresponding to three lines of a multiplex system in which the condition of balance is so perfect that transmission and reception may take place at the same frequency. As is well known, a filter, whether it be a sharply tuned circuit or a broad band filter of the Campbell type, does not have a sharp cut-off but attenuates frequencies outside of the critical frequency or range of frequencies to an increasing extent, as the frequency lies farther from the critical or limiting frequency of the transmitted band of frequencies. The curves of Fig. 2 roughly represent the condition for broad band filters instead of sharply tuned circuits. In the case of the transmitting and receiving channel indicated in the figure by "*a*", the characteristic frequency is 5,000 cycles and the filter transmits a band between the 5,000 and 7,000 cycles with equal amplitude. The amplitudes of frequencies lying without this range decrease with the distance from the limiting frequencies of the band, as indicated by the curve. In a similar manner the filters of the transmitting and receiving channels indicated by "*b*" readily transmit a band lying between 8,000 and 10,000 cycles but attenuate frequencies lying without this range. Thus the amplitude of a frequency of 8,000 cycles will be 12 units in the case of *b*, while the same frequency will only attain an amplitude of 2 units in the case of *a*. Assuming that this represents the maximum amount of permissible interfering energy, it will be seen that the frequency spacing of 1,000 cycles between the adjacent bands will be sufficient for the desired condition of noninterference between the channels corresponding to different terminal lines. It will be understood that the interference values used above are purely illustrative. Actually the ratio between amplitudes of the transmitted and the suppressed interfering frequencies should be somewhat less than 12 to 2 to prevent excessive crossfire between superimposed telegraph circuits and much less than this, more nearly 1,000 to 1, to prevent undue crosstalk between telephone circuits.

Noninterference between the outgoing and incoming transmission for a particular line depends, in the case illustrated by the curves of Fig. 2, not upon frequency separation but upon balance between the outgoing and the incoming circuit. If the balance is sufficiently good so that for the case of the transmitting and receiving channels indicated at *b*, a transmitted wave having a frequency of 8,000 cycles will have an ampli-

tude of 12 units in the outgoing circuit while the corresponding wave appearing in the incoming circuit due to unbalance is, say, 2 units or less, it will be sufficient to discriminate between outgoing and incoming transmissions by balance alone and to discriminate between transmissions of adjacent channels in the same direction by frequency separation alone, as indicated in Fig. 2. If a greater degree of unbalance exists than that assumed, it becomes necessary to discriminate between outgoing and incoming transmissions for the same line by frequency separation.

Fig. 3 illustrates curves similar to those of Fig. 2 for a condition where the outgoing and incoming transmissions are "staggered" in frequency. Each frequency band is here assumed to be 2,000 cycles in width and to be separated from the adjacent band by 500 cycles. The arrows indicate the direction of transmission of the characteristic carrier frequency of each band. It will be seen that the incoming transmission band of the channel corresponding to "*a*" is separated from the incoming band of the channel corresponding to "*b*" by 3,000 cycles so that a sufficient degree of separation between transmissions in the same direction is provided for. The outgoing transmission of the channel corresponding to "*a*" is located between the incoming transmissions of "*a*" and "*b*." For the condition illustrated an outgoing frequency of 7,500 cycles in the case of "*a*" would result in a wave having an amplitude of 4 units in the incoming circuit upon the assumption that no balance whatever were provided. If the condition of balance is sufficiently good to reduce this by one-half, the wave would have an amplitude of two units which may be assumed to satisfy the requirements as to interference, so that it will be seen that for a good balance a closer spacing is permissible between oppositely directed transmissions than is possible between transmissions in the same direction. The same holds true for the outgoing transmission corresponding to "*a*" and the incoming transmission of "*b*." Thus a frequency of 9,500 cycles in the case of "*a*" would have an amplitude of 4 units in the incoming circuit corresponding to "*b*" if no balance existed between the main line and its network at the terminal station. If, however, as assumed, the balance is sufficient to reduce the amplitude of the wave one-half, the required conditions for noninterference will be satisfied.

If, however, no balance whatever were provided or if the balance were inferior to that assumed for Fig. 3, it becomes necessary to effect the desired separation between oppositely directed channels of the same circuit by increasing the frequency separation between them. This gives rise to another possible disposition in the broad frequency range, of the channels of a multiplex system. This is called the "grouped" arrangement of the present invention and is illustrated in Fig. 4. Here the oppositely directed channels of one circuit are so widely separated in the frequency spectrum as to permit similarly directed channels of the multiplex system to be grouped together in individual frequency ranges. Referring to Fig. 4, the channels of one direction of transmission are brought as close together as the interference limit between similarly directed channels will permit, say within 1,000 cycles, and the frequency spacing between oppositely directed channels is made large enough to avoid interference between them.

The advantage of this "grouped" arrangements as compared with the "staggered" one is that it permits of obtaining the considerable frequency spacing between oppositely directed channels necessary for overcoming conditions of poor line balance without similarly and needlessly increasing the frequency separation between similarly directed channels. For example, in Fig. 4 the frequency separation between oppositely directed channels is 2,000 cycles and to obtain this separation with the staggered arrangement of Fig. 3 would involve moving the similarly directed channels apart 6,000 cycles. For this condition the staggered arrangement would require a considerably greater total frequency range than the grouped arrangement, as the staggered arrangement would extend from 5,000 to 27,000 cycles while the grouped arrangement only extends from 5,000 to 23,000 cycles.

The disposition of channels indicated in Fig. 4 is that in which the frequency spacing between the oppositely directed channels of a two-way circuit is the same for all of the circuits of the multiplex group, namely 10,000 cycles between carrier frequencies. Thus for circuit "*a*" one channel has a carrier of 5,000 cycles while the other has a carrier of the 15,000 cycles; for circuit "*b*" 8,000 and 18,000 cycles; and for circuit "*c*" 11,000 and 21,000 cycles.

An alternative disposition of the channels is to have them paired symmetrically with respect to the frequency spacing between the two groups. Thus, the 11,000 cycle and the 15,000 cycle carrier would be paired as the oppositely directed channels of one circuit, the 8,000 and 18,000 cycle channels of a second circuit and the 5,000 and 21,000 cycle channels of a third circuit as shown at *a' b' c'* in Fig. 4.

The "grouped" arrangement of channels characterizing the present invention is especially desirable in a multiplex system

wherein the carrier transmission is effected by radio instead of by wire. It is especially desirable in radio because the very large ratio between sent and received energy renders the separation of oppositely directed channels of two-way circuits by balance alone very difficult, if not impossible, in the present art. Because the frequency spacing which must be left between the sending and receiving channels is considerable as compared to that which is necessary between similarly directed channels, sending or receiving, the grouping arrangement is an economical one.

The arrangement of this invention is also particularly advantageous in preventing interference between oppositely directed channels, whether the interference be between oppositely directed channels superposed on the same transmission medium or oppositely directed channels superposed upon different transmission media. The condition of interference is most severe at the terminal stations and at the repeater points for the reason that outgoing transmission leaving a terminal station or a receiving point has an amplitude quite large in comparison with transmissions being received at either of these points, by reason of the fact that the received transmissions have undergone attenuation in being transmitted from distant points. Consequently an outgoing transmission produces an interference in an incoming circuit relatively much greater than is produced upon another outgoing channel or circuit. Inasmuch as the proposed arrangement provides a very wide separation in frequency between oppositely directed transmissions, it becomes at once apparent that if the frequency separation between transmissions in the same direction is sufficient to satisfy the required standard of noninterference, the frequency separation between the oppositely directed transmissions corresponding to a given channel will be so much greater as to satisfy the required conditions practically regardless of the condition of balance.

The proposed arrangement is also advantageous in connection with the separation of outgoing and incoming transmissions for separate amplification at repeater points. By grouping frequencies transmitted in one direction together in a frequency range lying outside of the range in which the frequencies transmitted in the opposite direction are grouped, the two sets of transmissions may be readily separated with regard to the east and west amplifiers of the repeater set by means of band filters.

While the invention has been disclosed as applied to a multiplex wire telephone system, it will be understood that the principles thereof are equally applicable to either wire systems or wireless systems and in general to the transmission of any character of signal. Furthermore, it will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a multiplex signaling system, a transmission circuit, means whereby a plurality of channels of communication may be established over said circuit in each direction, each channel employing characteristic carrier frequencies for signal transmission, and the frequencies of the channels being so chosen that the frequencies utilized by all of the channels for transmitting purposes will lie within one range and the frequencies used for receiving will all lie within another range the arrangement of the frequencies of the several channels in one range being axially symmetric with respect to the arrangement of the frequencies of the several channels in the other range, the axis of symmetry corresponding to a frequency midway between the limiting frequencies of the ranges.

2. In a multiplex signaling system, a plurality of signaling channels employing different carrier frequencies, the frequencies of the channels being so chosen that the frequency separation between oppositely directed transmissions will be greater than that between the most closely spaced transmissions in the same direction.

3. In a multiplex signaling system, a plurality of signaling channels employing different carrier frequencies, the frequencies of the channels being so chosen that all of the carrier frequencies used for transmission in one direction will lie within one range and all of the carrier frequencies used for transmission in the opposite directions will be within another range, the arrangement of the frequencies of the several channels in one range being axially symmetric with respect to the arrangement of the frequencies of the several channels in the other range, the axis of symmetry corresponding to a frequency midway between the limiting frequencies of the ranges.

4. In a multiplex signaling system, a common transmission circuit over which a plurality of signals may be simultaneously transmitted, a plurality of terminal lines adapted to transmit signals to said common circuit, means associated with each terminal line whereby it may transmit signals at one frequency and receive at another frequency, the frequencies employed by the several terminal lines being so chosen that the frequency employed by a given terminal line for transmitting will differ from that which it employs for receiving by an amount

greater than that by which it differs from the nearest frequency employed by another terminal line.

5. In a multiplex signaling system, a common transmission circuit over which a plurality of signals may be simultaneously transmitted, a plurality of terminal lines adapted to transmit signals to said common circuit, means associated with each terminal line whereby it may transmit signals at one frequency and receive at another frequency, the frequencies employed by the several terminal lines being so chosen that all of the frequencies employed by a plurality of terminal lines for transmitting will lie within one range, and all of the frequencies employed by said lines for receiving will lie within another range, the positions of the several transmitting frequencies in the range which they occupy being axially symmetric with respect to the positions of the several receiving frequencies in the range which the latter occupy, the axis of symmetry corresponding to a frequency midway between the limiting frequencies of the ranges.

6. In a signaling system, a common transmission circuit over which a plurality of signals may be simultaneously transmitted, a plurality of low frequency signaling circuits, a carrier channel for interconnecting each low frequency circuit with said transmission circuit for transmission in one direction, an oppositely directed carrier channel for interconnecting each low frequency circuit with said transmission circuit for transmission in the opposite direction, the frequencies employed by carrier channels transmitting in one direction being in one range, and the frequencies employed by carrier channels transmitting in another direction being in another range, the positions of the several transmitting frequencies in the range which they occupy being axially symmetric with respect to the positions of the several receiving frequencies in the range which the latter occupy, the axis of symmetry corresponding to a frequency midway between the limiting frequencies of the ranges.

7. In a multiplex signaling system, a transmission circuit, means whereby a plurality of channels of communication may be established over said circuit in each direction, each channel employing characteristic carrier frequencies for signal transmission, and the frequencies of the channels being so chosen that the frequencies utilized by all of the channels for transmitting purposes will lie within one range and the frequencies used for receiving will all lie within another and entirely different range.

8. In a multiplex signaling system, a plurality of signaling channels employing different carrier frequencies, the frequencies of the channels being so chosen that all of the carrier frequencies used for transmission in one direction will lie within one range and all of the carrier frequencies used for transmission in the opposite direction will be within another and entirely different range.

9. In a multiple signaling system, a common transmission circuit over which a plurality of signals may be simultaneously transmitted, a plurality of terminal lines adapted to transmit signals to said common circuit, means associated with each terminal line whereby it may transmit signals at one frequency and receive at another frequency, the frequencies employed by the several terminal lines being so chosen that all of the frequencies employed by a plurality of terminal lines for transmitting will lie within one range, and all of the frequencies employed by said lines for receiving will lie within another and entirely different range.

10. In a signaling system, a common transmission circuit over which a plurality of signals may be simultaneously transmitted, a plurality of low frequency signaling circuits, a carrier channel for interconnecting each low frequency circuit with said transmission circuit for transmission in one direction, an oppositely directed carrier channel for interconnecting each low frequency circuit with said transmission circuit for transmission in the opposite direction, the frequencies employed by carrier channels transmitting in one direction being in one range, and the frequencies employed by carrier channels transmitting in another direction being in another and entirely different range, whereby it is unnecessary to maintain oppositely directed channels conjugate.

11. In a multiplex signaling system, a transmission circuit, means whereby a plurality of channels of communication may be established over said circuit in each direction, each channel transmitting a band of frequencies of sufficient width to accommodate a desired signal, and the bands transmitted by the channels being so related to each other and so spaced that the bands utilized by all of the channels for transmitting purposes will lie within one range as closely adjacent to each other as will be consistent with non-interference between the bands of that range, and the bands utilized by the channels for receiving will be spaced in substantially the same manner within another range displaced in the frequency spectrum with respect to said first mentioned range.

12. In a multiplex signaling system, a plurality of signaling channels each employing a band of frequencies of sufficient width to accommodate a desired signal, the bands of the channels being so related to each other and so spaced that all the bands used for transmission in one direction will be as closely adjacent to each other as will be consistent with non-interference between

the bands of that range, and all of the bands used for transmission in the opposite direction will be spaced in substantially the same manner within another range displaced in the frequency spectrum with respect to said first mentioned range.

13. In a multiplex signaling system, a common transmission circuit over which a plurality of signals may be simultaneously transmitted, a plurality of terminal lines adapted to transmit signals to said common circuit, means associated with each terminal line whereby it may transmit a band of frequencies, means associated with each terminal line whereby it employs one band of frequencies to transmit signals and a different band of frequencies to receive signals, the bands employed by the several terminal lines being so related to each other and so spaced that all of the bands employed by a plurality of terminal lines for transmitting purposes will lie within one range as closely adjacent to each other as will be consistent with non-interference between the bands of that range, and all of the bands employed by said lines for receiving will be spaced in substantially the same manner within another range displaced in the frequency spectrum with respect to said first mentioned range.

14. In a signaling system, a common transmission circuit over which a plurality of signals may be simultaneously transmitted, a plurality of low frequency signaling circuits, a carrier channel for interconnecting each low frequency circuit with said transmission circuit for transmission in one direction, an oppositely directed carrier channel for interconnecting each low frequency circuit with said transmission circuit for transmission in the opposite direction, the bands of frequencies employed by the carrier channels transmitting in one direction being of such width as to accommodate a desired signal and being so spaced and related to each other that they will lie within one range as closely adjacent to each other as is consistent with non-interference between the channels, and the bands employed by the carrier channels transmitting in the opposite direction being spaced in substantially the same manner and lying within a range which is displaced in the frequency spectrum with respect to said first mentioned range.

15. In a multiplex carrier wave signaling system, a plurality of two-way transmission channels distinguished from one another by the carrier frequencies which they employ, the carrier frequencies of the channels used for transmission in one direction being comprised in an upper range and the carrier frequencies used for transmission in the opposite direction being comprised in an entirely different and lower range, the pairing of the oppositely directed carrier waves of the respective ranges to form the opposite sides of the two-way channels being such that the lowermost carrier frequency of the upper range is paired with the uppermost carrier frequency of the lower range to form one two-way channel, the second lowest carrier frequency of the upper range is paired with the second highest carrier frequency of the lower range to form a second two-way channel, and so on.

16. In a multiplex carrier wave signaling system, a plurality of two-way transmission channels distinguished from one another by the respective carrier frequencies which they employ, the carrier frequencies being included in two separate groups, those used for transmission in one direction being all higher than a definite limiting or group-separation frequency, and those used for transmission in the opposite direction being all lower than said limiting or group-separation frequency, the two carrier frequencies employed for the opposite sides of any given two-way channel being the correspondingly positioned carrier frequencies of said respective groups in the order of frequencies counting from the group-separation frequency.

In testimony whereof, I have signed my name to this specification this 18th day of September 1919.

LLOYD ESPENSCHIED.