Oct. 20, 1925.

1,557,544

H. A. AFFEL

CARRIER FREQUENCY ARRANGEMENT

Filed April 18, 1924

4 Sheets-Sheet 1

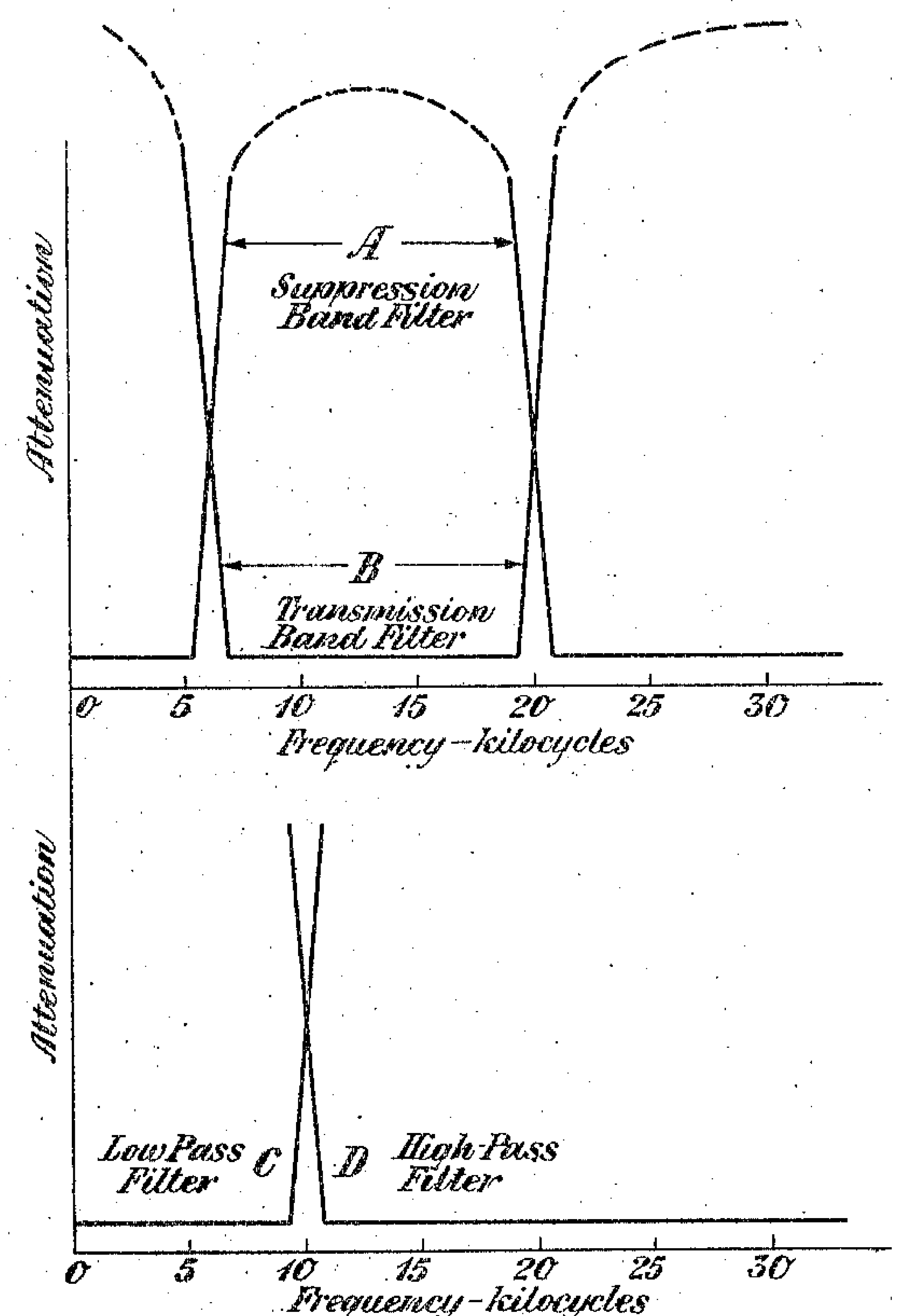

Fig. 1

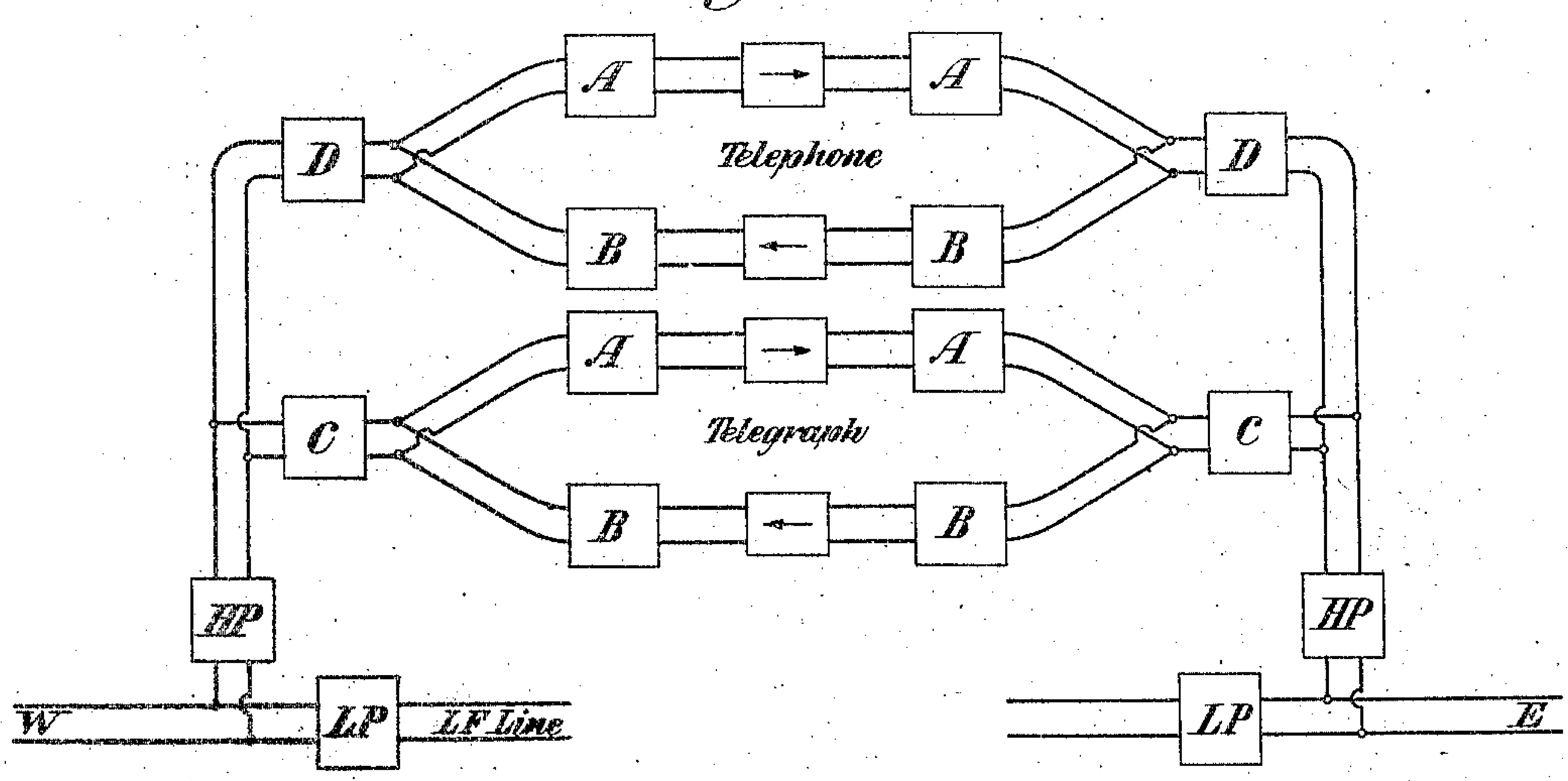

Fig. 4

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CARRIER FREQUENCY ARRANGEMENT

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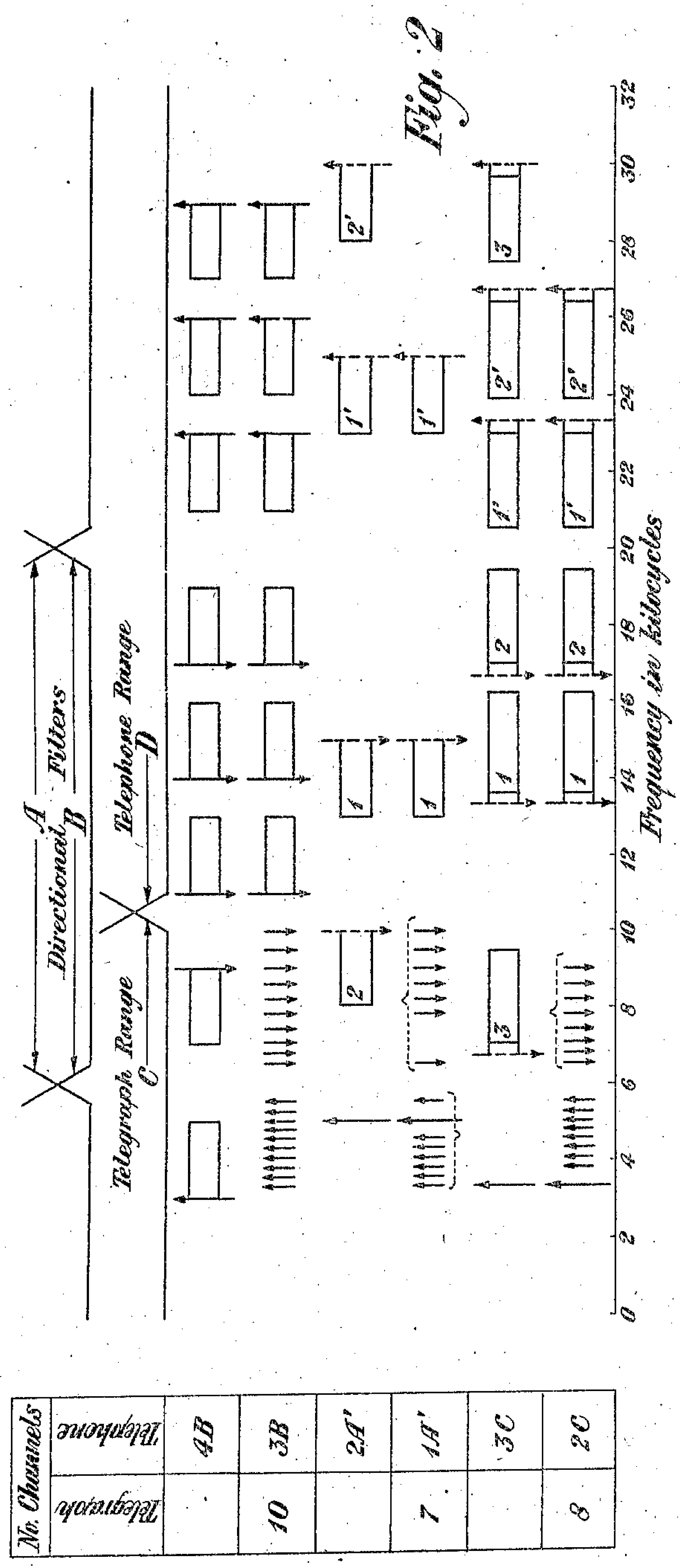

Fig. 2

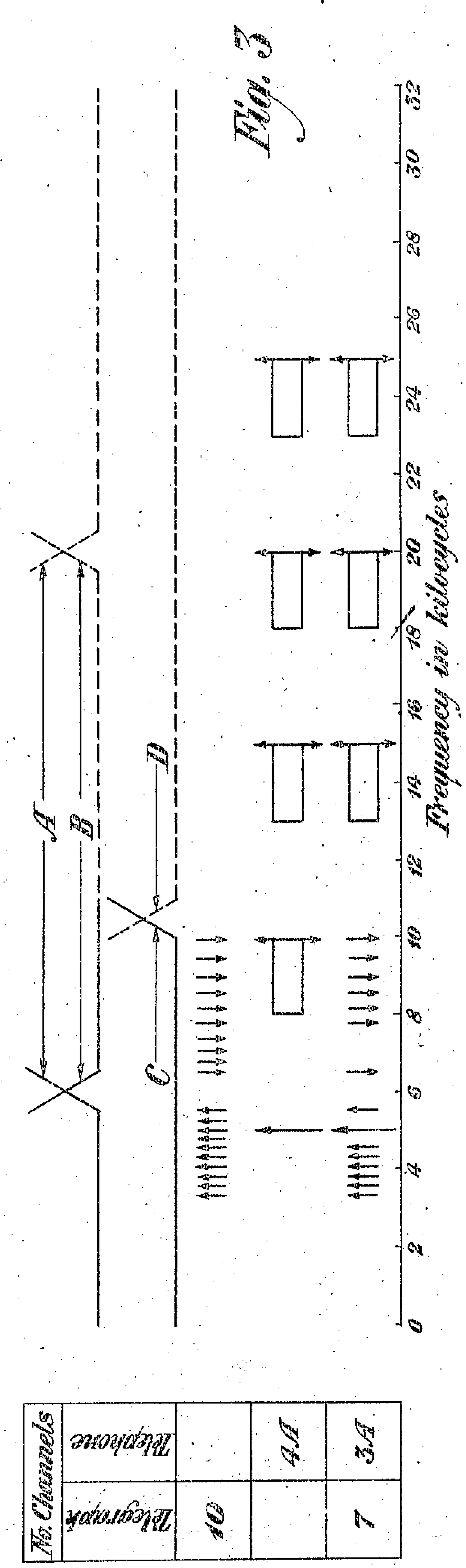

Fig. 3

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CARRIER FREQUENCY ARRANGEMENT

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4 Sheets-Sheet 3

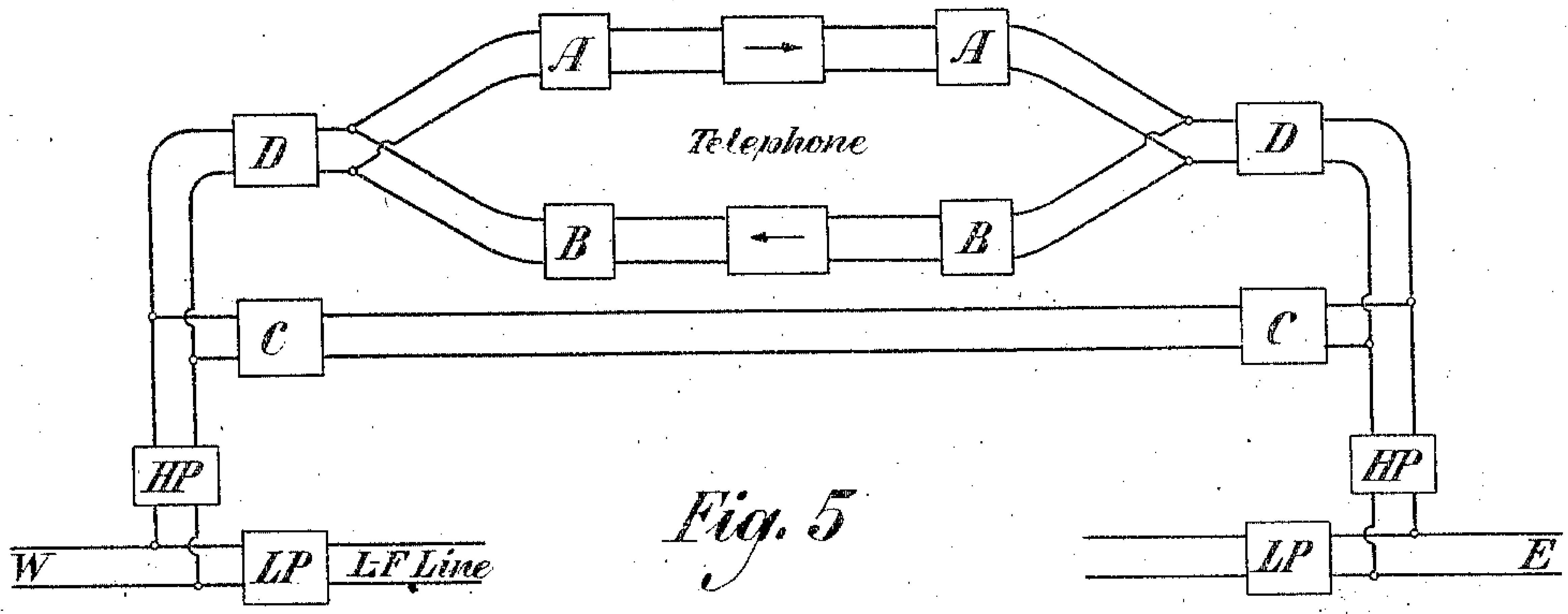

Fig. 5

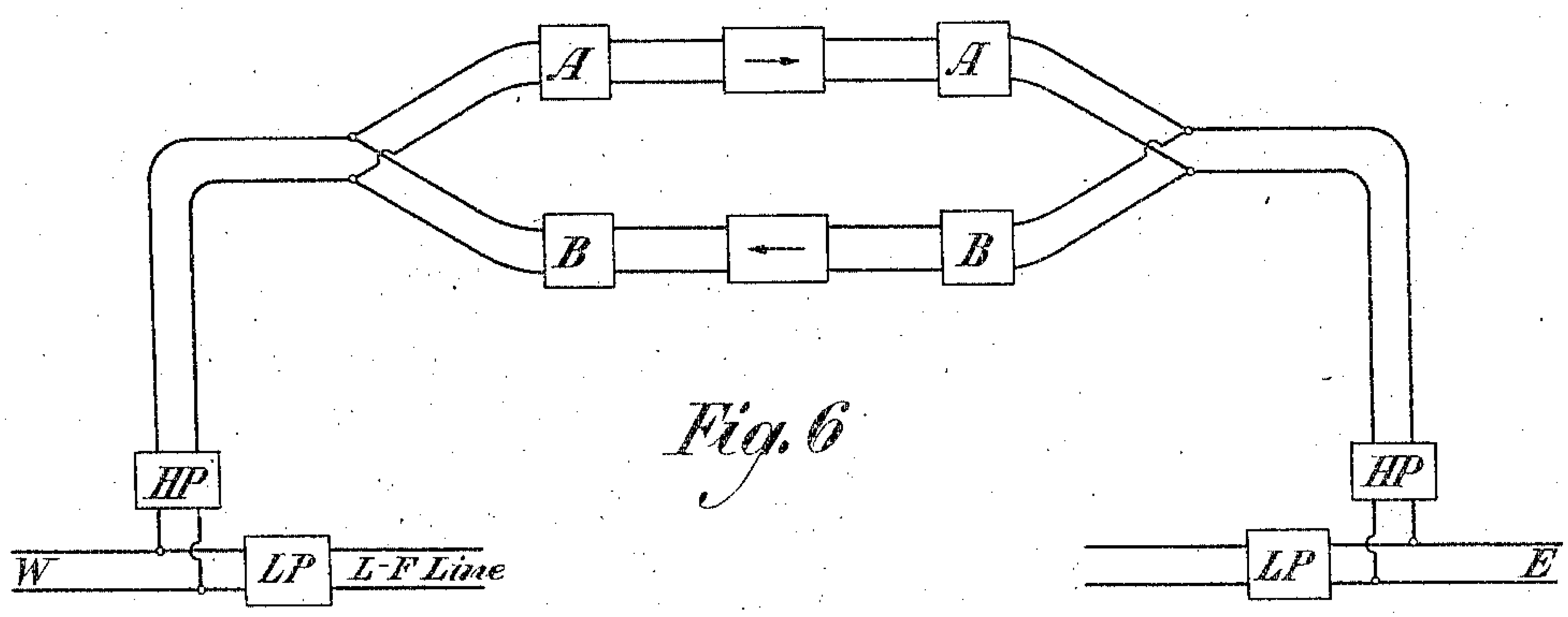

Fig. 6

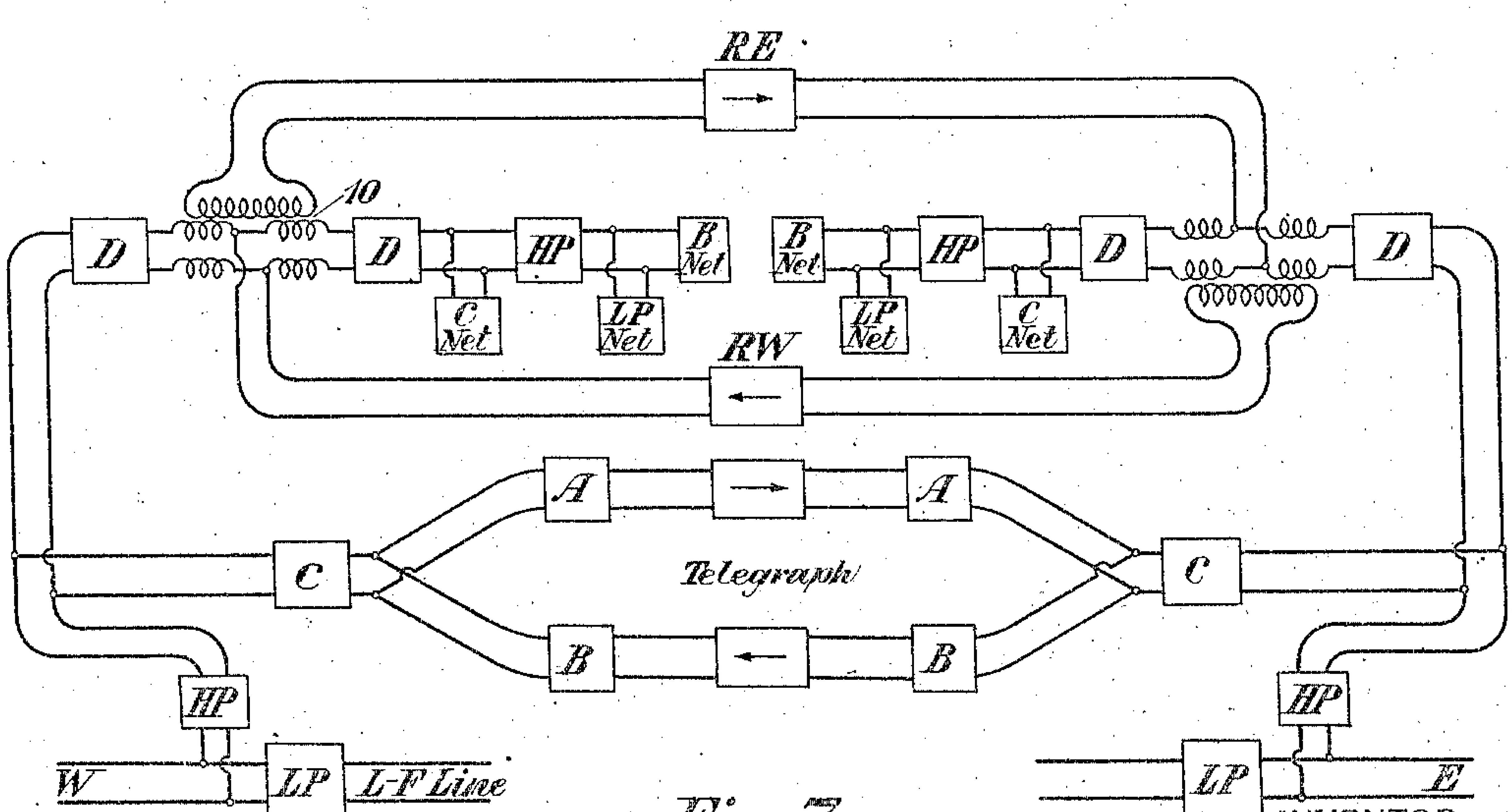

Fig. 7

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CARRIER FREQUENCY ARRANGEMENT

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4 Sheets-Sheet 4

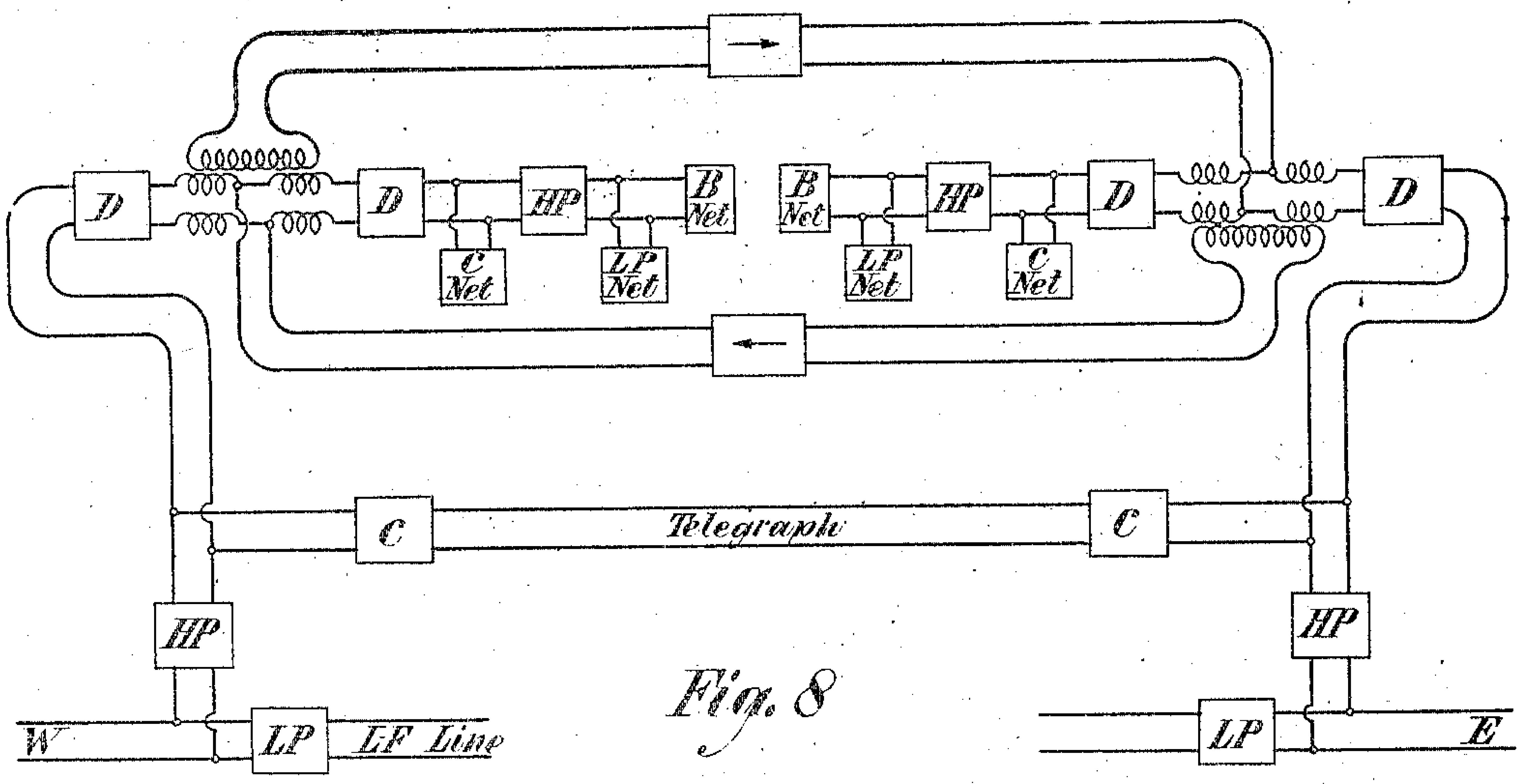

Fig. 8

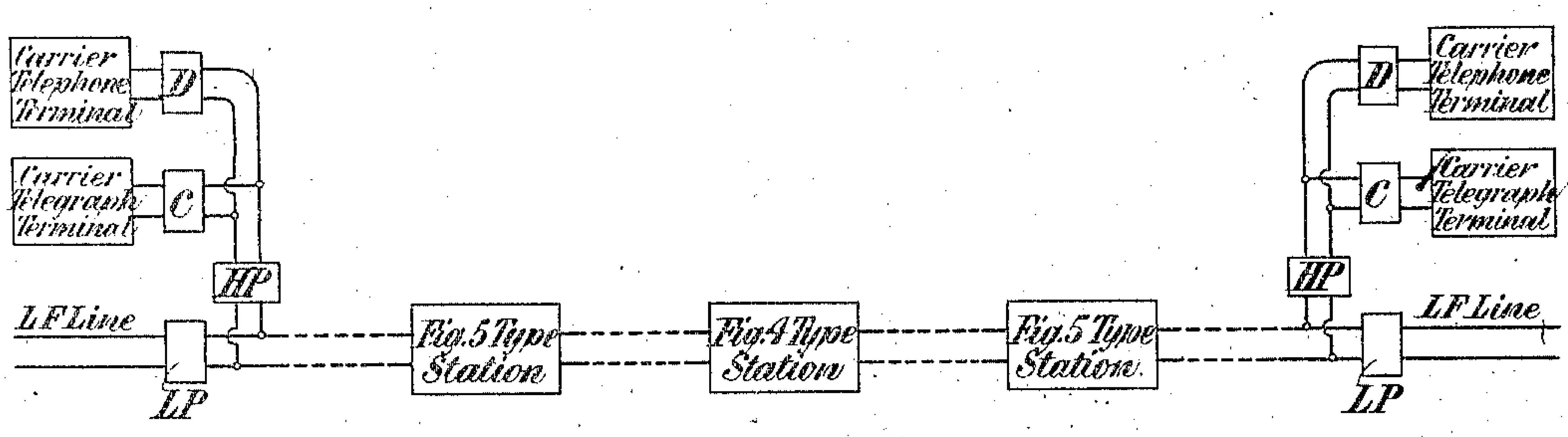

Fig. 9

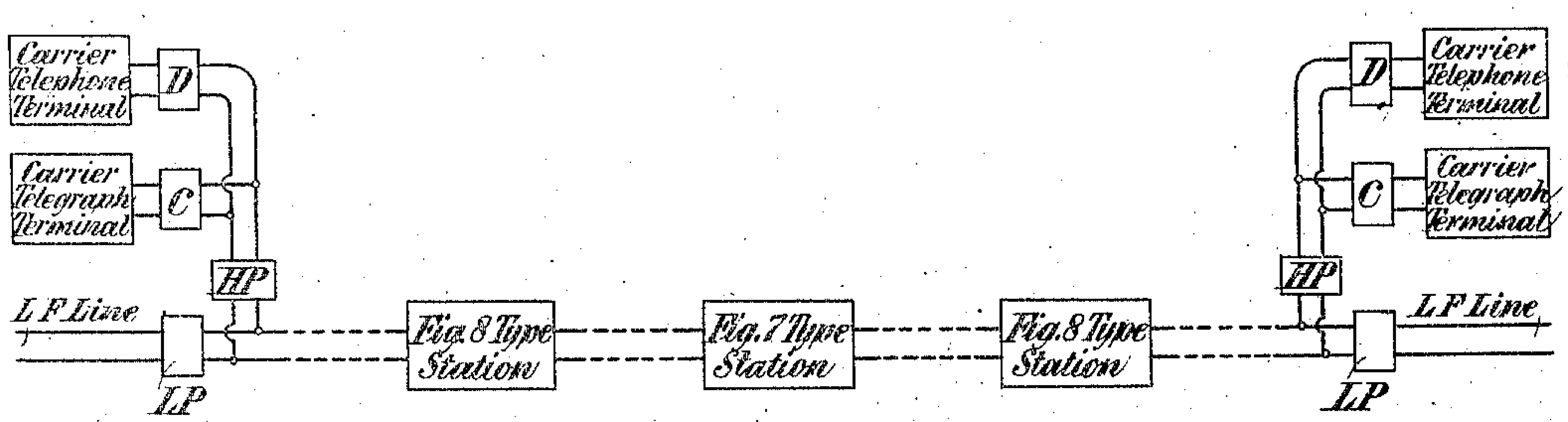

Fig. 10

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Patented Oct. 20, 1925. **1,557,544**

UNITED STATES PATENT OFFICE.

HERMAN A. AFFEL, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

CARRIER FREQUENCY ARRANGEMENT.

Application filed April 18, 1924. Serial No. 707,494.

To all whom it may concern:

Be it known that I, HERMAN A. AFFEL, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Carrier Frequency Arrangements, of which the following is a specification.

This invention relates to multiplex signaling and more particularly to frequency arrangements of the signaling channels in such a system.

Multiplex carrier signaling arrangements, as at present developed for commercial operation, are of four general types:

(1) Multiplex carrier telegraph systems in which a group of carrier frequencies all lying within one range are used for transmitting in one direction while a group of carrier frequencies lying within another range are used for transmitting in the opposite direction. Because of limitations in the design of the apparatus of this type of system it is not expedient to operate with carrier frequencies above about 10 kilocycles.

(2) Multiplex carrier telephone systems in which the carrier and one side band are suppressed at the transmitting station and the carrier is supplied at the receiving station by the homodyne method, the same carrier frequency being employed in connection with each two-way channel for transmission both ways. In systems of this type discrimination between oppositely directed transmissions is obtained by balancing the circuits at the terminals and at repeater points. The carrier frequencies employed in this type of system have been related to each other as harmonics of a fundamental frequency of 5,000 cycles, so that the spacing between successive carrier frequencies is 5,000 cycles. This system will be hereinafter referred to as a type A system.

(3) Multiplex carrier telephone systems in which the carrier is transmitted along with one side band, the other side band being suppressed. In this type of system different frequencies are used for transmission each way for each two-way channel and all of the frequencies transmitted in one direction are grouped in one frequency range and all of the carrier frequencies transmitting in the opposite direction are grouped in another frequency range. No balance is used in this system for discrimination between oppositely directed frequencies, frequency selectivity being relied upon for this purpose. The carrier frequencies are not derived as harmonics of a common fundamental frequency but are spaced from each other about 3,000 cycles, the carrier for each channel being separately generated. Systems of this character will hereinafter be referred to as type B systems.

(4) Multiplex carrier telephone systems in which the carrier frequency and one side band are suppressed at the transmitting station and the carrier supplied at the receiving station by the homodyne method, different carriers being used for transmission in each direction in connection with each two-way channel. As in the type B system no balance is employed, frequency selectivity being relied upon to discriminate between oppositely directed transmissions, the carrier frequencies transmitting in one direction are all grouped in one frequency range and those transmitting in the opposite direction in another frequency range. In this system the carrier frequencies are related to each other as harmonics of a fundamental frequency of about 3,333⅓ cycles and successive carrier frequencies are separated from each other by the same number of cycles. Systems of this character will hereinafter be referred to as type C systems.

It has been found in practice that systems employing balance at the terminals and at repeater points in order to discriminate between oppositely directed transmission are not entirely satisfactory because of the difficulty of balancing over a wide range of frequencies and, consequently, systems in which the carrier frequencies are grouped for transmission in the two different directions are preferred. It is also desirable in order to minimize cross-talk between systems, that where the frequencies are grouped the groups should be the same on all lines of the same pole lead and the same frequency range should be employed on all the lines of the same pole lead for channels transmitting in the same direction. Also the selective arrangements which are employed at terminal and repeater points should be adapted for use in connection with either telephone or telegraph systems. It has also been found that the superposition of telephone and telegraph channels on the same telephone line will frequently be desired and in order to prevent intermodulation between telephone and telegraph signals, separate repeaters should be provided at repeater points for telephone purposes and for telegraph purposes.

It is proposed by the present invention to so divide up the frequency range employed for carrier transmission and to so locate and direct carrier frequencies that the factors above mentioned will be satisfactorily taken care of, consideration being also given to the different spacings employed between the carriers of the type A, type B and type C telephone systems so that selectivity may be provided to best meet the conditions involved in all of these systems.

These results and objects are accomplished in accordance with the present invention by:

(1) Dividing the economical carrier range (which may be assumed to extend from about 3 to 30 kilocycles) into two parts with the dividing point at approximately 10 kilocycles, the lower of these ranges to be considered as the telegraph range and the upper as the telephone range;

(2) Further dividing each of these ranges into two directional groups of channels, one group transmitting east in each range and one group transmitting west in each range;

(3) Operating the upper group of channels of the telegraph range and the lower group of channels of the telephone range in the same direction in order to simplify selectivity at repeater points;

(4) Providing for selective discrimination at repeater points between the three main ranges (two transmitting one way and one the other) by which the east groups are separated from the west groups. The particular selective arrangements employed comprise preferably a transmission band type of filter (that is, a filter which transmits a band freely but suppresses frequencies on either side thereof) in one path of the repeater, and a suppression band filter (that is, a filter which suppresses a band of frequencies and freely transmits all frequencies on either side of the suppressed band) in the other path of the repeater;

(5) Further provision of selective arrangements where necessary at repeater or terminal points for separation between the telephone and telegraph ranges, these selective arrangements comprising preferably a low pass filter for selecting the telegraph range and a high pass filter for selecting the telephone range.

It will be noted that the combination, consisting of a suppression band filter and a transmission band filter, segregates the channels transmitting in different directions into their proper groups. These filters may be made up as a part of a repeater unit, and a repeater unit as thus made up may be used for amplifying either telephone channels or telegraph channels or both. If a given repeater is to be employed for amplifying the telegraph channels only, a low-pass filter will be arranged at the repeater point to select to the repeater only the telegraph channels, which in turn will be separated by the combination of suppression band and transmission band filters in accordance with the direction of transmission. If the repeater, on the other hand, is to amplify the telephone channels only, a high pass filter will be used in connection with it to confine the operation of the repeater to the telephone range, the suppression band filter and transmission band filter separating the channels as to direction. Where the repeater is to amplify both telephone and telegraph channels, high and low pass filters will not be used.

The invention may now be further understood from the following detailed description when read in connection with the accompanying drawings, Figure 1 of which is a curve diagram showing the transmission characteristics of the filter combinations employed in connection with the invention; Figs. 2 and 3 are charts showing the disposition of the channels of different types of multiplex systems in accordance with the invention; Figs. 4 to 8 inclusive are schematic diagrams showing the selective arrangements at different types of repeater stations; while Figs. 9 and 10 are schematic diagrams showing how different types of repeater stations may be employed in the same transmission circuits at different repeater points.

Referring to Fig. 1, the curves show the transmission characteristics of filter combinations which may be employed in connection with the present invention. As has been previously stated, it is proposed to divide the total carrier range into two parts, one to be used for telegraph purposes and the other for telephone purposes, the individual channels in the two parts being grouped in separate ranges in accordance with the direction of transmission, and finally the upper group of the telegraph range and the lower group of the telephone range being arranged to transmit in the same direction. This divides the available carrier range into three main bands, two of which transmit in one direction and the intermediate one of which transmits in the other direction. In order to separate the total carrier range into these three main bands, it is proposed to use two filters, one of which will be hereinafter referred to as an A type of filter, and the other of which will be referred to as a B type of filter. The A type of filter is a suppression filter, that is, a filter which suppresses a band of given width while freely transmitting a range of frequencies from zero up to the lower limit of the suppression band and also a range from the upper limit of the suppressed band to infinity. By means of this filter all of the channels transmitting in one direction may be selected while the channels transmitted in the opposite direction will be suppressed.

The second type of filter, which will be hereinafter referred to as a B type of filter, is of the kind known as a transmission band filter, that is, a filter which freely transmits a definite band of frequencies while suppressing all frequencies from zero up to the lower limit of the band and all frequencies from the upper limit of the band to infinity. The B type of filter may therefore be used to select the upper group of telegraph channels and the lower group of telephone channels while suppressing the other channels, it being recalled that the upper group of telegraph channels and lower group of telephone channels are arranged to transmit in the same direction. As shown in the diagram, the A and B types of filters may be arranged to divide the available carrier range into three main subbands at frequencies corresponding to about 6 kilocycles and 20 kilocycles.

In order to select or discriminate between the telephone part of the carrier range and the telegraph part of the carrier range, a low pass filter, hereinafter referred to as a C type filter, and a high pass filter hereinafter referred to as a D type of filter, may be employed. These two filters may have their cut-off points so arranged as to divide the total carrier range into two parts at a frequency corresponding to about 10 kilocycles, as illustrated in the drawing.

If the C type of filter is used in combination with the A and B filters, the C filter confines the range of free transmission to the telegraph part of the range, while the A and B filters divide this part of the frequency range into two parts in accordance with the direction of transmission. On the other hand, if the D type filter is used in combination with the A and B type filters, free transmission is restricted to the telephone part of the carrier range, and the A and B filters divide this part of the range into two sub-ranges in accordance with the direction of transmission. If all four filters are employed, the total carrier range is divided into four parts, two of which transmit in one direction and the other two of which transmit in the opposite direction.

With this understanding of how the carrier range is to be divided up in accordance with the invention, the manner in which the channels may be allocated in accordance with different types of carrier systems will be clear from Fig. 2. In this figure the free transmission bands of the filters and their cut-off points are represented by the full line curves at the top of the figure. The frequency in kilocycles from zero to 34 is plotted as ordinates. Carrier frequencies for telephone channels, where transmitted, are shown in long full line arrows. Where the carrier frequencies are suppressed, they are represented by dotted arrows. The carriers for the telegraph channels are represented by short arrows. The side bands of the telephone channels are represented by rectangles. The arrangements for several different combinations are shown in Fig. 2, the type of the system and the number of the channels being designated in the vertical column at the left of the figure. The arrangement of the frequencies for each system are shown in the horizontal columns of the chart.

The lower horizontal column shows an arrangement involving eight two-way telegraph channels and two two-way type C telephone carrier channels. The general scheme of dividing the frequency range already described provides a maximum of about ten two-way telegraph channels. The ten channels transmitting in each direction may, for example, have the frequencies represented in the following table:

Channel No.	Freq.		Channel No.	Freq.	
10	10000	Transmits to south or west	1	5500	Transmits to north or east
9	9500		2	5250	
8	9030		3	5010	
7	8590		4	4770	
6	8180		5	4530	
5	7800		6	4290	
4	7440		7	4050	
3	7110		8	3810	
2	6800		9	3570	
1	6500		10	3330	

Since the type C telephone system involves the generation and transmisison of a fundamental carrier frequency which is not used for signaling but is transmitted in order that the actual carrier frequencies used for signaling may be obtained as harmonics of the fundamental, it is necessary to omit the two lowest frequencies used for telegraph purposes, as the lower frequency, $3\frac{1}{3}$ kilocycles corresponds with the fundamental carrier frequency from which the harmonics are obtained, and the next one above 3,570 cycles is so near to the frequency assigned for the fundamental that some of the telegraph modulations might be transmitted in the channel assigned to the fundamental. Since telegraph channels 9 and 10 of the lower group are therefore eliminated because of the necessity of utilizing the range corresponding to these channels at the bottom of the available carrier spectrum, the corresponding frequencies of channels 9 and 10 at the top of the telegraph range will also be eliminated, these frequencies being $9\frac{1}{2}$ and 10 kilocycles.

Two two-way telephone channels are provided involving carrier frequencies of 13⅓, 16⅔, 23⅓ and 26⅔ kilocycles. The first two of these carriers correspond to channels transmitting west and the last two to channels transmitting east. In this system the carrier frequencies are suppressed as indicated by the dotted arrows and one side band of each channel is also depressed. In the case of the channels transmitting west, the upper side bands are transmitted, and in the case of the channels transmitting east the lower side bands are transmitted.

This arrangement wastes a certain amount of space between the upper telegraph channel and the lower telephone channel. There is also room for a one-way telephone channel at the upper part of the telephone range. Inasmuch as the carrier is not transmitted, it would be possible to squeeze in an additional two-way channel (if the cut-off of the filters is made fairly sharp) by transmitting the lower side band instead of the upper with telephone channels 1 and 2. The channel transmitting west for the third two-way channel might then have a carrier of 20 kilocycles assigned to it, the corresponding transmitted lower side band occupying substantially the range now shown for the upper side band of channel No. 2. The corresponding east channel of the third two-way channel would have the carrier frequency of 30 kilocycles assigned to it, and the lower side band would be transmitted. To permit of the provision of the additional two-way telephone channel would, of course, involve very accurate design of the filtering arrangements.

If desired, the telegraph channels may all be omitted, and a third two-way channel may be provided by using the upper part of the telegraph range for the channel transmitting west on a carrier frequency of 6⅔ kilocycles, the upper side band being transmitted, and the corresponding eastbound channel having assigned hereto the carrier frequency of 30 kilocycles. In this case a fourth two-way channel may be provided where the filters are carefully designed by transmitting the lower side bands in connection with the west channels 1 and 2 and providing two additional carrier frequencies at 20 kilocycles and 33⅓ kilocycles in connection with which the lower side bands are transmitted.

The third horizontal column shows an arrangement involving seven two-way telegraph channels and one modified type A two-way telephone channel. The type A system involves the transmission of a frequency of 5,000 cycles as the fundamental from which the telephone carriers are obtained as harmonics. This involves the elimination of the frequencies corresponding to the eastbound telegraph channels 2, 3 and 4. Consequently the corresponding frequencies of the upper telegraph range are also omitted.

In connection with the telephone part of the range, since it is divided up by the filtering arrangement into two ranges only capable of transmission in a single direction it is necessary to modify the type A system so that the corresponding channels of a given two-way transmission employ different carrier frequencies. Accordingly, one two-way telephone channel is provided by utilizing a carrier frequency of 15 kilocycles transmitting west and a carrier frequency of 25 kilocycles transmitting east. As the carrier frequencies in the type A system are all harmonics of 5 kilocycles, and the side bands are closely spaced to the carrier, the type A system is obviously not very economical where the available range is divided up as herein shown, for no channel involving carrier frequency of 20 kilocycles can be obtained. A second two-way telephone channel may be obtained, however, as indicated in the fourth horizontal column where no telegraph channels are provided. In this case the eastbound channel of the second pair will utilize the carrier frequency of 10 kilocycles and the corresponding channel in the opposite direction will utilize the carrier frequency of 30 kilocycles.

In the fifth horizontal column is shown a combination involving ten two-way telegraph channels and three two-way type B telephone channels. The three telephone channels transmitting west will have assigned to them the carrier frequencies of 11, 14 and 17 kilocycles while the eastbound channels will have carrier frequencies of 23 26 and 29 kilocycles respectively. In this system the carrier is transmitted in connection with each channel, and, as shown, the upper side bands are transmitted in connection with the westbound channels and the lower sidebands in connection with the eastbound channels. It will be observed that the available frequency range is practically all utilized by this arrangement.

If desired, an additional pair of telephone channels constituting an additional two-way telephone circuit may be provided as indicated in the sixth horizontal column by utilizing the space assigned to the telegraph channels. In this case a carrier frequency of 3,000 cycles will be used for the additional eastbound channel and a carrier frequency of 9,000 cycles will be used for the additional westbound channel.

Fig. 4 illustrates in schematic form an arrangement of repeaters which may be employed at a repeater station where both telephone and telegraph channels are provided. It will be noted that the carrier channels are selected from the ordinary telephone transmission by means of a high pass filter designated HP in the drawing, so that all of the carrier channels may be amplified without disturbing in any way the ordinary telephone part of the system. For carrier amplification it will be noted that two repeater units are provided, one for amplifying the telephone channels and the other for amplifying the telegraph channels. Each of these sets consists of two paths, each path including a one-way amplifier, and an A type filter in the one path and a B type filter in the other path on either side of the amplifier. The two sets are identical and consequently the repeater units may be made up with the A and B filters for use either for telephone purposes or telegraph purposes. C type filters are interposed on either side of the telegraph repeater unit and D type filters on either side of the telephone repeater units. The C type filters select the telegraph part of the range from the telephone part and transmit the corresponding channels to the telegraph repeater. The A and B type filters in the repeater then function to divide the east bound channels from the westbound channels at the point of separation, which, in the cases illustrated, corresponds to 6 kilocycles. Consequently the eastbound channels are amplified by the amplifier of the one path while the westbound channels are amplified by the amplifier of the other path. No balancing arrangements are necessary at the repeater point.

Inasmuch as the telephone part of the range involves higher frequencies than the telegraph part, it may be necessary to provide additional repeater stations at which only the telephone channels will be amplified, and no repeater will be provided at such stations for amplifying the telegraph frequencies. Such an arrangement is illustrated in Fig. 5 in which the telephone repeater unit is identical with that illustrated in Fig. 4 and the filter arrangement is the same. The telegraph channels, however, are by-passed around the repeater through the C type filters with no repeating unit included in the by-pass. The schematic layout shown in Fig. 9 will indicate a typical circuit arrangement involving the two types of repeaters. As shown at the terminal stations, the carrier frequencies are all taken off through the usual high pass filter HP, and C and D type filters are provided to separate the carrier telegraph channels from the carrier telephone channels so that the two types of circuits may be treated at the terminal separately. The first repeater station nearest the terminal would, in general, be a repeater station of the type shown in Fig. 5, as the telegraph channels would not be attenuated as much as the telephone channels at this point. At the next station repeater apparatus of the type shown in Fig. 4 might be employed for amplifying both the telephone and the telegraph channels. The third station again might be of the type shown in Fig. 5 in which only the telephone channels are amplified.

Where the entire range is used for telephone purposes, or, on the other hand, where no telephone channels at all are provided but only telegraph range is used for telegraph purposes, a repeater of the type shown in Fig. 6 may be employed. Here no C and D filters are necessary, but all of the channels in the three main ranges are passed to the repeater through the high pass filters HP, and in the repeater the ranges are separated by the A and B filters in accordance with the direction of transmission.

As has already been observed, the type A system is not well adapted to the general scheme of dividing up the frequency range as already described, and where type A systems are to be provided a slight modification should be made as illustrated by the chart in Fig. 3. This modification involves segregating the telegraph range from the telephone range by means of C and D filters and only providing A and B filters in connection with the telegraph part of the range, so that the telephone part of the range may be employed for transmission in either direction. This is indicated in Fig. 3 by the dotted line portions of the characteristics of the A and B filters which are supposed to represent portions of the frequency spectrum in which the A and B filters are ineffective because their action is confined to a range previously selected by the C type filter.

Referring to the lower horizontal column of Fig. 3, an arrangement is shown involving seven carrier telegraph channels and three type A telephone channels. The telephone channels are all confined to the telephone part of the carrier range and have assigned to them carrier frequencies of 15, 20 and 25 kilocycles. Owing to the fact that the frequency of 5,000 cycles is used for the fundamental from which the telephone carriers are generated, the three nearest telegraph channels are omitted so that only seven channels remain. It will readily be seen that at any point where it is necessary to separate the telephone and telegraph parts of the total carrier range the telegraph frequencies may be selected into an appropriate circuit by a C filter and the telephone frequencies into another appropriate circuit by a D filter. If in the former circuit A and B filters are employed, the action of the A and B filters will merely be to separate the groups of channels transmitting in opposite directions without producing any similar separation in the telephone part of the range. Consequently it is possible to use the same carrier for transmission both ways in the telephone part of the range, and at repeater points appropriate types of repeaters may be employed for telephone purposes as will be described later.

If, instead of using the telegraph part of the range for telegraph purposes, it is desired to employ this portion of the spectrum for an additional two-way telephone channel, the C and D filters may be omitted as well as the A and B filters in which case the arrangement will be as indicated in the second horizontal column of Fig. 3. This gives four type A systems of the ordinary type with the channels arranged exactly as in type A systems of the prior art. If, on the other hand, it is desired to use the circuit only for telegraph purposes, the C and D filters may be omitted and only the A and B filters used, the latter filters in this case separating the channels transmitting in opposite directions as before. This will give ten complete telegraph channels as indicated in the third horizontal column of Fig. 3.

A repeater arrangement suitable for use in connection with a system such as is laid out in the lower horizontal column of Fig. 3 is illustrated in Fig. 7. It will be noted that the telegraph repeater is identical with the telegraph repeater of Fig. 4. The C filter functions to select into the telegraph repeater circuit the frequencies lying in the telegraph range only, and the A and B filters in the repeater circuit itself then discriminate between oppositely directed channels within the range selected by the filter C.

The telephone repeater is of the two-way two-repeater type as indicated at RE and RW. Since the same carrier is used for transmitting in both directions, oppositely directed channels cannot be separated by frequency discrimination, but balance must be employed. The D filters at the terminals of the repeater serve to select and transmit to the repeater frequencies lying within the telephone carrier range only, and these frequencies may be in either direction.

The balancing arrangement is somewhat complicated but may be readily understood. On the artificial line side of the circuit beyond the terminals of the hybrid coil 10, for example, a D filter is provided to balance the D filter on the line side of the circuit. Beyond the D filter the network is branched, and one branch includes a C network to simulate the impedance of the C filter in the telegraph repeater branch while the other branch of the net includes a high pass filter to balance the high pass filter HP of the high frequency composite set. Beyond the high pass filter HP in the network two branches are provided, one including a low pass network having an impedance equivalent to the low pass filter LP of the high frequency composite set. The other branch designated in the drawing as the B network simulates the impedance of the line section itself.

As already discussed in connection with Figs. 4 and 5, some repeater installations need make no provision for amplifying the frequencies in the carrier telegraph range. At such stations the circuit arrangement may be as indicated in Fig. 8. This figure differs from Fig. 7 in that the telegraph repeater is omitted and the telegraph channels are transmitted directly through a by-pass including C type filters. The telephone part of the repeater installation is identical with that in Fig. 7.

Fig. 10 shows schematically a typical system employing repeaters of the type shown in Fig. 7 and also of the type shown in Fig. 8. As the principles of the layout of Fig. 10 are similar to those of Fig. 9, no further description thereof is deemed necessary.

In the foregoing description reference has been made to certain definite frequencies for the purpose of giving concrete examples. It will be understood, however, that the principles of the invention are independent of the particular frequencies and frequency ranges hereinbefore referred to. It will also be understood 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. A selective arrangement to be employed in connection with a multiplex carrier system in which the carrier range is divided into two subranges, each of which is split into two directional groups of channels transmitting in opposite directions of which the adjacent groups of the two subranges are operated in the same direction, comprising a low pass filter for selecting the lower subrange into one path, a high pass filter for selecting the upper subrange into another path, means in said first path comprising a combination of a band suppression filter and a band transmission filter for discriminating between the two oppositely directed groups of the subrange selected, and means in the other path comprising a combination of a band suppression filter and a band transmission filter identical with the filters in the first mentioned path for discriminating between the oppositely directed groups of the subrange selected into the path.

2. A selective arrangement to be employed in connection with a multiplex carrier system in which the carrier range is divided into two subranges, each of which is split into two directional groups of channels transmitting in opposite directions of which the adjacent groups of the two subranges are operated in the same direction,

comprising a low pass filter to select the lower subrange in the one path, a high pass filter to select the higher subrange into another path, means in said first mentioned path to discriminate between oppositely directed groups, said means comprising a combination of a band suppression filter and a band transmission filter, the band suppressed by the suppression filter being coincident with the band transmitted by the band transmission filter, and means in the said second mentioned path for discriminating between oppositely directed groups, said means comprising a combination consisting of a band suppression filter and a band transmission filter identical with the corresponding filters in said first mentioned path.

3. In a multiplex carrier system in which the available carrier range is divided into two subranges and one, at least, of the subranges is further split into two directional groups of channels each group transmitting in opposite directions, a selecting arrangement comprising a high pass filter for selecting one subrange into one path, a low pass filter for selecting the other subrange into another path, and means in one of said paths for discriminating between the oppositely directed groups of channels. said means comprising a combination of a band suppression filter and a band transmission filter, the band suppressed by the suppression filter being coincident with the band transmitted by the transmission filter.

4. In a carrier system in which the available carrier range is divided into two subranges each of which is split into two directional groups of channels transmitting in opposite directions of which the adjacent groups of both subranges are operated in the same direction, a repeater station comprising separate two-repeater combinations for amplifying the two subranges, the two-repeater arrangements being identical in construction and each comprising two oppositely directed paths, one of which includes a band suppression filter and the other of which includes a band transmission filter for discriminating between oppositely directed groups transmitted through the repeater, and a high pass filter in circuit with one repeater and a low pass filter in circuit with the other repeater to select one subrange into one repeater and the other subrange into the other.

5. In a carrier system in which the available carrier range is divided into two subranges each of which is split into two directional groups of channels transmitting in opposite directions of which adjacent groups of both subranges are operated in the same direction, a repeater station comprising separate two-repeater combinations for amplifying the two subranges, the two-repeater arrangements being identical in construction and each comprising two oppositely directed paths, one of which includes a band suppression filter and the other of which includes a band transmission filter for discriminating between oppositely directed groups transmitted through the repeater, the band suppressed by the suppression filter and the band transmitted by the transmission filter being identical, and a high pass filter in circuit with one repeater and a low pass filter in circuit with the other repeater to select one subrange into one repeater and the other subrange into the other.

In testimony whereof, I have signed my name to this specification this 17th day of April 1924.

HERMAN A. AFFEL.