

Aug. 18, 1925.

1,549,849

H. A. AFFEL

VOICE FREQUENCY CARRIER TELEGRAPH

Filed Nov. 14, 1922

3 Sheets-Sheet 1

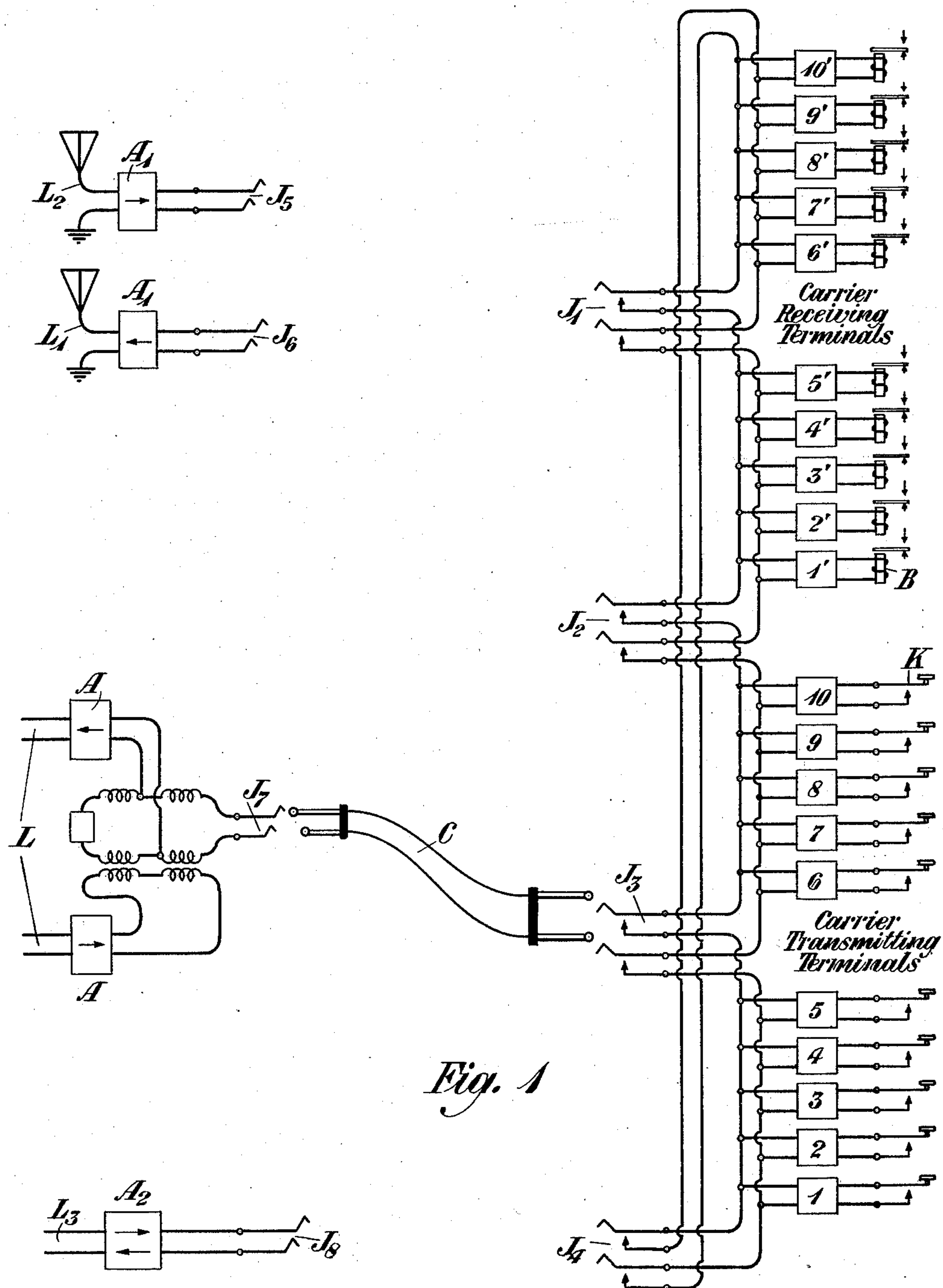


Fig. 1

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3 Sheets-Sheet 2

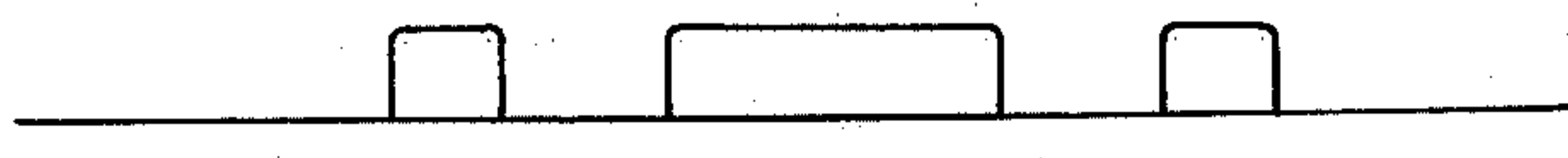
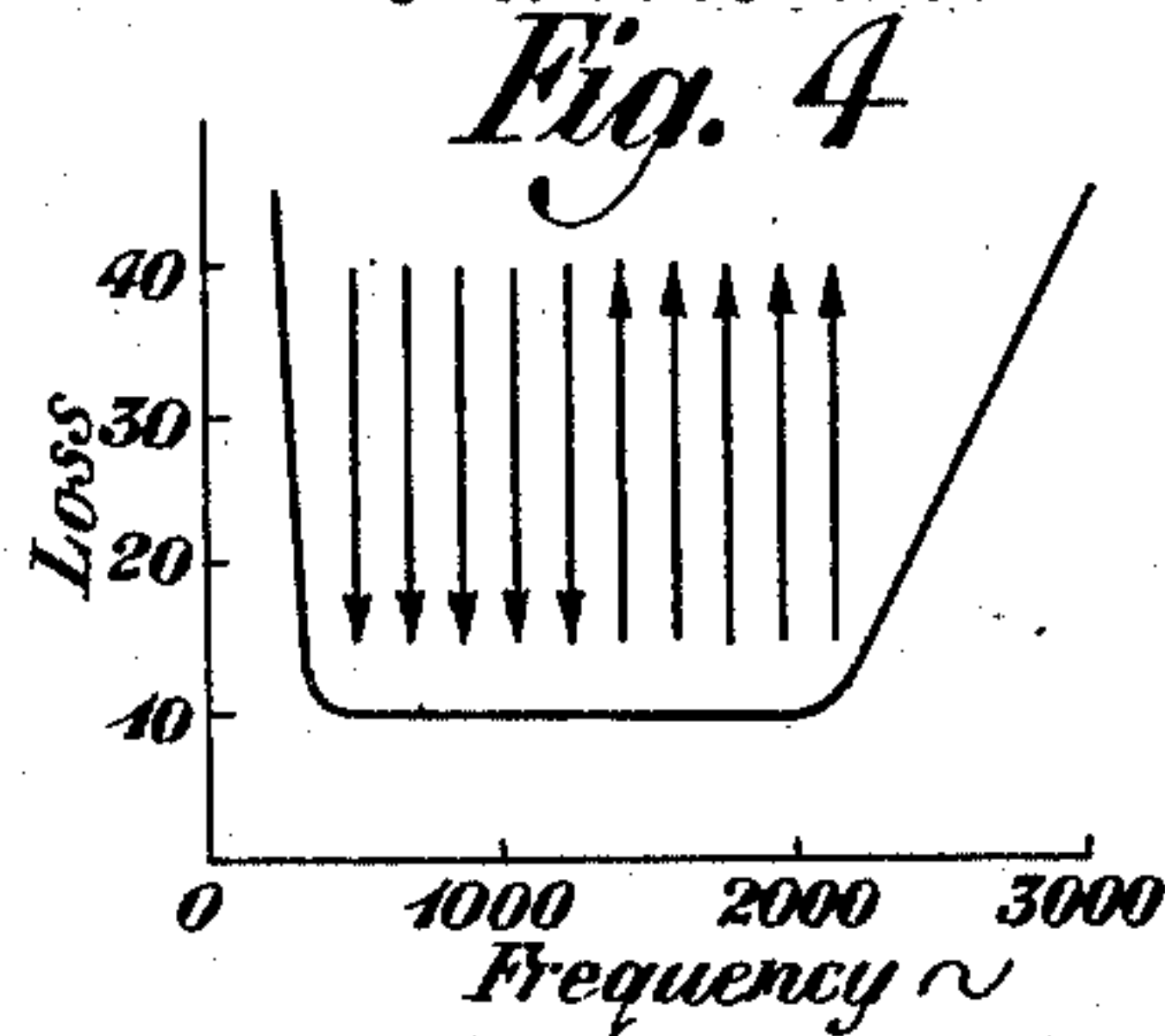
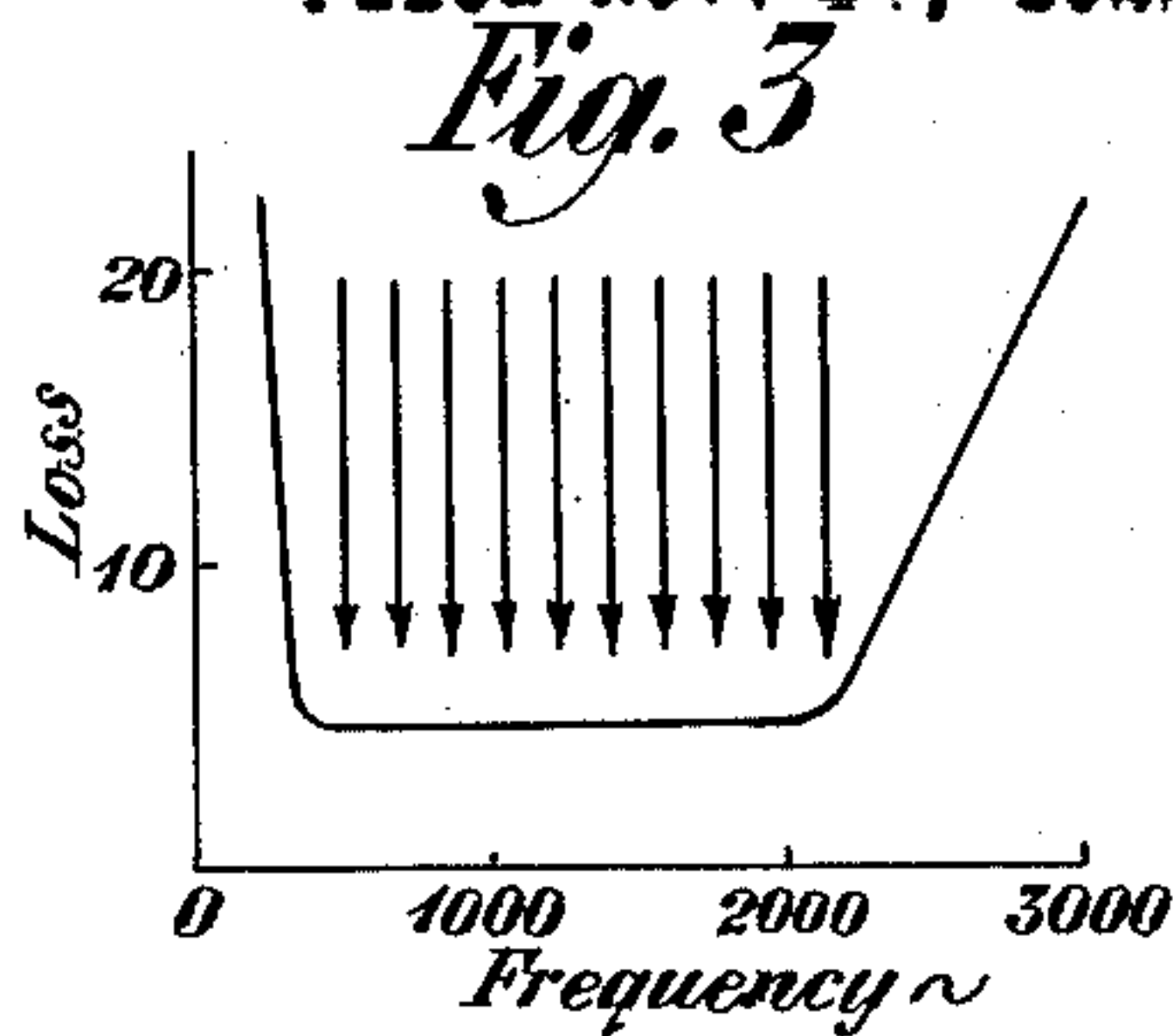
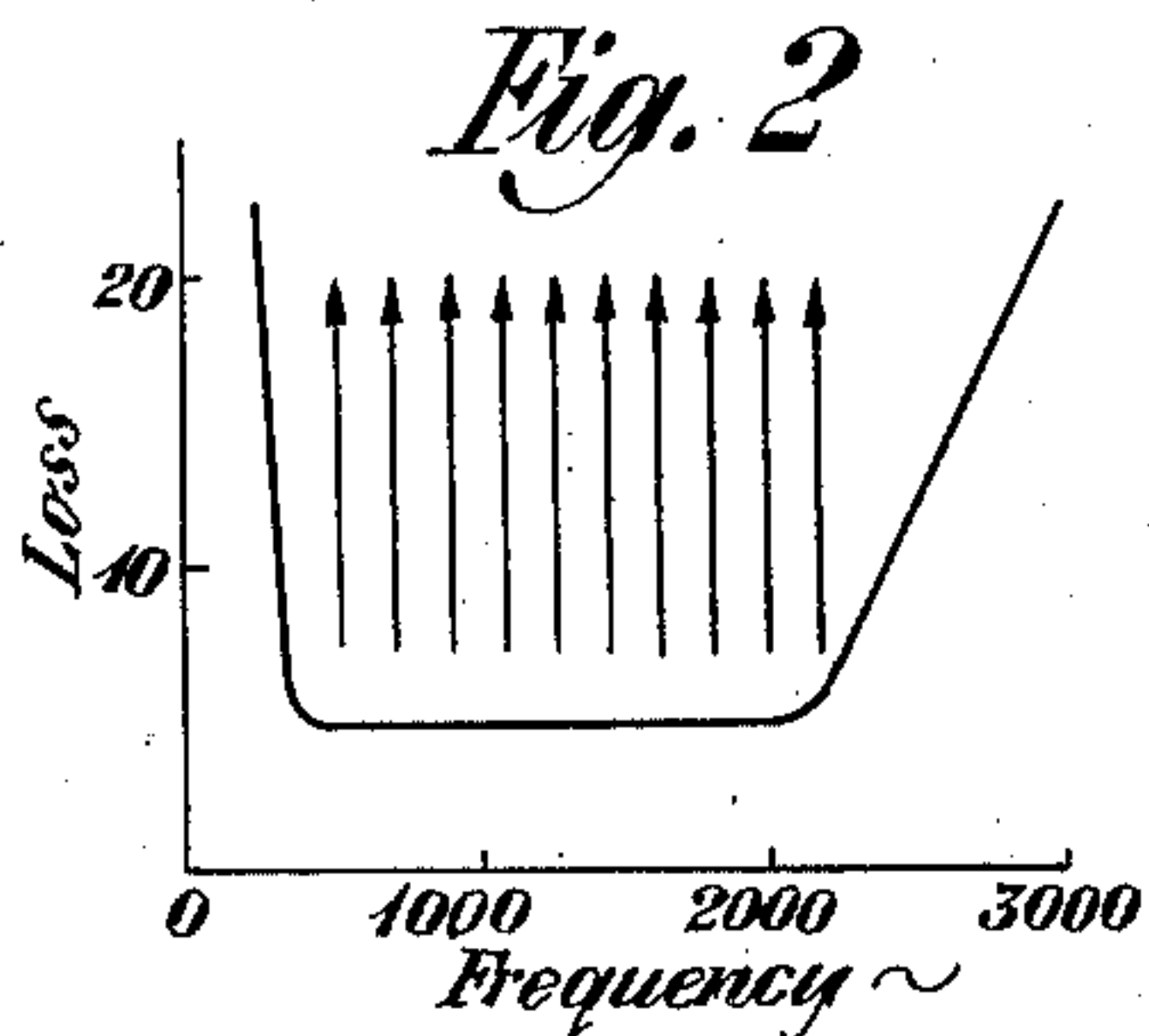


Fig. 5

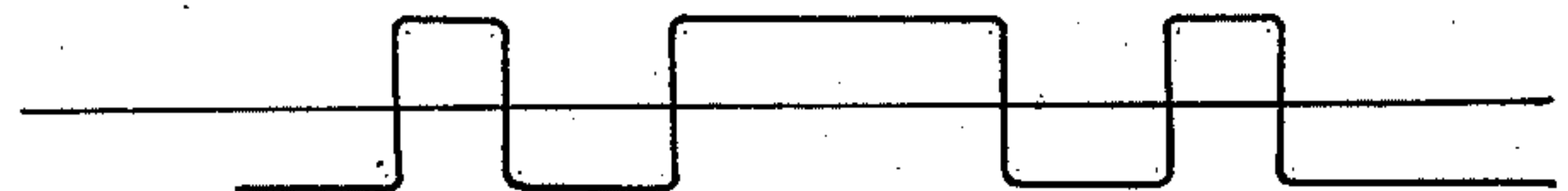


Fig. 6

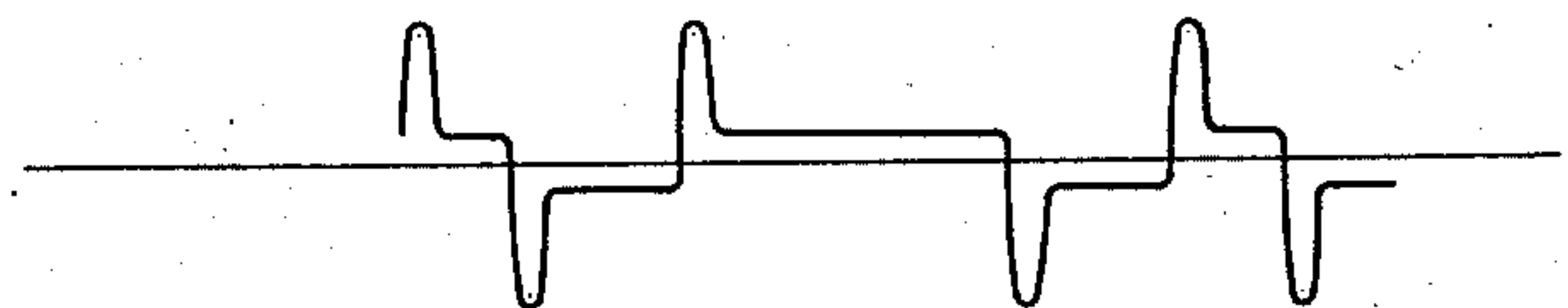


Fig. 7

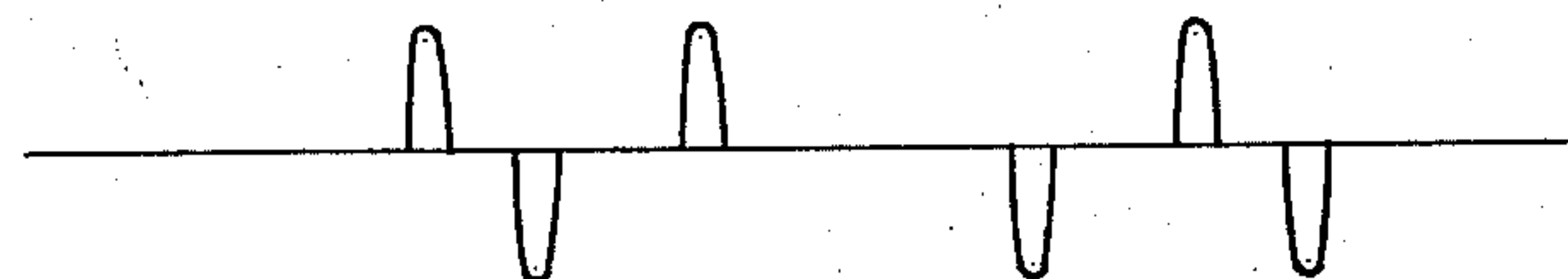


Fig. 8

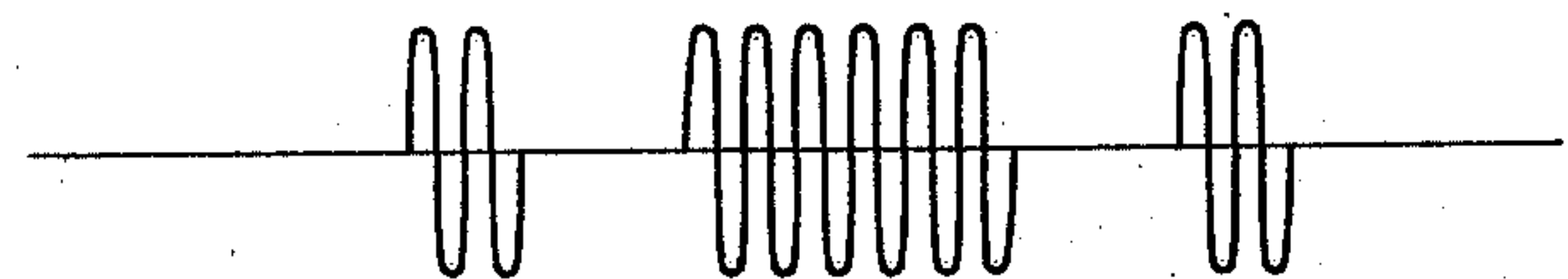


Fig. 9

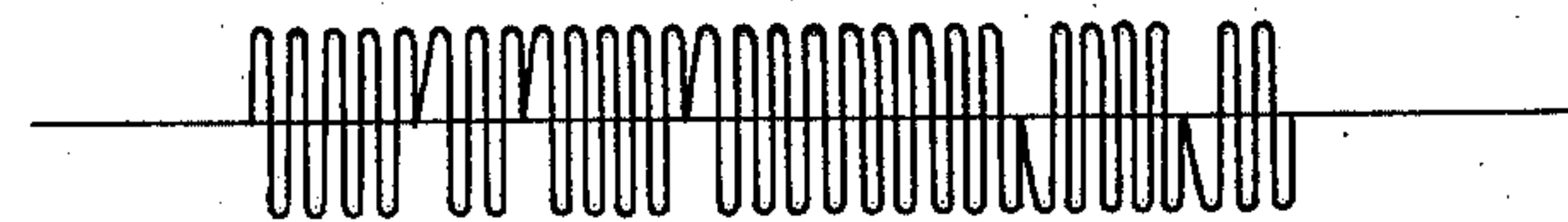


Fig. 10

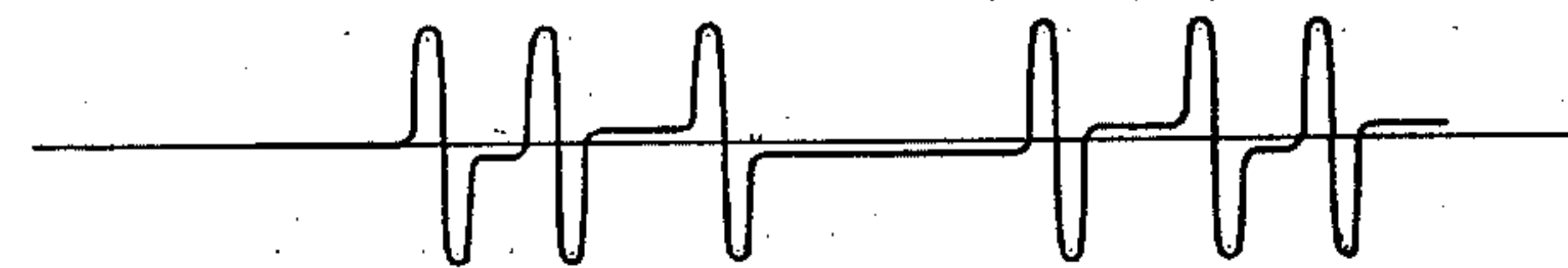


Fig. 11

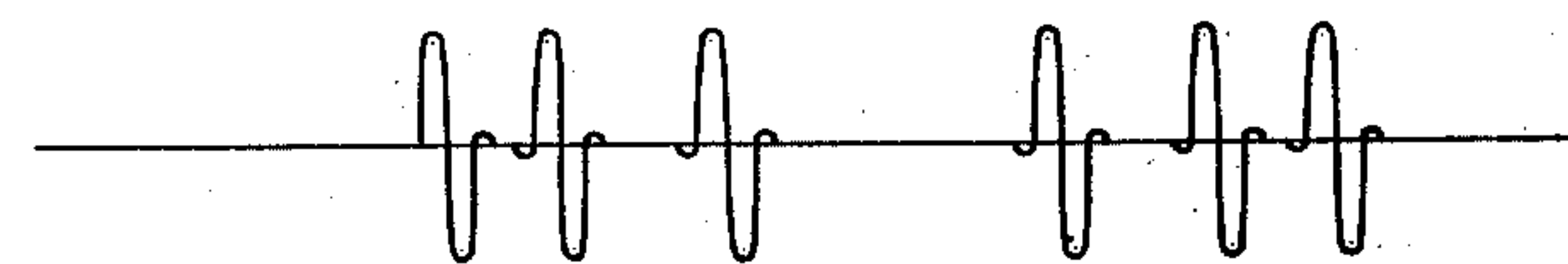


Fig. 12

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3 Sheets-Sheet 3

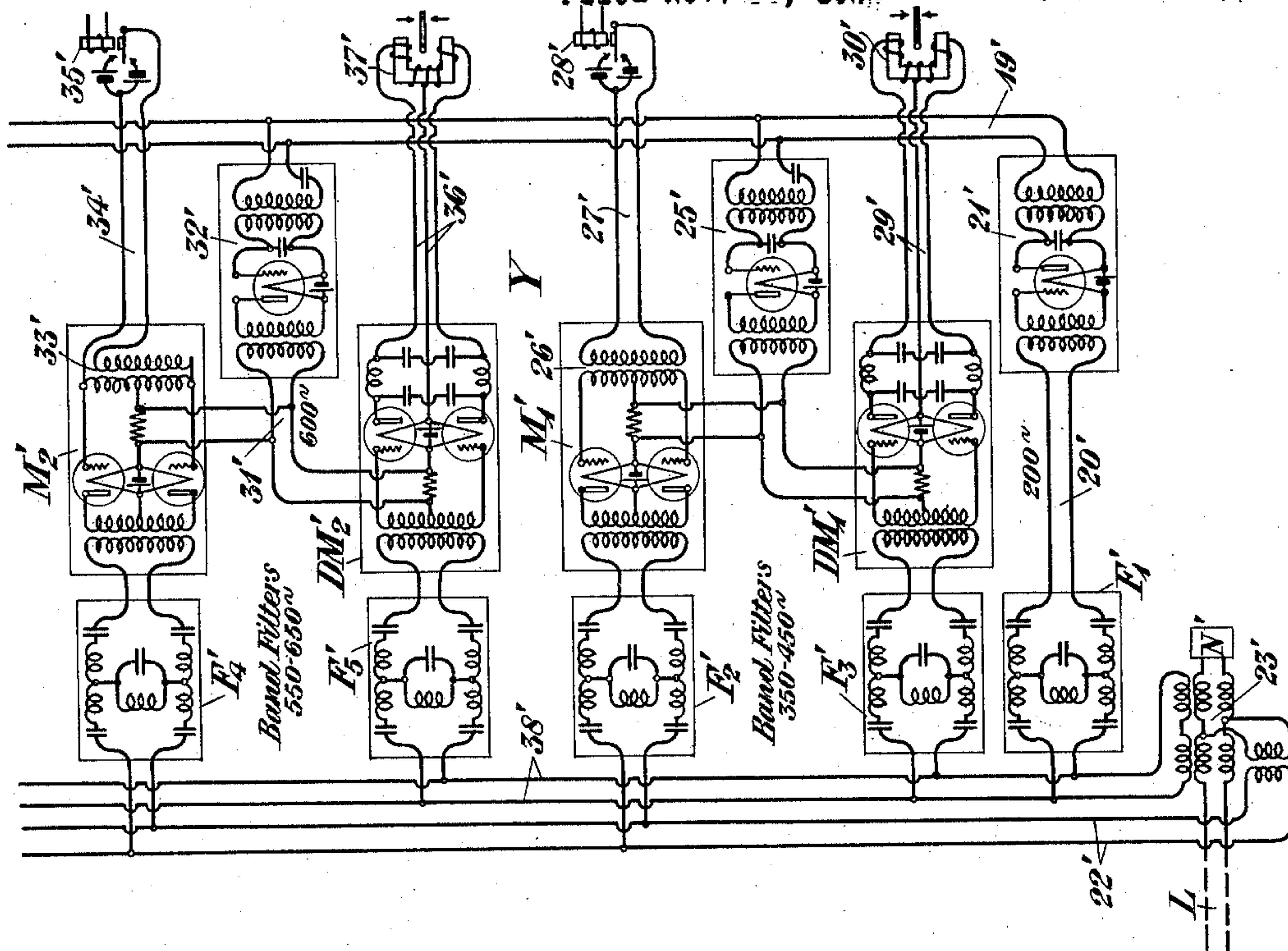


Fig. 14

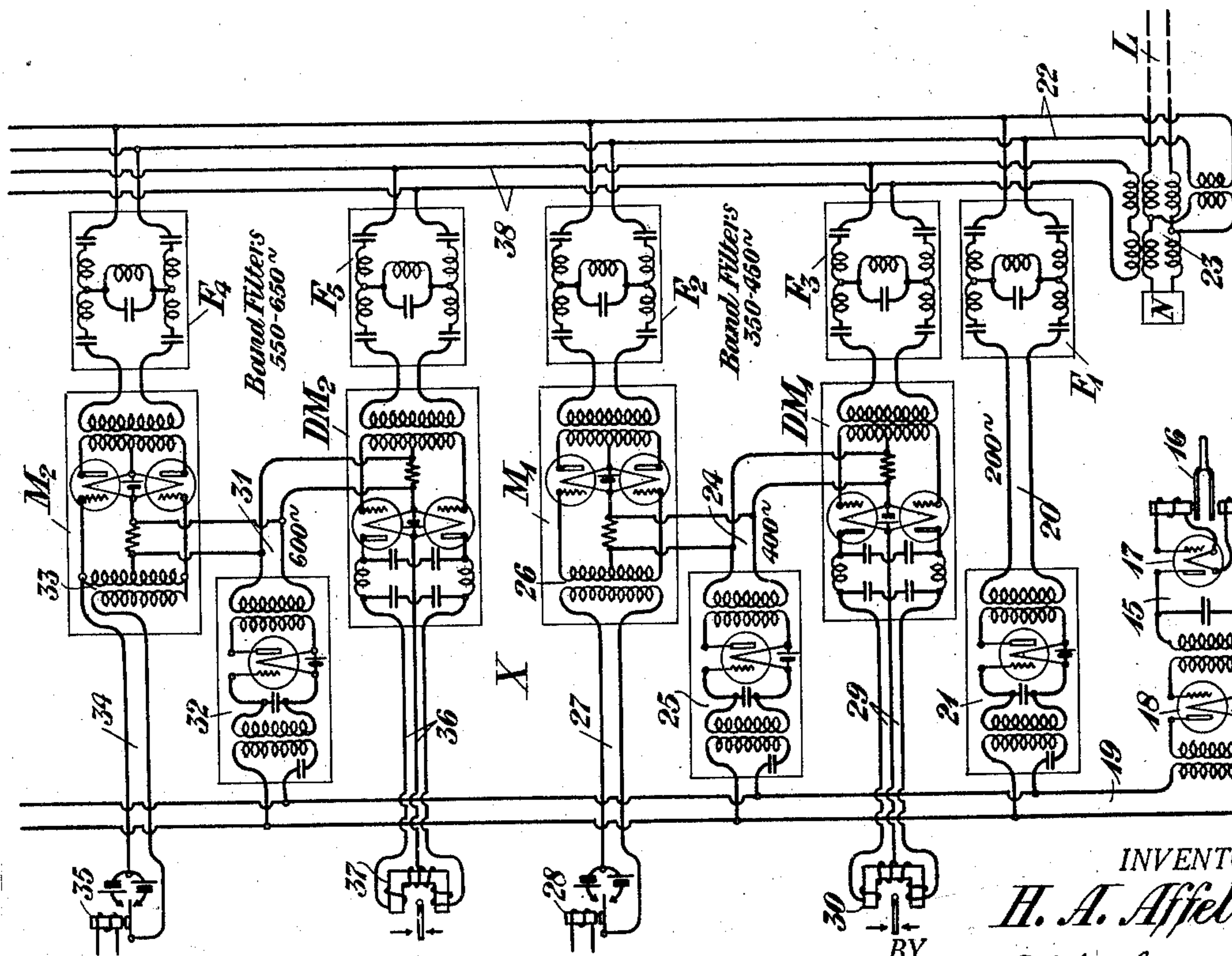


Fig. 13

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Patented Aug. 18, 1925.

1,549,849

UNITED STATES PATENT OFFICE.

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

VOICE FREQUENCY CARRIER TELEGRAPH.

Application filed November 14, 1922. Serial No. 600,958.

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 Voice Frequency Carrier Telegraphs, of which the following is a specification.

This invention relates to multiplex telegraphy and more particularly to the transmission of telegraph signals by so called carrier currents.

In general it is the purpose of the invention to provide arrangements whereby long distance telephone lines may be utilized to great advantage for telegraph purposes and accordingly in the arrangements of the invention the carrier frequencies utilized for transmitting the telegraph signals are within the voice range. Long distance telephone lines are by their very nature, as designed for telephone use, efficient for the transmission of carrier frequencies within the voice range, but inefficient, because of the cut-offs at the upper and lower end of the range, for frequencies without the voice range. This is particularly true of long repeater circuits, where the repeaters, which are usually of the vacuum tube type, are normally designed to pass merely the voice frequency bands and to exclude frequencies above and below. Such conditions would also exist on a long distance telephone line which included cable circuits as a portion thereof, or which included loaded circuits, as such circuits would have very great attenuation for frequencies outside of the voice range but would readily transmit the voice frequencies. Accordingly, there would normally exist on long distance telephone lines a carefully carved out range of frequencies within which the transmission efficiency is high and the invention in its broad aspect consists in utilizing the good transmission path thus formed for the transmission of a plurality of carrier telegraph channels within the voice frequency range.

The ordinary carrier system, which utilizes frequencies relatively higher than voice frequencies, cannot be applied to the average type of long distance telephone line because of its transmission characteristics pointed out heretofore and accordingly the use of such would either have to be restricted to open wire lines or to special lines constructed at

great expense. By utilizing voice frequency carrier currents this invention makes it possible to utilize practically any of the types of lines at present in existence without the necessity for any change in their equipment and apparatus. Accordingly it affords a new field of usefulness for existing telephone circuits in that without substantial change they may be utilized to great advantage for multiplex telegraphy. Furthermore the arrangements of the invention provide the advantage of great flexibility in plant and equipment as the voice frequency carrier telegraph apparatus can readily be switched from one line to another in much the same way as is done in the ordinary telephone uses of the lines. Other features and objects of the invention will appear more fully from the detailed description hereinafter given.

The invention may be more fully understood from the following description together with the accompanying drawing in the figures of which the invention and its application are illustrated. In Figure 1 the invention is illustrated schematically as associated with various types of telephone lines such as a two wire line, a four wire circuit, and a radio transmitting and receiving set. In Figs. 2, 3 and 4 are shown curves illustrating graphically the transmission characteristics of the telephone lines suitable for use with this invention and the position of the voice frequency carrier channels with respect to said curves. Figs. 5, 6, 7, 8, 9, 10, 11 and 12 show various types of telegraph currents which may be used in the system of the invention. Figs. 13 and 14 when taken together illustrate in detail circuit arrangements suitable for a system embodying the invention.

In Fig. 1 is shown a plurality of types of telephone transmission lines which may be utilized for telegraph purposes in accordance with the arrangements of this invention. The line L illustrates the well known type of four wire circuit consisting of two one way circuits for transmission in either direction. These circuits would include apparatus especially designed for the efficient transmission of voice frequency currents, such as repeaters, shown schematically as A. These circuits would terminate in a hybrid coil and switching arrangements, such as

jack J_7 . Lines L_1 and L_2 illustrate sending and receiving circuits of a radio system. These lines would include apparatus, such as A_1 , designed to be highly efficient for currents within the voice frequency range and are shown terminating in the switching arrangements, such as jacks J_5 and J_6 . The line L_3 illustrates a two way two wire circuit including apparatus, such as A_2 , which might be vacuum tube repeaters, and terminates in the jack J_8 . While the apparatus A in the various lines might be repeater apparatus, it is understood that it may include any type of intermediate circuit or apparatus which would cause the line to have transmission characteristics highly efficient for currents within the voice frequency range and inefficient for currents outside of said range. The telegraph arrangements comprise the jacks J_1 , J_2 , J_3 , and J_4 . Jacks J_3 and J_4 may be termed the transmitting jacks and with them are associated a plurality of voice frequency carrier transmitting sets. It has been found in practice that a desirable number of carrier channels within the voice frequency range is ten and hence ten sets of apparatus have been illustrated, although it is to be understood that this number may be varied as desired. The carrier transmitting sets are numbered 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 and each set is controlled by a key, such as K. The carrier frequencies of these sets are within the voice frequency range and of sufficient difference to avoid interference with each other. The specific arrangements of the sets will be shown in more detail hereinafter. Associated with the jacks J_1 and J_2 , which may be termed receiving jacks, are a plurality of voice frequency carrier receiving sets termed 1', 2', 3', 4', 5', 6', 7', 8', 9', and 10' which are adapted to receive the telegraph signals set out from the transmitting sets similar to 1, 2, 3, 4, 5, 6, 7, 8, 9, and 10 respectively. Each of the carrier receiving sets would be associated with a telegraph sounder, or other suitable receiving apparatus, such as B. The telegraph apparatus may be associated with the various types of lines by means of a link circuit C.

Figs. 2, 3 and 4 are curves illustrating graphically the transmission characteristics of the usual types of telephone lines. The abscissæ and ordinates represent the loss and frequency. The curves 11, 12, and 13 hence would represent the loss which would take place at the different frequencies and it will be seen that during the voice frequency range this loss is low and relatively constant. In other words the lines would have high transmission qualities for the voice range of frequencies and this range is well defined. It is in this range that the carrier telegraph channels are to be oper-

ated. For lines such as a four wire circuit or a radio transmitting or receiving station each line might be utilized for ten telegraph channels in the same direction, as shown by the arrows in Figs. 2 and 3, while in a two wire two way circuit there would be ten channels, five in one direction and five in the other, as shown in Fig. 4 by the arrows.

The invention may be more readily understood from a brief consideration of the optional transmission methods of operating direct current telegraph systems. In general, this operation may be effected by one of three methods. One of these may be termed the single battery or neutral method, which is provided in a simple series circuit of key, battery, and relay. When the key is closed current flows on the line and when the key is open no current flows. The relay provided is of the so-called neutral type furnished with a retractile spring to return the armature to a neutral position when no current flows. The line currents in a typical case of operation of this kind would be as illustrated in Fig. 5. Another method of operation is that utilized on so called duplex systems. In these systems the spacing signal, i. e. key open, is provided by a current reversal instead of current interruption, so that it is necessary to employ a polar relay at the receiving terminal. A relay of this kind provides an armature which rests on one contact with the coil current flowing in one direction and on the opposite contact with the reversed current. In this case it will be noted that energy exists on the line at substantially all times to approximately the same degree. The line currents in a case of this kind would appear, for example, as illustrated in Fig. 6. Another method of operation which has been utilized in certain cases is the direct current suppression method in which by means of transformers in the circuit or otherwise, the steady state or direct current component of the telegraph signal is eliminated or partially eliminated and there remain for operating polar relays the transient pulses or kicks which normally, if the transformers were inserted between the key, battery and relay circuit, would provide a pulse of a certain polarity during the establishment of a current when the key was closed and a pulse of the reversed polarity when the key was open and the current died down. In Fig. 7 is illustrated the relay current which would flow in a case of this kind when the direct current component is partially suppressed. In such a case the adjustment of the relay armature would be such as to provide its remaining on either contact, depending on the polarity of the preceding pulse. The advantage of this method of operation is that it provides a stability of signal quality more independent of line current variations

than in other methods. In Fig. 8 is shown the relay current which would flow in a case of this kind when the direct current component is completely eliminated. In Fig. 9 is illustrated the typical line currents which would exist in the case where an ordinary carrier current was definitely interrupted to form dots and dashes or in other words when the carrier current is modulated by a current such as shown in Fig. 5. In Fig. 10 are shown the carrier currents in a polarized system using current reversals as the basis of signaling modulation. In this case the current such as shown in Fig. 6 would be utilized to modulate the carrier frequency to obtain the current as shown in Fig. 10. In such a case the reversal of current in the modulating input results in the necessary reversal of current in the demodulator output circuit. This action of signal current reversal manifests itself on the carrier frequency line substantially as the reversal of a phase, as shown in Fig. 10, of what, after the circuit had reached a practically steady state condition, is essentially the carrier frequency itself. The energy on the line in this case will, as in the direct current method noted above, be practically constant during the entire period of signaling.

In the arrangements of this invention instead of applying the simple current reversal method of operation noted above, it is proposed that the direct current suppression system be used in signaling by a carrier suppression type of system with the object that line currents of any appreciable degree will exist only during the periods of making and breaking the circuit. The line currents in such a case would be as shown in Figs. 11 and 12. The advantage of such an arrangement would be that the average line current and consequent repeater loading for the case of a number of such carrier channels applied on a single pair of wires would be considerably minimized.

In Figs. 13 and 14, when taken together, there is illustrated in detail the carrier transmitting and receiving sets and the circuit arrangements therefor of the invention. Two stations, X and Y, are shown interconnected by a two wire line L and transmitting and receiving sets are shown at both stations. Like numerals with the added designation of prime have been utilized to denote parts at one station similar to parts at another station. The carrier transmitting and receiving sets of these arrangements are constructed to operate on the direct current suppression method heretofore referred to. Some of the sets operate to completely suppress the direct current component while others operate to partially suppress it as will be pointed out hereinafter. At station X the line L terminates in the

balancing network N and the hybrid coil 23. Associated with coil 23 is the transmitting circuit 22 over which the messages transmitted from station X are sent to line L. Associated with coil 23 is the receiving circuit 38 over which the messages from line L are received. Associated with transmitting circuit 22 is a transmitting set comprising the filter F_2 , the modulator M_1 , and the direct current telegraph circuit 27. The filter F_2 is of the type illustrated in the U. S. patent to G. A. Campbell, No. 1,227,113, May 22, 1917, and is designed to allow the transmission of a band of frequencies, which for purposes of illustration may be within the range of 350 to 450 cycles. The modulator M_1 is of the duplex vacuum bulb type illustrated in the U. S. Patent to J. R. Carson No. 1,343,307. The direct current telegraph circuit 27 is associated with the input of modulator M_1 by the transformer 26. Circuit 27 may include two oppositely poled sources of current adapted to be operatively associated with the circuit by switching means such as a relay 28. By means of transformer 26 the direct current component will be completely eliminated and only pulses of different polarity will be transmitted to the modulator M_1 . These pulses of current will modulate a carrier frequency, which will be within the voice range and for purposes of illustration may be termed 400 cycles, supplied from the circuit 24. This carrier current, which will be of the type illustrated in Fig. 12, will be transmitted through filter F_2 and over circuit 22 to line L and thence to station Y. The carrier channel of 400 cycles supplied from circuit 24 to the modulator is produced in the following manner. Circuit 24 is made resonant by the apparatus 25 to a frequency of 400 cycles and is associated with the base frequency circuit 19. The base frequency circuit 19 is associated with a circuit 15 comprising a source 16 of a basic frequency of 200 cycles and a vacuum tube 17 arranged to operate as an oscillator. Interconnecting circuits 15 and 19 is a circuit including a vacuum tube 18 adapted to function as a harmonic producer. Accordingly a basic frequency of 200 cycles and harmonics thereof will be transmitted over circuit 19 and the 400 cycle component will be picked out therefrom and transmitted over circuit 24. By the above arrangements a carrier channel within the voice frequency range, as for example 400 cycles, is supplied for telegraph messages. Another transmitting set is shown connected to the circuit 22. This set comprises the filter F_4 , modulator M_2 , and direct current telegraph circuit 34 controlled by relay 35. This set is substantially similar to the one heretofore described except that the direct current telegraph cir-

5 cuit 34 is connected to modulator M_2
 through an autotransformer 33 rather than
 through a transformer. Accordingly the
 currents transmitted to the input of the
 10 modulator will be of the type shown in Fig.
 7 in which the direct current component is
 only partially suppressed. The carrier cur-
 rent when modulated by this current and
 transmitted over line L will be of the type
 15 shown in Fig. 11. The carrier current is
 supplied to the modulator M_2 from the cir-
 cuit 31. This carrier current is shown for
 purposes of illustration as of a frequency
 of 600 cycles. It is pointed out, however,
 20 that this frequency value may be different
 if desired. The frequency would neverthe-
 less be within the voice range and sufficiently
 different from the other channels to avoid
 interference. This carrier frequency of 600
 25 cycles, in circuit 31 is supplied from the
 base frequency circuit 19. By means of the
 apparatus 32 circuit 31 is made resonant at
 this frequency and is connected to circuit
 19. As has been pointed out the base fre-
 30 quency circuit 19 has continuously trans-
 mitted thereover the basic frequency of 200
 cycles and harmonics thereof. Accordingly
 the 600 cycle component may be picked out
 therefrom and transmitted over circuit 31
 35 to the modulator. The band filter F_4 will
 be designed to readily transmit frequencies
 between 550 and 650 cycles. Other trans-
 mitting sets similar to the types illustrated
 may be connected to circuit 22 and to the
 40 base frequency circuit 19 as desired. The
 carrier frequencies would be within the
 voice range and would differ from the other
 channels already in use to avoid interfer-
 ence. In this manner a plurality of chan-
 nels within the voice range may be provided
 and connected to telegraph apparatus to
 afford multiplex transmission over line L.

45 At station Y the line L terminates in the
 net work N' and the hybrid coil 23' with
 which are associated the transmitting cir-
 cuit 22' and the receiving circuit 38'. Con-
 nected to receiving circuit 38' is a receiving
 set comprising the filter F_3' , the demodu-
 50 lator DM_1' , and the telegraph receiving cir-
 cuit 29', the latter being connected to the
 output of the demodulator and including
 receiving apparatus herein shown as the re-
 lay 30'. This receiving set is adapted to re-
 55 ceive the messages sent over the carrier
 channel of 400 cycles and hence the filter
 F_3' will be adapted to pass a band of fre-
 quencies between 350 and 450 cycles. The
 demodulator DM_1' , which may be of the du-
 60 plex vacuum tube type illustrated in the
 U. S. Patent No. 1,343,308 to J. R. Carson,
 will accordingly be supplied with a carrier
 frequency of 400 cycles from the circuit
 24'. In a carrier suppression system
 65 of this type synchronism of the car-
 rier currents at both of the terminal sta-

tions is required both as regards phase
 and frequency. In other words the carrier
 current supplied from circuit 24' to demodu-
 lator DM_1' must be substantially identical
 70 with the carrier current supplied from cir-
 cuit 24 to the modulator M_1 . Accordingly
 at station Y there is provided a base fre-
 quency circuit 19' and circuit 24' is con-
 nected thereto through the apparatus 25'.
 Apparatus 25' will be resonant at 400 cycles
 75 for reasons pointed out hereinafter. Cir-
 cuit 19' is connected through circuit 20' to
 circuit 22'. Circuit 20' includes the vacuum
 tube apparatus 21' adapted to function as a
 harmonic producer. In the circuit 20' is
 80 also included the filter F_1' adapted to trans-
 mit frequencies of the order of the basic
 frequency heretofore referred to as 200 cy-
 cles. At the station X is provided the cir-
 cuit 20 which interconnects the base fre-
 85 quency circuit 19 with the transmitting cir-
 cuit 22. Circuit 20 includes the filter F_1
 adapted to transmit frequencies of the order
 of the basic frequency of 200 cycles. The
 circuit 20 is made resonant at this frequency
 90 by the apparatus 21. Accordingly current
 of the basic frequency of 200 cycles gen-
 erated from circuit 15 at station X will be
 transmitted over circuits 20 and 22 to the
 line L and thence to station Y where they
 95 will be transmitted over circuits 22' and 20'
 to the harmonic producer 21'. The har-
 monic producer 21' will cause frequencies
 which are harmonics of the original basic
 frequency to be transmitted over circuit 19'.
 100 The apparatus 25' will cause the 400 cycle
 component to be picked off and transmitted
 to circuit 24'. Accordingly the carrier fre-
 quencies for the modulator M_1 at station X
 and for the demodulator DM_1' at station Y
 105 will both be supplied from the same source
 and will be in synchronism.

At station Y is provided a transmitting
 set for the 400 cycle channel. This set is
 110 substantially similar to the 400 cycle trans-
 mitting set at station X and comprises the
 filter F_2' , the modulator M_1' , and the direct
 current telegraph circuit 27'. The circuit
 27' may be controlled by relay 28' and is
 115 associated with the input of modulator M_1'
 by the transformer 26'. The filter F_2' con-
 nects the output of the modulator to the
 transmitting circuit 22' which in turn is as-
 sociated with line L through transformer
 23'. At station X there is provided a re-
 120 ceiving station for this last mentioned trans-
 mitting set. This receiving set is substan-
 tially similar to the 400 cycle receiving set
 already described with respect to station Y
 and comprises the filter F_3 , the demodulator
 125 DM_1 , and the telegraph circuit 29. The
 filter F_3 is connected to the receiving cir-
 cuit 38 and is adapted to pass a band of fre-
 quencies between 350 and 450 cycles. The
 output of the demodulator DM_1 is connected
 130

to the telegraph circuit 29 which may include receiving apparatus herein shown as the relay 30.

In order to receive the messages sent out from station X over the 600 cycle channel heretofore referred to there is provided at station Y a receiving set comprising the filter F_5' , the demodulator DM_2' , and the telegraph circuit 36'. The filter F_5' is adapted to pass a band of frequencies between 550 and 650 cycles and is connected to the receiving circuit 38' over which the 600 cycle channel is transmitted. The filter F_5' is connected to the input of demodulator DM_2' and the output of the demodulator is connected to the telegraph circuit 36', which may include receiving apparatus herein shown as the relay 37'. The demodulator DM_2' is supplied with a frequency of 600 cycles from the circuit 31' which is connected to the base frequency circuit 19' and made resonant at this frequency by the apparatus 32'.

A transmitting set suitable for transmitting messages over a 600 cycle channel is provided at station Y and is substantially similar to that already described with respect to station X. This transmitting set comprises the direct current telegraph circuit 34' connected through an autotransformer 33' to a modulator M_2' in the manner shown. The modulator will be connected to the output circuit 22' and thence to line L through a filter F_4' adapted to transmit a band of frequencies between 550 and 650 cycles. Likewise there will be provided at station X a 600 cycle receiving set to receive the messages from this last mentioned transmitting set. This receiving set is similar to those heretofore described and comprises the filter F_5 , the demodulator DM_2 , and the telegraph circuit 36 connected in the manner shown. While only two voice frequency channels are herein illustrated and referred to additional channels may be utilized by the provision at stations X and Y of additional transmitting and receiving sets similar to those shown and connected in the circuit in a similar manner.

It is pointed out that in the arrangements of Figs. 13 and 14 each station is utilizing the same channel frequency for transmitting. For example at station X the transmitting channels are 400 cycles, 600 cycles, etc., and at station Y the transmitting channels are also 400 cycles, 600 cycles, etc. Simultaneous transmission cannot however take place between corresponding transmitting sets at both of the stations unless the line circuit is practically perfectly balanced in the hybrid coil network circuit 23. Ten one way channels between stations may of course be provided in a A-wire circuit with the channels positioned as shown in Figs. 2 and 3. In order to provide for simultaneous

transmission between corresponding transmitting sets in an ordinary two wire circuit without relying on balance, a slight rearrangement of the transmitting frequencies would have to take place. The transmitting frequencies utilized at station X might be 400, 600, 800, 1000 and 1200 cycles, while those of the corresponding sets at station Y might be 1400, 1600, 1800, 2000 and 2200 cycles as shown in Fig. 4. Corresponding changes would necessarily have to be made in the receiving sets and associated apparatus at each station. This would of course limit operation to five duplex channels. Accordingly while the invention has been illustrated in certain specific arrangements which are deemed desirable, it is understood that it is capable of embodiment in many and widely varied forms without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. A multiplex signaling system comprising the combination of a transmission line including telephone repeater apparatus, means for impressing on said line a plurality of carrier currents of different frequencies within the voice range, means for impressing separate telegraph messages on each of said carrier currents, and means to individually detect from said carrier currents signal currents corresponding to said telegraph messages.

2. A multiplex signaling system comprising the combination of a transmission line designed to be highly efficient for frequencies within the voice range, means for impressing on said line for telegraph purposes a plurality of carrier currents of different frequencies within the voice range, means for impressing separate telegraph messages on each of said carrier currents, and means to individually detect from said carrier currents signal currents corresponding to said telegraph messages.

3. The method of simultaneously transmitting a plurality of telegraph messages over a long distance transmission line, which comprises transmitting over said line a plurality of carrier currents within the voice frequency range, superimposing a telegraph message on each of said currents, and individually detecting from said carrier currents signal currents corresponding to said telegraph messages.

4. A multiplex transmission system comprising a transmission line interconnecting two stations, a transmitting set at one station comprising means for applying to said line a carrier frequency within the voice range and means for superimposing a telegraph message on said carrier frequency, and a second transmitting set at said station comprising means for applying to said line a carrier frequency also within the voice

- range but different from said first mentioned carrier frequency and means for superimposing a telegraph message on said carrier frequency, and receiving sets corresponding 5 to each transmitting set, each receiving set including a detector for detecting from the corresponding carrier current signal currents corresponding to the telegraph message superimposed on the carrier current.
- 10 5. A transmission line, a plurality of sources of single frequency carrier currents all within the voice frequency range, means to modulate current from each of said sources in accordance with telegraph signals individual thereto, a band filter individual 15 to each carrier current connected between said modulating means and said transmission line to transmit said modulated currents to said line, and means for individually detecting from said carrier currents signaling 20 currents corresponding to said telegraph signals.
- In testimony whereof I have signed my name to this specification this 11th day of November 1922.
- HERMAN A. AFFEL.