Oct. 6, 1925. 1,556,319

L. ESPENSCHIED

HIGH FREQUENCY MULTIPLEX SIGNALING SYSTEM

Filed Sept. 30, 1919 3 Sheets-Sheet 1

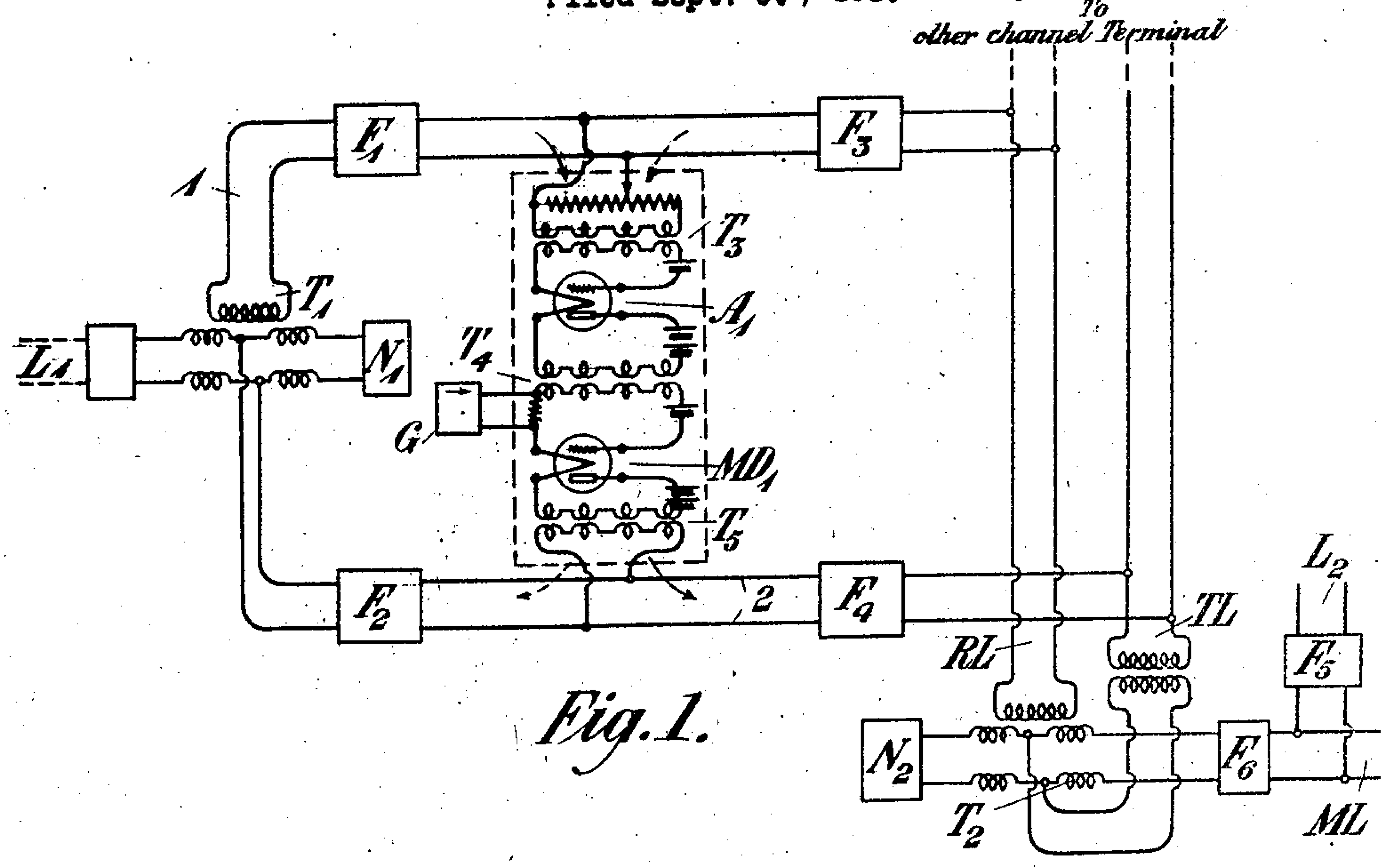


Fig. 1.

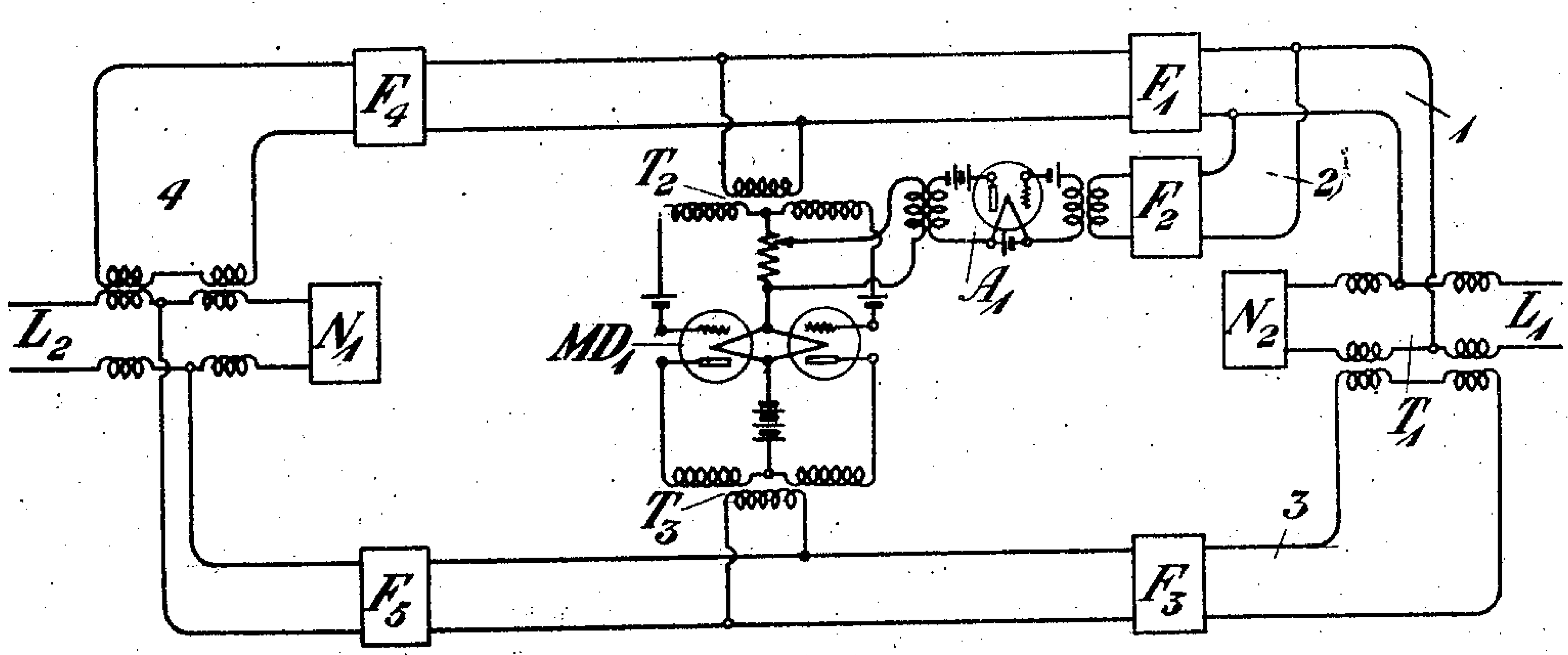


Fig. 4.

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Filed Sept. 30, 1919 3 Sheets-Sheet 2

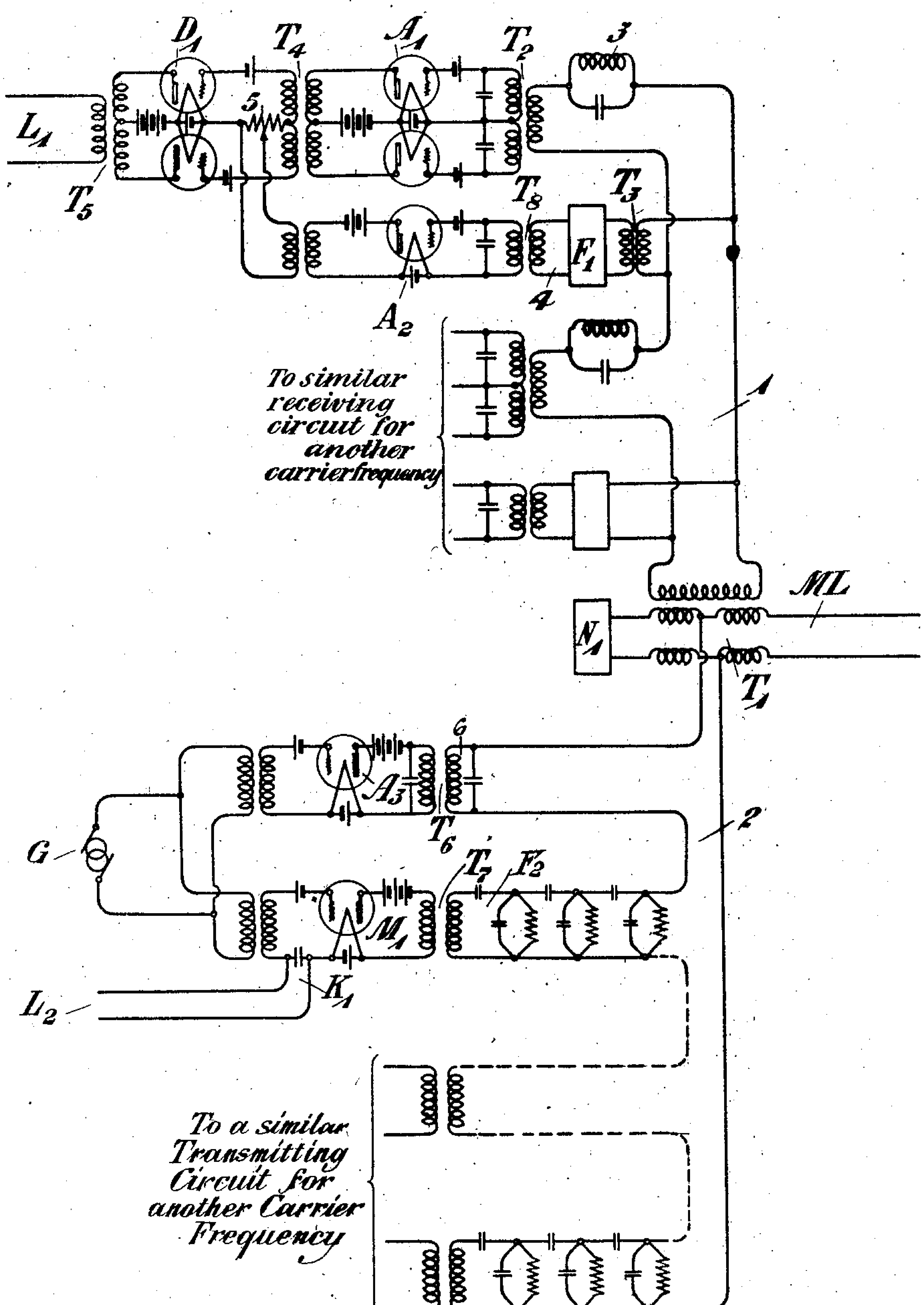


Fig. 2.

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Filed Sept. 30, 1919 3 Sheets-Sheet 3

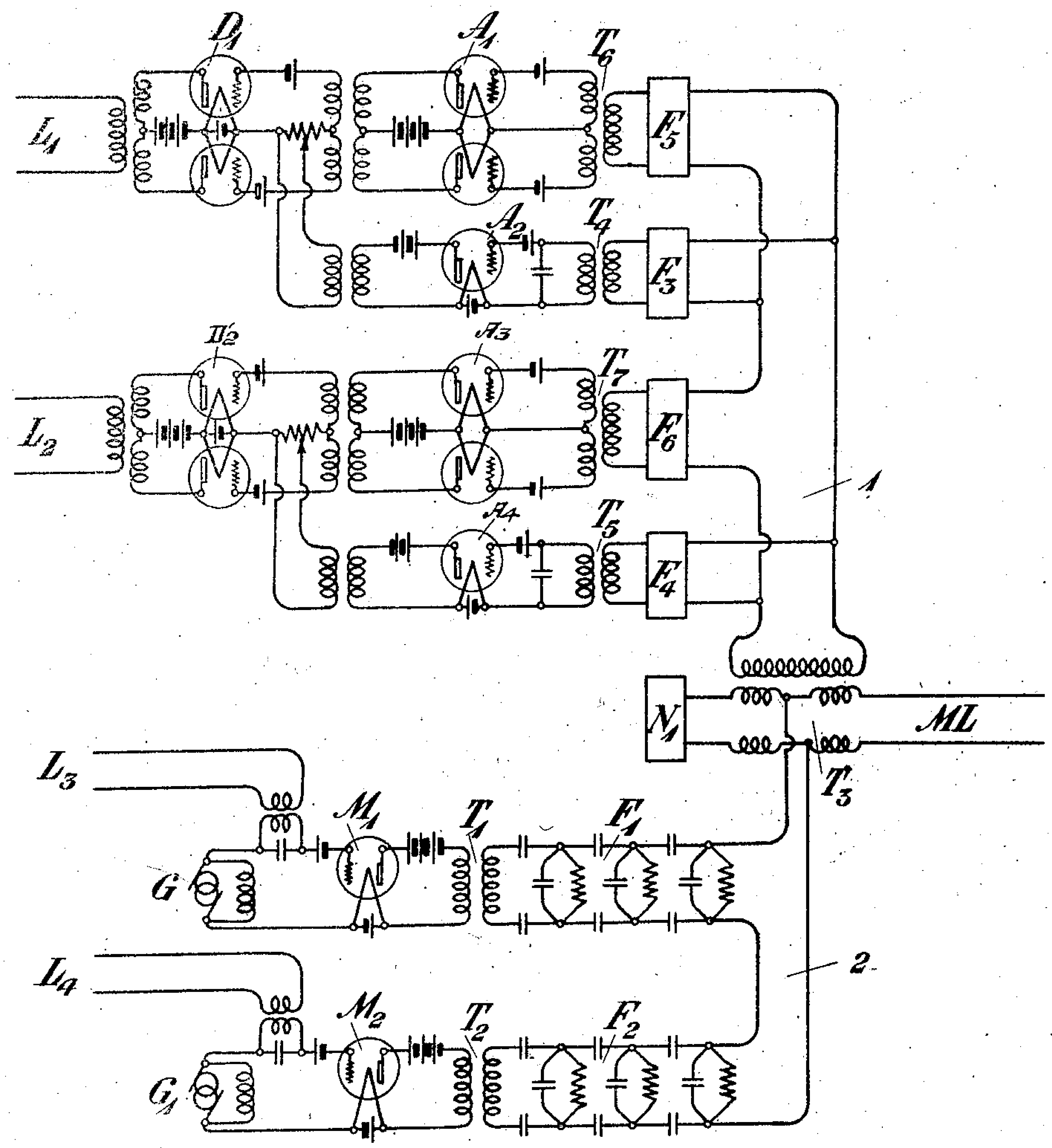


Fig. 3.

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Patented Oct. 6, 1925. **1,556,319**

# UNITED STATES PATENT OFFICE.

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

## HIGH-FREQUENCY MULTIPLEX SIGNALING SYSTEM.

Application filed September 30, 1919. Serial No. 327,501.

*To all whom it may concern:*

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

This invention relates to high frequency multiplex signaling systems and more particularly to a terminal circuit arrangement embodying the use of amplifiers adapted to amplify the side band and the carrier frequency oscillations received by the said terminal circuit.

The broad object of the invention is to improve the transmission efficiency and the transmission quality of carrier current circuits. One feature is the provision of a carrier current amplifier for improving the transmission efficiency of the carrier circuit. A further object of the invention is to provide means whereby the ratio of the unmodulated carrier current transmitted over the system to the modulated or side band component may be controlled for the purpose of insuring good quality in the carrier transmission circuit.

A comprehensive undestanding of the invention will be facilitated by recognizing that in the ordinary form of carrier current transmission represented by radio, there are involved really two channels, one the unmodulated carrier current which is transmitted over the system at the original carrier frequency and the other the modulated or side band component which is transmitted at a frequency differing from the original carrier frequency by an amount corresponding to the signaling frequency. These two channels are commonly treated in radio, for example, as a single channel, and at the receiving end are fed unseparated into the detector. The detecting action obtains, however, only by virtue of modulation between, that is, the beating together of, the currents of the two channels, the carrier and one or both side bands. The present invention is concerned with carrier current systems, both wire and wireless, wherein the carrier is transmitted directly along with the side bands as per ordinary radio practice, as distinguished from the type of carrier system first employed for multiplex service over wires wherein the carrier channel is suppressed at the sending end and resupplied at the receiving end by a control system.

One feature of the invention resides in the use of an amplifier in the high frequency part of the circuit which amplifies simultaneously both the carrier and the side band currents. A given amplification inserted in this manner in the high frequency circuit results in a twofold amplification of the detected current by virtue of the fact that the amplitude of the detected current is a function of the product of the amplitudes of the carrier and the side band currents.

It has been found that for the obtaining of good quality in carrier telephone transmission, it is necessary that the carrier supply current be large compared with the side band currents. This relation is necessary in order that in detection or demodulation, the product term of carrier and side band, representing the desired detected current of signaling frequency, be large in amplitude compared with the other product terms such as those resulting from modulation between the two side bands or between the component currents of one side band, which currents represent undesired detected currents tending to interfere with and depreciate the quality of the transmission. A further feature of the invention is the provision of means whereby the carrier and the side bands may be amplified in different proportions, that is, the ratio of the amplitudes of the carrier to the side band currents may be varied for the purpose of improving quality in the manner indicated. This is accomplished by combining with the high frequency amplifying apparatus, selective circuits which discriminate as between the carrier frequency and the side band frequency.

This invention will be better understood from the following description when read in connection with the attached drawing, of which Figure 1 shows an arrangement for amplifying jointly both the carrier and side band; Figs. 2, 3, and 4 show methods by which the carrier current and the side band oscillations may be amplified separately to the desired degree.

In Fig. 1, $L_1$ shows a source of low frequency signaling currents which is connected with the terminal circuit by means of a transformer $T_1$ having a network $N_1$ associated therewith adapted to balance the line $L_1$. This terminal circuit, which is of the four-wire type, has associated with it low frequency filters $F_1$ and $F_2$ and the high frequency filters $F_3$ and $F_4$. The transmitting path of this circuit is connected with the branch transmission circuit TL, which is in turn connected with the main transmission line ML by means of transformer $T_2$. A network $N_2$ associated with transformer $T_2$ is adapted to balance the line ML. Another circuit $L_2$ is connected with the main transmission line ML through the low frequency filter $F_5$, the function of the said line being to transmit low frequency voice currents over the line ML simultaneous with the transmission of the high frequency signaling currents from the terminal circuits. High frequency oscillations received over the line ML pass through the high frequency filter $F_6$ and are impressed on the branch receiving circuit RL by the transformer $T_2$. Connected between the two sides of the four wire circuit is a translating circuit which forms a common path for the outgoing and incoming currents of the terminal circuit. The input side of this translating circuit is connected with one side of the terminal circuit by means of the transformer $T_3$ which is of a type designed for the efficient transfer of both low frequency and high frequency currents from the terminal circuit to the translating circuit. Connected with the translating circuit is an amplifier $A_1$ adapted to amplify the currents impressed upon the translating circuit by the transformer $T_3$ and the currents thus amplified are impressed upon a modulating and demodulating device $MD_1$ by means of a transformer $T_4$. The modulating and demodulating device has associated with it a source of high frequency carrier supply current G. The currents resulting from modulation and demodulation are impressed upon the output side of the terminal circuit by means of the transformer $T_5$.

In the operation of this circuit low frequency signaling currents arising in the circuit $L_1$ are impressed by the transformer $T_1$ upon the low frequency circuit 1 and passing through the filter $F_1$ are impressed upon the translating circuit by the transformer $T_3$. These low frequency currents are amplified by the amplifier $A_1$, and by means of the device $MD_1$, serve to modulate the carrier current. The modulated high frequency oscillations are impressed upon the high frequency output circuit from whence they pass through the high frequency filter $F_4$ to the transmission lines TL and ML. Simultaneous with the transmission of the modulated high frequency oscillations unmodulated carrier oscillations produced by the source G are transmitted through device $MD_1$ and over the lines TL and ML to the corresponding terminal circuit at the opposite end of the said line.

The modulated high frequency oscillations received from the terminal circuit at the said other end of the line ML are impressed upon the branch receiving line RL and pass through the filter $F_3$ into the translating circuit. Simultaneous with the reception of these modulated oscillations unmodulated oscillations of the same frequency are received by the line RL and are impressed upon the translating circuit passing through the filter $F_3$ which is adapted to transmit the carrier frequency and the band of frequencies based thereon. The received band of oscillations and the carrier oscillations of the same frequency are amplified together by the amplifier $A_1$ and are impressed by means of the transformer $T_4$ upon the device $MD_1$ in which they are modulated. The low frequency signaling current resulting therefrom passes through the filter $F_2$ to the line $L_1$ and actuates the low frequency signaling apparatus associated therewith. The amplification of the oscillations of the side band frequencies and of the carrier frequency itself results in a two fold amplification of the detected current by virtue of the fact that the amplitude of detected current is a function of the product of the amplitude of the carrier oscillations and the amplitude of the side band oscillations. Thus an amplification which doubles the received high frequency currents of both the side band and of the carrier supply results in quadrupling the detected current as a result of this product relationship. It is therefore apparent that the arrangement shown in Fig. 1 results in a substantial gain in the transmission of signals over a system employing high frequency carrier currents. As has been stated, the modulated high frequency oscillations transmitted over the lines TL and ML from the terminal circuit shown in Fig. 1 will be received at the other end in a terminal circuit preferably similar to that shown in Fig. 1, and the modulated high frequency oscillations and the unmodulated carrier oscillations will pass through a filter similar to $F_3$ and will be impressed upon a translating circuit similar to that shown in Fig. 1. Although the high frequency amplifier is illustrated in Fig. 1 applied in a type of circuit wherein one amplifier is common to both sending and receiving it will be understood that the amplifier may be employed in a circuit of any type such as the 22 type circuit wherein separate high frequencies amplifiers are employed for sending and receiving.

Fig. 2 shows a method by which the unmodulated carrier oscillations may be separated from the modulated high frequency oscillations at the terminal circuit and each set of oscillations may be amplified independently of the other set of oscillations received at the said terminal circuit. In the figure $L_1$ represents the line over which low frequency current may be received and $L_2$ a line over which low frequency current may be transmitted. ML represents the main transmission line over which the high frequency oscillations may be transmitted between terminals at opposite ends thereof. The line ML is connected with the input circuit 1 and the output circuit 2 by means of the triple winding transformer $T_1$ having a network $N_1$ associated therewith to balance the line ML. The receiving circuit 1 has associated with it an antiresonant circuit 3, adapted to prevent oscillations of carrier frequency from being impressed by the transformer $T_2$ upon the amplifying circuit $A_1$. Oscillations of carrier frequency are impressed by means of transformer $T_3$ upon the circuit 4, from which oscillations other than those of the carrier frequency are excluded by means of the filter $F_1$. The amplifier $A_2$ amplifies oscillations of carrier frequency and the amplified output is impressed across a resistance or inductance 5 of the duplex translating circuit embracing the demodulating device $D_1$. The output of the amplifying circuit $A_1$ is impressed by transformer $T_4$ across the demodulating circuit, wherein the modulated high frequency oscillations are demodulated by the carrier frequency oscillations, and the low frequency signaling currents resulting therefrom are impressed upon the low frequency circuit $L_1$ by the transformer $T_5$.

A low frequency signaling device such as a transmitter is connected with the low frequency line $L_2$ which in turn is connected to the input side of the modulator $M_1$. A source of high frequency carrier oscillations G is adapted to impress said oscillations upon the input sides of an amplifier $A_3$ and the modulator $M_1$. The output sides of the amplifier $A_3$ and the modulator $M_1$ are connected through selecting circuits 6 and $F_2$ respectively with transmitting circuit 2, and the modulated and unmodulated carrier oscillations are impressed upon the transmission circuit ML by means of the transformer $T_1$. The opposite end of the transmission line ML is preferably equipped with a circuit arrangement for transmitting and receiving, similar to that shown in Fig. 2.

The mode of operation of the transmitting side of this terminal circuit is as follows: The low frequency signaling currents from the line $L_2$ will be impressed across the condenser $K_1$ in the input side of the modulator $M_1$, thereby serving to modulate the high frequency carrier oscillations from the source G. If we designate the frequency of the signaling currents by $f$ and the frequency of the carrier oscillations by $n$, the frequencies passing through the transformer $T_7$ may be represented by $n$, $n+f$, and $n-f$. By means of a high frequency band filter $F_2$, the frequencies represented by $n+f$ may be suppressed thereby allowing the frequencies represented by $n$ and $n-f$ to be transmitted to the output circuit 2. Simultaneously the transformer $T_6$ is transmitting unmodulated oscillations of frequency $n$, the amplitude of which is greatly increased by the amplifier $A_3$. All of these oscillations are transmitted over the line ML to the terminal circuit at the other end similar to that shown in Fig. 2. The operation of the circuit at that end of the line will be best understood by considering what takes place in the receiving circuit shown in Fig. 2 when similar sets of high frequency oscillations are received over the line ML and impressed upon the circuit 1 by means of the transformer $T_1$. The received frequencies $n$ and $n-f$ will be directed into separate channels by means of suitable devices such as filters or their equivalents. The antiresonant device 3, which is anti-resonant to the frequency $n$, prevents oscillations of that frequency from being impressed by the transformer $T_2$ across the input side of the amplifying circuit $A_1$ but the oscillations of the side band represented by $n-f$ will pass through the said anti-resonant device and will be impressed across the input side of $A_1$. This side band of oscillations will be amplified and will be impressed by the transformer $T_4$ across the input side of the detector or demodulator $D_1$. The carrier frequency $n$ will be impressed by the transformer $T_4$ across the circuit 4, from which the oscillations of the side band frequencies $n-f$ are excluded by the filter $F_1$. The carrier frequency oscillations are impressed by transformer $T_3$ upon the amplifier $A_2$ by means of which the carrier frequency may be given the desired degree of amplification. The amplified carrier currents are impressed across the potentiometer 5 in the common conductor of the input side of the duplex translating device $D_1$ serving to demodulate the frequencies of the side band $n-f$. The low frequency currents resulting from demodulation are impressed upon the line $L_1$ by the transformer $T_5$.

It will be seen that the arrangement in Fig. 2 shows means for amplifying the oscillations of carrier frequency separate and distinct from the means for amplifying the oscillations of the side band of frequencies. Thus the carrier frequency may be amplified before transmission by the amplifier $A_3$ and after reception by the amplifier $A_2$. Also the frequencies of the side band may be amplified to a certain degree in the process of modulation by the modulator $M_1$ and the desired band of frequencies may be reamplified separate from the carrier frequency at the receiving end of the system by means of an amplifier $A_1$, which may or may not be of the duplex type shown in Fig. 3. A further advantage of the arrangement in resetting is that it permits of suppressing the carrier in the detector output by the use of the duplex or balanced detector circuit as indicated at $D_1$.

Fig. 3 shows another terminal circuit arrangement for the selective amplification of the carrier frequency and the desired side band frequencies. In the drawing $L_1$ represents one low frequency signaling circuit and $L_2$ another low frequency signaling circuit for the reception of the low frequency currents resulting from demodulation of the carrier frequency. $L_3$ and $L_4$ represent low frequency transmission circuits which are adapted to impress low frequency signaling currents upon the high frequency transmission system. G and $G_1$ represent two sources of high frequency carrier currents, the frequencies of which may be represented by $n$ and $n_1$ respectively. The lines $L_3$ and $L_4$ are connected with the input side of the modulating devices $M_1$ and $M_2$ respectively, the output sides of which are connected by means of the transformers $T_1$ and $T_2$ with the output circuit 2, which in turn is connected to the main transmission line ML by means of the transformer $T_3$. A network $N_1$ adapted to balance the line ML is connected with transformer $T_3$. Filters $F_1$ and $F_2$ associated with the output circuit 2 are adapted to permit the transmittal of oscillations of one of the bands, for example that represented by $n-f$ and also oscillations of the carrier frequency $n$ therethrough but to suppress oscillations of the frequency $n+f$. These frequencies will be transmitted through the line ML to a circuit connected with the other end of the said line preferably similar to that shown in Fig. 3. The receiving circuit 1 shows two branch receiving circuits connected therewith, which form the receiving circuits for carrier frequencies $n$ and $n'$, and the side bands $n-f$ and $n_1-f$, respectively. The upper receiving circuit, connected with the low frequency line $L_1$, has connected therewith a demodulating device $D_1$, an amplifier $A_1$ for amplifying the desired side band, and an amplifier $A_2$ for amplifying the carrier frequency. In a similar manner the other receiving circuit has connected therewith a demodulating device $D_2$, an amplifier $A_3$ to amplify the side band oscillations, and an amplifier $A_4$ to amplify the oscillations of carrier frequency $n_1$. The method of operation of this circuit is as follows: Low frequency signalling currents represented by $f$ will be impressed across the input circuit of the modulator $M_1$, thereby serving to modulate the high frequency oscillations $n$ from the source G. Oscillations of the frequencies $n$, $n+f$, and $n-f$ will be found in the output side of the modulator $M_1$. Since the filter $F_1$ is designed to transmit only the carrier frequency $n$, and the side band $n-f$, these frequencies only will be impressed by the transformer $T_3$ upon the line ML and will be transmitted to the terminal circuit at the opposite end of this line. In like manner low frequency signaling currents $f$, arising within the line $L_4$, will be impressed across the input side of the modulator $M_2$ upon which is also impressed carrier frequency $n_1$ from the source G. The carrier current will be modulated by the low frequency signaling current and the transformer $T_2$ will impress upon the output circuit two frequencies represented by $n_1$, $n_1+f$, and $n_1-f$. Since the filter $F_2$ transmits only the carrier frequency and the oscillations represented by $n_1-f$, these frequencies will be impressed upon the line ML by the transformer $T_3$. In a similar manner similar sets of frequencies will be transmitted from the circuit at the other end of the line ML and will be impressed upon the receiving circuit 1 by the transformer $T_3$. If we assume that the filters $F_3$ and $F_4$ are adapted to pass the carrier frequencies $n$ and $n_1$ respectively, these frequencies will be impressed by the transformers $T_4$ and $T_5$ upon the input sides of the amplifiers $A_2$ and $A_4$ respectively. Since the filters $F_5$ and $F_6$ are adapted to transmit the desired side bands, namely those represented by the frequencies, $n-f$ and $n_1-f$, oscillations of these frequencies will be impressed by transformer $T_6$ and $T_7$ upon the input side of the amplifiers $A_1$ and $A_3$ respectively. The amplified oscillations of the carrier and of the side band frequencies in each receiving circuit will be impressed upon the demodulating devices $D_1$ and $D_2$ and the low frequency signaling currents resulting therefrom will pass to the low frequency lines $L_1$ and $L_2$ respectively. This circuit arrangement shows means for transmitting a plurality of unmodulated carrier frequencies, also a plurality of bands of oscillations based upon these carrier frequencies, and for separating each carrier frequency from its accompanying side band in the receiving circuit so that the carrier frequency and the side band frequencies may be separately amplified, and the amplified oscillations may be impressed upon a demodulating device for detecting the transmitted signal.

Fig. 4 shows the application of the invention to a terminal circuit of the type characterized by a single translating circuit adapted to modulate and demodulate the outgoing and incoming currents. In the figure $L_1$ represents the high frequency line over which it may be assumed that currents of the frequency $n$ and $n-f$ are being received. These frequencies are impressed by the transformer $T_1$ upon the input circuit 1. The high frequency band filter $F_1$ adapted to pass oscillations represented by the frequency $n-f$ is inserted in the input side of the terminal which is connected with the translating circuit by the transformer $T_2$. Bridged across the input circuit 1 is a bypass 2, having therein a filter $F_2$ adapted to transmit only the carrier frequency $n$. The oscillations of this frequency are amplified by the amplifier $A_1$ and are impressed upon the common conductor of the duplex modulating and demodulating device $MD_1$. Associated with the high frequency output branch 3 is a high frequency band filter $F_3$. $F_4$ and $F_5$ represent low frequency filters which are adapted to transmit currents of the signaling frequency. The mode of operation of this circuit is as follows: Let it be assumed that the carrier frequency $n$ and a band of frequencies represented by $n-f$, are being received over the line $L_1$ from the circuit at the opposite end of the said line, and are being impressed upon the receiving branch 1 of the terminal circuit shown in Fig. 4. The band of frequencies represented by $n-f$ will pass through the filter $F_1$ and will be impressed by the transformer $T_2$ upon the modulating and demodulating device $MD_1$. The carrier frequency $n$ will be selectively amplified by the amplifier $A_1$ and the amplified oscillations of this frequency will be impressed upon the translating device $MD_1$. The low frequency signaling current resulting from demodulation will be impressed by the transformer $T_3$ upon the output side of the terminal circuit and passing through the low frequency filter $F_5$ will be impressed upon the low frequency signaling circuit $L_2$. The low frequency signaling currents set up in the circuit $L_2$ by the low frequency signaling apparatus associated therewith will be impressed upon the input branch 4 of the transmitting path and passing through the low frequency filter $F_4$ will be impressed upon the translating circuit by the transformer $T_2$. These low frequency currents will modulate the amplified high frequency carrier current impressed upon the translating circuit by the amplifier $A_1$ and the modulated high frequency current resulting therefrom will be impressed upon the output circuit by the transformer $T_3$. These modulated high frequency oscillations will pass through the high frequency band filter $F_3$ and over the transmission line $L_1$. It will be seen therefore that by means of the arrangement shown in Fig. 4 the unmodulated carrier oscillations which are simultaneously transmitted together with one or more of the side bands based upon this carrier frequency may be separated from the said band or bands in the receiving branch of the terminal circuit and may be amplified separately from the side bands and impressed upon a translating circuit, common to the transmitting and receiving paths of the terminal circuits.

It will be apparent that this invention provides means whereby the received carrier frequency may be amplified simultaneous with the amplification of the frequencies impressed in the received side band, the various frequencies being amplified to the same degree, as in Fig. 1, or the carrier frequency may be separated from the received band of frequencies and each separately amplified, by means of separate selecting circuits as in Figs. 2, 3, and 4. Although these figures show the invention applied to a carrier system over wire transmission lines, it is to be understood that it is equally applicable to radio transmission systems.

Although this invention has been shown as embodied in certain specific forms and arrangements of parts, it is to be understood that it may be embodied in other and different forms and arrangements than those shown without departing from the spirit and intent of the appended claims.

What is claimed is:

1. In a signaling system the combination of a terminal circuit adapted to transmit and receive oscillations of the side band frequencies and oscillations of the carrier frequency, means for separating the side band oscillations and the carrier oscillations, means for amplifying separately each set of oscillations, and means for impressing both sets of oscillations upon a translating device for detecting the same.

2. In a high frequency signaling system the combination of a receiving circuit adapted for the reception of oscillations of the side band frequencies and oscillations of the carrier frequency, a detector, means for selecting oscillations of the side band frequencies, separate means for selecting oscillations of the carrier frequency, means individual to each selecting means for amplifying each set of oscillations, and means for impressing said amplified oscillations upon said detector.

3. In a signaling system the combination of a terminal circuit having a detector associated therewith, and adapted for the transmission of oscillations of the side band frequencies, and for the reception of oscillations of both the side band frequencies and of the carrier frequency, means associated with the receiving circuit for the separate amplification of oscillations of the side band frequency and oscillations of the carrier frequency, and means for impressing both sets of amplified oscillations upon said detector.

4. In a signaling system characterized by the simultaneous reception of modulated

and unmodulated oscillations, the method for improving the quality of detection of received signals, which consists in separating by filtering the modulated oscillations and the unmodulated oscillations, amplifying one of said types of oscillations and combining both types of oscillations to produce detection.

5. In a signaling system characterized by the simultaneous reception of modulated and unmodulated oscillations, the method for improving the quality of detection of received signals, which consists in separating by filtering the modulated oscillations and the unmodulated oscillations, amplifying both types of oscillations and combining them to produce detection.

6. In a signaling system characterized by the simultaneous reception of unmodulated carrier frequency oscillations and side band of oscillations, the method for improving the quality of detection which consists in separating by filtering the carrier frequency oscillations and the oscillations of the side band frequencies, separately amplifying the two groups of oscillations and simultaneously combining the amplified oscillations to produce detection.

7. In a signaling system characterized by the simultaneous reception of unmodulated carrier frequency oscillations and side band of oscillations, the method for improving the quality of detection which consists in separating by filtering the carrier frequency oscillations from the side band oscillations, separately amplifying each group of oscillations, simultaneously combining both groups to produce detection, and transmitting the resultant detected current while suppressing the carrier frequency current.

8. In a signaling system the combination with a transmission line of a terminal circuit having transmitting and receiving branches, the receiving branch having means for the separate selection and the separate amplification of the carrier frequency and a side band of frequencies, and also having a common detection circuit and means for impressing both the amplified carrier and the side band frequencies thereon.

9. In a signaling system, the combination with a line transmitting a carrier current and side band currents of a terminal circuit having transmitting and receiving branches, the receiving branch having means for selectively passing the carrier and one of the side band currents, and means for amplifying the carrier current.

In testimony whereof, I have signed my name to this specification this 29th day of September, 1919.

LLOYD ESPENSCHIED.