

Feb. 8, 1927.

L. ESPENSCHIED ET AL

1,616,892

DUPLEX RADIO SYSTEM

Filed Aug. 18, 1922

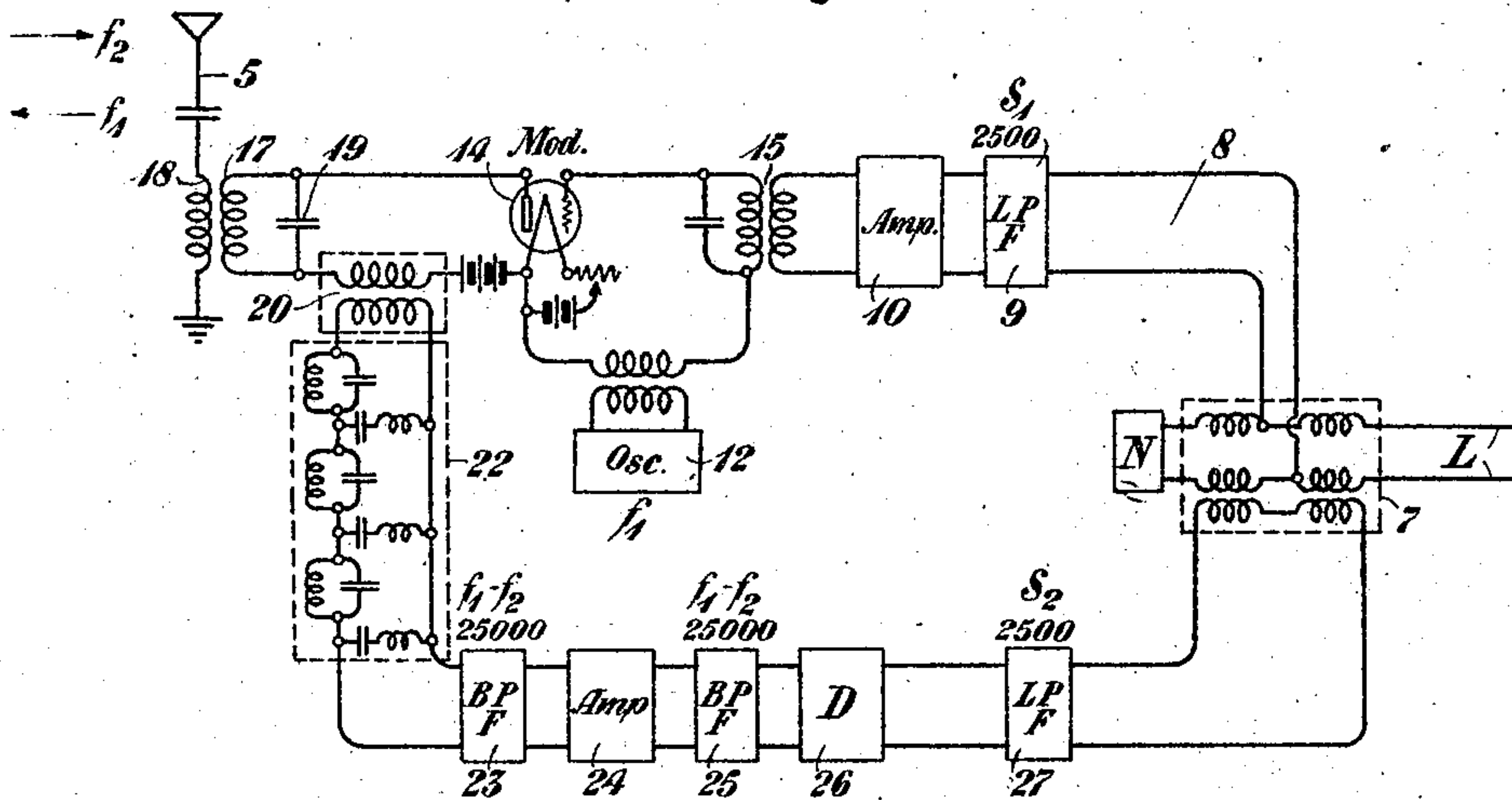


Fig. 1

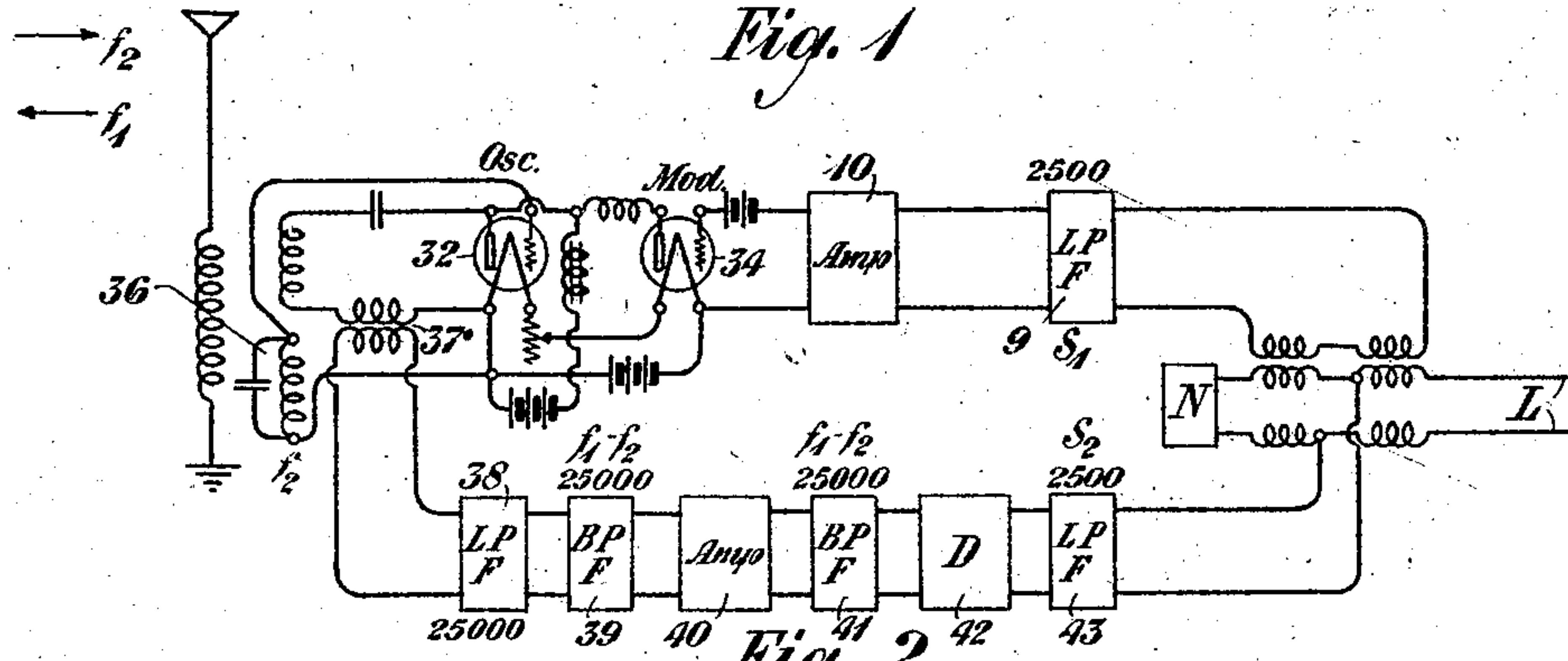


Fig. 2

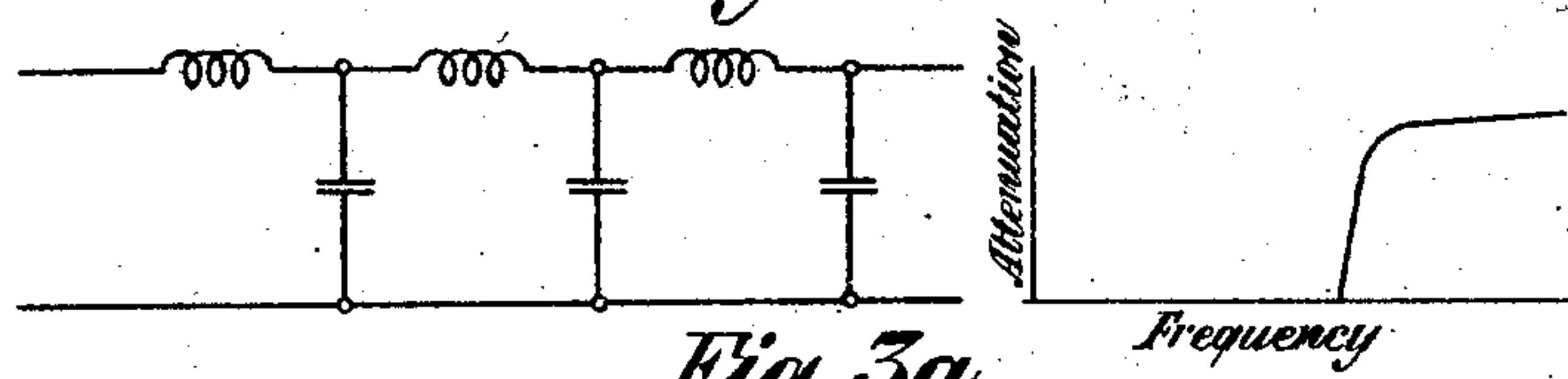


Fig. 3a

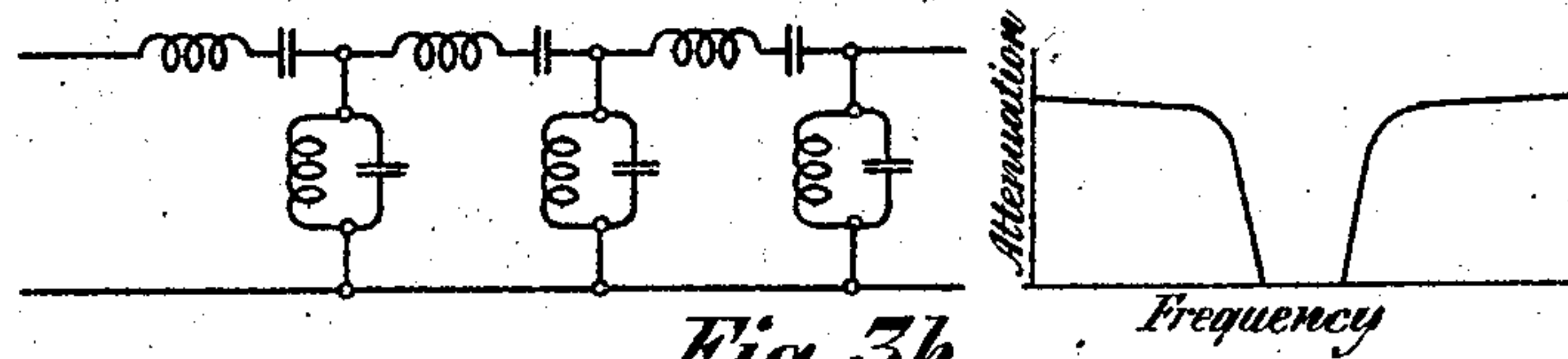


Fig. 3b

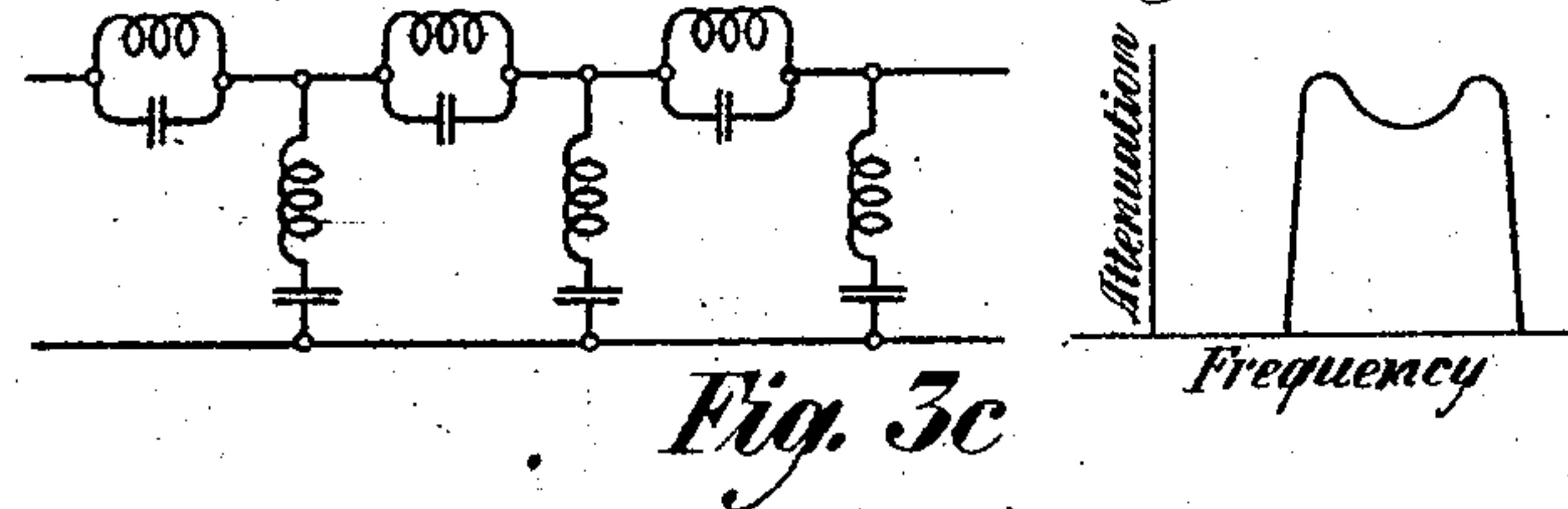


Fig. 3c

INVENTORS
L. Espenschied and
D. K. Martin
BY
J. E. H. 404
ATTORNEY

UNITED STATES PATENT OFFICE.

LLOYD ESPENSCHIED, OF HOLLIS, NEW YORK, AND DE LOSS K. MARTIN, OF ORANGE, NEW JERSEY, ASSIGNORS TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

DUPLEX RADIO SYSTEM.

Application filed August 18, 1922. Serial No. 582,766.

This invention relates to an improvement in duplex radio signaling, and in particular has for its purpose that of enabling a better and more complete separation of the transmitted and the received waves.

In duplex radio signaling, especially in those cases where one antenna is used for the transmitted and received signals, the enormous value of the ratio of the transmitted power to the received power makes the problem of separation an extremely difficult one. In this invention we propose to use one frequency for transmitting and a slightly different frequency for receiving. Heretofore, in such cases, reliance has been placed for separation mainly on the discrimination which is afforded by tuned circuits. However, if the tuning of such circuits is made too sharp and selective, the range of frequencies transmitted by the respective circuits is too narrow for practical signaling purposes. This is especially true in the case of radio telephony, for in that case the band of frequencies transmitted or received must be at least as wide as the speech range of frequencies which is to be transmitted. Normally this speech band is about 2,500 wide, and if the carrier frequency is, for example, 100,000, then the transmitted or received oscillations will vary from about 97,500 to about 102,500. This means that the antenna and associated circuits should not be tuned too sharply; otherwise important parts of the signal will be substantially eliminated. The usual method heretofore for obtaining sufficient width for these circuits is to refrain from too sharp tuning, either of the antenna or its associated circuits. But in "flattening" the tuning of the circuits, discrimination is lost so far as frequencies outside of the desired range is concerned. As a result, it is extremely difficult to obtain satisfactory separation of the transmitted and the received oscillations. Conditions, so far as this discrimination or separation is concerned, may, of course, be improved by separating the frequencies of transmission and reception, but such separation means that a larger portion of available frequencies is required for one signaling channel. One object of this invention is to bring the transmitted and the received fre-

quencies closer together and still permit of satisfactory separation.

In this invention we propose to make use of the peculiar characteristics of wave filters which have the property of transmitting or suppressing certain bands of frequencies, and which at the same time enable a sharp cut-off at any desired point. Such wave filters have been used heretofore in radio and other circuits in various places, but in this invention we propose to use them in combinations to bring out their inherent selective properties to the best advantage.

The invention will be better understood by reference to the accompanying drawings, in which Figure 1 shows one form of circuit for duplex signaling; Fig. 2 shows a modification thereof; and Figs. 3^a to 3^c show various forms of wave filters with their characteristics which may be used in one place or another as disclosed hereinafter.

Referring more particularly to Fig. 1, there is shown an antenna 5 which is used both for transmission and reception. The first of these may, for example, take place on a frequency of 525,000 and the second on a frequency of, say, 500,000. This antenna may be tuned with sufficient flatness to be sensitive to both of these frequencies with their associated side bands, or it may be given two degrees of freedom, one of these corresponding to the transmission frequency and the other to the reception frequency, for both of these frequencies the tuning being sufficiently broad for the passage of the necessary band of frequencies required for signaling purposes. Associated with this antenna is a circuit adapted to take off the received oscillations or impress the transmitted oscillations, this circuit in turn being associated with some remote subscriber's station, the message coming in and going out on a line L. This line L may be associated with the local circuits for duplex operation by means of the standard hybrid coil 7 and balanced network N. From two terminals of the coil 7 come a pair of conductors 8, leading to a filter which we here designate as a low-pass filter 9, adapted to pass all frequencies of importance to speech signaling, that is, all frequencies less than 2500. From this filter the circuit leads to an amplifier

10 which may be of any suitable form but is preferably of the thermionic vacuum tube type. A radio frequency oscillation generator 12 is arranged to impress oscillations on a
 5 modulating device 14, which latter is preferably of the thermionic vacuum tube type. The amplified speech signals are also, by means of the transformer 15, impressed on the input circuit of the device 14 and in
 10 series with the oscillations from the generator 12. The device 14 is a modulator by virtue of its distorted or curved characteristic and will contain in its output circuit, among other things, a modulated wave on a
 15 carrier of 525,000 cycles. If s_1 be taken to represent the variable frequency of the speech message to be transmitted, the modulated wave will consist of three components whose values will be f_1 , $f_1 + s_1$ and $f_1 - s_1$,
 20 where f_1 represents the carrier frequency which is here taken as 525,000. These modulated waves will now be impressed upon and radiated from the antenna 5 by virtue of a transformer coupling including the coils 17
 25 and 18. The condenser 19 may be used in addition to the coil 17 for the purpose of tuning this circuit to any desired frequency. Received signals consisting of some carrier frequency f_2 , with the corresponding modulated side bands $f_2 + s_2$ and $f_2 - s_2$, will
 30 be received by the antenna and impressed on the output circuit of the modulating device 14. By virtue of its curved characteristic, this device will also act as a demodulator to give certain frequencies including, among
 35 others, sum and difference frequencies of the received signals and the signals to be transmitted. If, for example, the person at the remote end of the line L is silent, there will
 40 be present in the output of the device 14 oscillations of frequency f_1 . These, combining with the incoming signals, will give the difference frequencies $f_1 - f_2$ and $f_1 - f_2 \pm s_2$. In the case assumed, $f_1 - f_2$ has the value of
 45 25,000 but this may be made any value desired, although we prefer to have it of fairly low ultra-audio frequency, for reasons which will appear later. For convenience, this intermediate frequency $f_1 - f_2$ will be
 50 designated by f_3 . Associated with the circuit of the device 14 by means of a transformer 20 is a circuit which leads to a detecting device. This circuit comprises first a band exclusion filter 22 which has the
 55 property of excluding any band of frequencies for which it may be adjusted, and in this case it is adjusted to exclude frequencies in the neighborhood of f_1 and f_2 but in such a manner as to permit freely the passage of the intermediate frequency f_3 and its associated side bands. Following this, there
 60 is inserted a band filter 23 which passes the intermediate frequency and its side bands but is adjusted to cut off as sharply as possible on both sides. The circuit now leads to

an amplifier 24, then to a second band filter 25 of the same properties as the filter 23. The output of the filter 25 is impressed on a detecting device 26 which may be of any
 70 desired form, although again we prefer the thermionic vacuum tube type. The output of this device 26 will contain a plurality of different oscillations among which will be the message s_2 , and to permit the ready passage of this message but the suppression of
 75 all other frequencies, there is now inserted in the line a filter 27, preferably of the low-pass type, allowing all frequencies below, say, 2500 to pass. From here the circuit goes to the conjugate terminals of the coil 7, thus
 80 permitting a message to be transmitted to the remote speaker.

In the description thus far we have spoken of the use of different types of filters. Such filters are described fully in the patents to
 85 Campbell, No. 1,227,113, May 22, 1917, and No. 1,493,600, dated May 13, 1924. Without desiring to go into a detailed explanation of these, reference may be made to Figs. 3^a to 3^c, which will illustrate the characteristics
 90 of these filters. If the filters for example, be constructed of a series of elements consisting of an inductance L in series and a capacity C in shunt, the circuit will have the properties of a low-pass filter, that is, it will
 95 permit all frequencies below a certain value to pass but will suppress all frequencies above that value as indicated in the characteristic curve of Fig. 3^a. The sharpness of the cut-off will be increased by using inductances and capacities of very low resistance values, and it is the intention in this invention that filters with sharp cut-off characteristics shall be used. By increasing the
 100 complexity of the filter arrangement so that each element of the filter consists of an inductance and capacity in series with each other in the line, and of an inductance and a capacity in parallel to each other and in shunt to the line, a filter may be obtained
 105 which permits the passage of a band only as indicated in the curve of Fig. 3^b. Such a filter has been termed a band-pass filter and with suitable precautions the cut-off may be made such as to give a selectivity far surpassing that obtainable with tuned circuits. Fig. 3^c indicates the structure for a band-exclusion filter. In this case, the series elements comprise an inductance and capacity in parallel to each other, and the shunt elements comprise an inductance and capacity in series with each other. The characteristic then obtained is as indicated by the curve of Fig. 3^c, where frequency is again plotted as abscissæ and attenuation as
 110 ordinates.

In view of the large voltages of the transmitting frequency present in the circuit of the modulator 14, it is necessary to provide some protection for the amplifier 24 and it
 130

is for this reason that we insert the band-exclusion filter 22, this serving to take up or suppress the high voltage transmission oscillations. This high voltage filter is desirable also to protect the band-pass filter 23, which is designed essentially for passing the intermediate frequencies f_3 and $f_3 \pm s_2$, but which, in general, is not constructed to withstand such high voltages as would otherwise be impressed upon it. Having now suppressed these high frequency high voltage currents, it is possible to rely on the band filter 23 to transmit only those frequencies which lie in a band of width $2s_2$ and having f_3 as its mid-value. If this f_3 is in the neighborhood of some tens of thousands, a filter can be constructed which is extremely selective, that is, having extremely sharp cut-off points.

Obviously, the output from the filter 23 may pass directly to the detector 26. However, as in the figure, we prefer to use an amplifier and an additional wave filter. The filter 23 in front of the amplifier 24 serves the added function of protecting the amplifier from excessive power which might possibly come in, of frequencies either above or below the band which is passed. At the same time, the band filter 25, following the amplifier, performs the function of suppressing any additional frequencies which may be developed in the circuit of the tube 24 by virtue of the fact that it is not a perfect amplifier. While the low-pass filter 27 is not absolutely essential in this circuit, we desire to use it to suppress such high frequencies as will be generated in the circuit of the detector 26. If such oscillations were permitted to pass, they would, in general, find sufficient unbalance in the coil 7 to permit the passage of such frequencies into the circuit 8 with the possibility that the transmitting and receiving circuits will oscillate at some undesired frequency. With such a filter as 27, however, this is prevented and the oscillations which do pass the filter will find a well balanced coil at 7, permitting the ready transmission of the signal s_2 to the remote end of the line.

It is evident that in case the message s_1 is coming forward at the same time as s_2 is received, modulated signals for s_2 will still be transmitted through the receiving circuit and be carried to the speaker. It will thus be evident to the speaker that the party at the other station is endeavoring to speak.

In Fig. 2 we have shown a modification of the circuit arrangement. The message s_1 is, as before, impressed on a low-pass filter 9 and an amplifier 10. An oscillator 32, preferably of the thermionic tube type, is supplied to generate oscillations of the transmitting frequency f_1 , which may in this case be taken as 525,000. A modulating device 34 is associated with the oscillator in any

suitable manner, as, for example, in the well-known Heising shunt circuit which is shown in this figure. The amplified signal s_1 from the amplifier 10 is then impressed on the modulator 34 and as a result there exists in the output circuit of the tube 32 modulated oscillations of the frequency f_1 and $f_1 \pm s_1$, which may then be radiated as before.

Incoming modulated messages on the carrier f_2 are received on the antenna and picked up by a circuit 36 tuned to the carrier f_2 , by which these oscillations may be impressed on the grid of the oscillator 32. There will then be a modulation in the oscillator circuit of the locally generated frequency f_1 and the received signal giving, among other things, the intermediate frequencies $f_1 - f_2$ and $f_1 - f_2 \pm s_2$. These oscillations of intermediate frequency are transmitted by means of the transformer 37 to a receiving circuit which we have shown as consisting of a low-pass filter 38, a band-pass filter 39, an amplifier 40, a band-pass filter 41, a detector 42 and a low-pass filter 43. These various elements have the following properties and functions. The low-pass filter 38 has a cut-off which may be in the neighborhood of 30,000. The band-pass filter 39 has a mid-value of $f_1 - f_2$, which in this case is 25,000, and the width of this filter is such as to just permit the passage of the band $f_1 - f_2 \pm s_2$. The filter 41 has the same properties as the filter 39. The detector 42 may be of any suitable form, such as the thermionic type, and detects the modulated intermediate frequency down to the speech signal. The low-pass filter 43 transmits all frequencies below 2500 and suppresses all others.

The low-pass filter 38 performs the same function as the band-exclusion filter of Fig. 1. In general, it may be stated that filters which cut off on one side only and which have fewer elements, as seen from Fig. 3^a, can be constructed to withstand higher voltages and also with sharper cut-off characteristics. It is desirable, however, to follow this filter 38 with a band-pass filter to eliminate such low frequencies as may be set up in the circuit of the oscillator 32, of which there will be certain ones. The arrangement of two band-pass filters with an amplifier between has the same desirable properties as indicated in connection with Fig. 1.

Having now described our invention, what is claimed is:

1. In a duplex high frequency signaling system, a transmitting and receiving circuit, a modulating-demodulating circuit associated therewith comprising a vacuum tube, the plate circuit of said tube carrying the oscillations to be transmitted and the received oscillations and acting to demodulate said received oscillations to an intermediate frequency, a band-excluding filter connected

with the said plate circuit to suppress the transmitting and receiving frequencies and to pass the demodulated oscillations, a band-passing filter to pass the intermediate frequency, and a detector for demodulating said passed intermediate frequency.

2. In a duplex radio telephone system, an antenna, a transmitting circuit associated therewith, means for separating the transmitted and the received signals comprising a filter adjusted to exclude the transmitting and the received frequencies, and band filters in series therewith to pass an intermediate frequency produced by beating the received frequencies with the transmitting carrier frequency.

3. In a duplex radio telephone system, a transmitting and receiving antenna adapted to transmit on one frequency and receive on a different frequency, means for generating and impressing modulated high frequency oscillations on said antenna, said means comprising a vacuum tube circuit, said vacuum tube circuit having means to receive and demodulate the incoming signals to an intermediate frequency equal to the difference between the transmitting and the receiving frequency, and a filter for separating out the intermediate frequency, said filter comprising a band filter excluding the transmitted and received frequency in series with a band filter passing the intermediate frequency only.

4. In a duplex high frequency telephone system, a transmitting and receiving circuit, a vacuum tube associated therewith for impressing on the circuit the oscillations to be transmitted and for demodulating the received oscillations, a receiving circuit associated with said tube, a filter for suppress-

ing the high voltage transmitting oscillations, and a band-pass filter for passing the demodulated frequencies.

5. In a duplex radio telephone system adapted to transmit on one frequency and receive on another frequency, a transmitting and receiving circuit, a vacuum tube having a source of oscillations associated therewith for impressing on the circuit the oscillations to be transmitted and for demodulating the received oscillations to an intermediate frequency equal to the difference between the transmitting and the received frequencies, a receiving circuit associated with said tube, and a filter therein for suppressing the received and transmitted frequencies and a band-pass filter for passing the intermediate frequency.

6. In a duplex radio telephone system adapted to transmit on one frequency and receive on a different frequency, an antenna, a transmitting and receiving circuit, a vacuum tube having a source of oscillations associated therewith for impressing on the antenna the oscillations to be transmitted and for demodulating the received oscillations to an intermediate frequency equal to the difference between the transmitted and received frequencies, a receiving circuit associated with said tube, a filter for suppressing the high voltage high frequency oscillations, and a band-pass filter in series therewith for passing the intermediate modulated frequency, and a detector for demodulating said last frequency to the message frequency.

In testimony whereof, we have signed our names to this specification this 14th day of August, 1922.

LLOYD ESPENSCHIED.
DE LOSS K. MARTIN.