L. ESPENSCHIED.

LOW FREQUENCY AMPLIFIER.

APPLICATION FILED SEPT. 26, 1919.

1,428,156.

Patented Sept. 5, 1922.

3 SHEETS—SHEET 1.

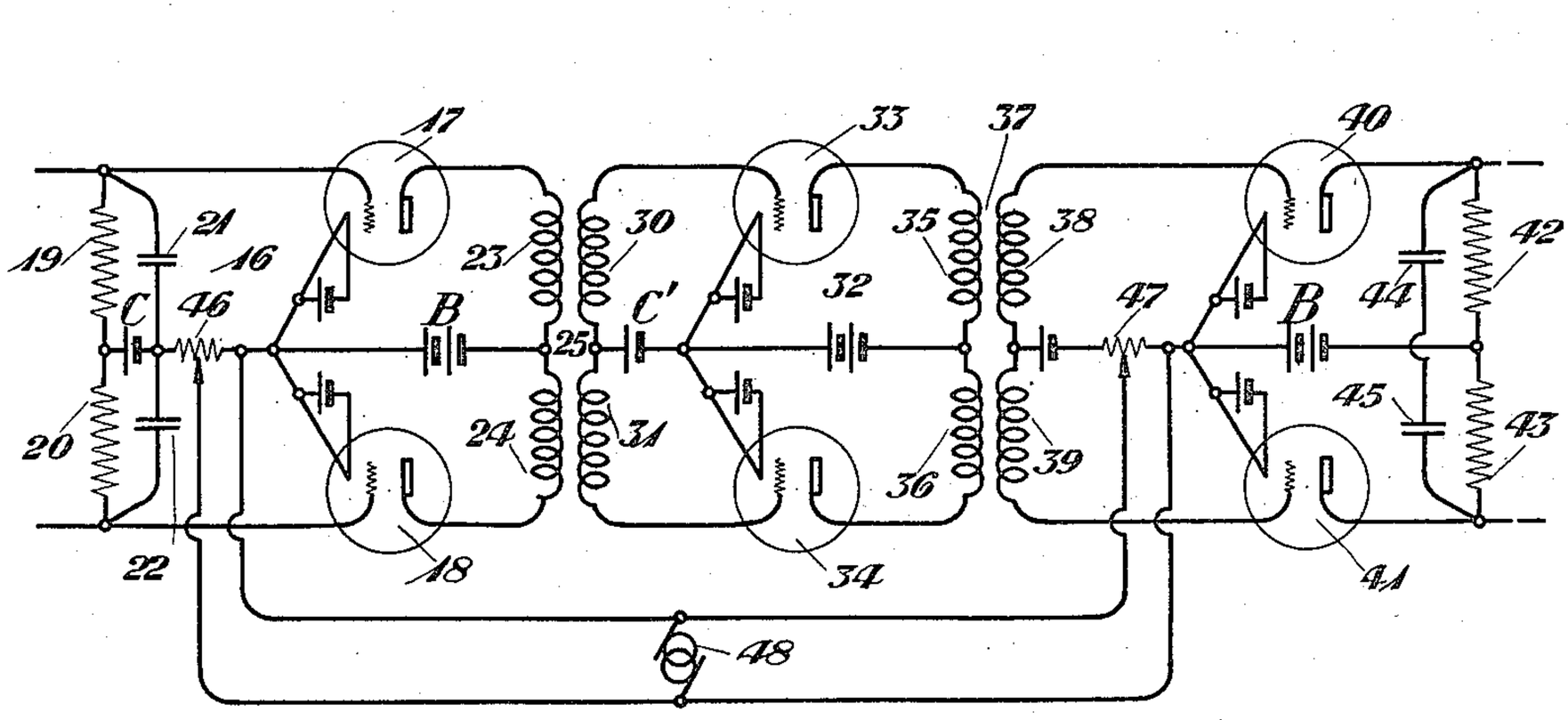

Fig. 1

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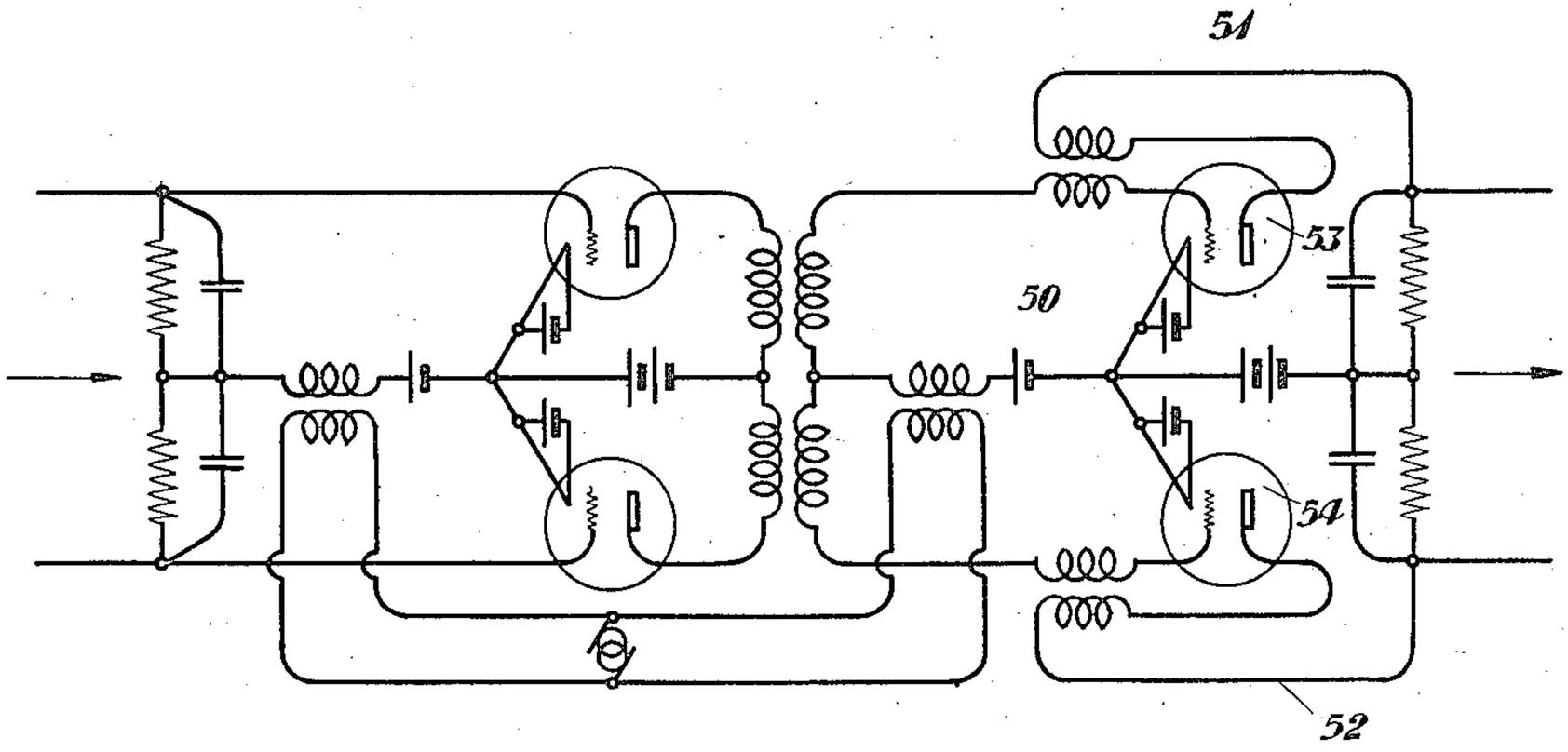

Fig. 2

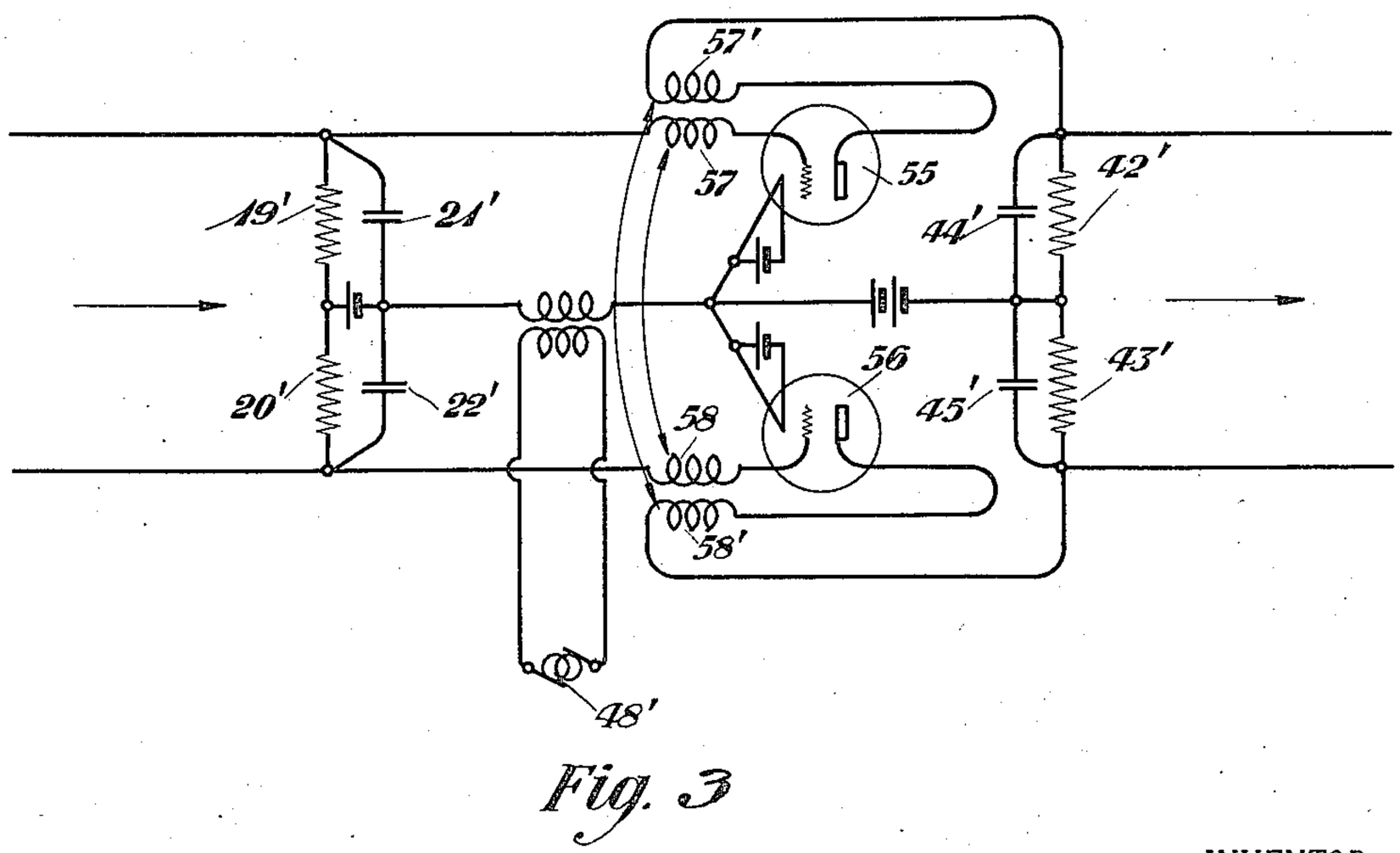

Fig. 3

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3 SHEETS—SHEET 3.

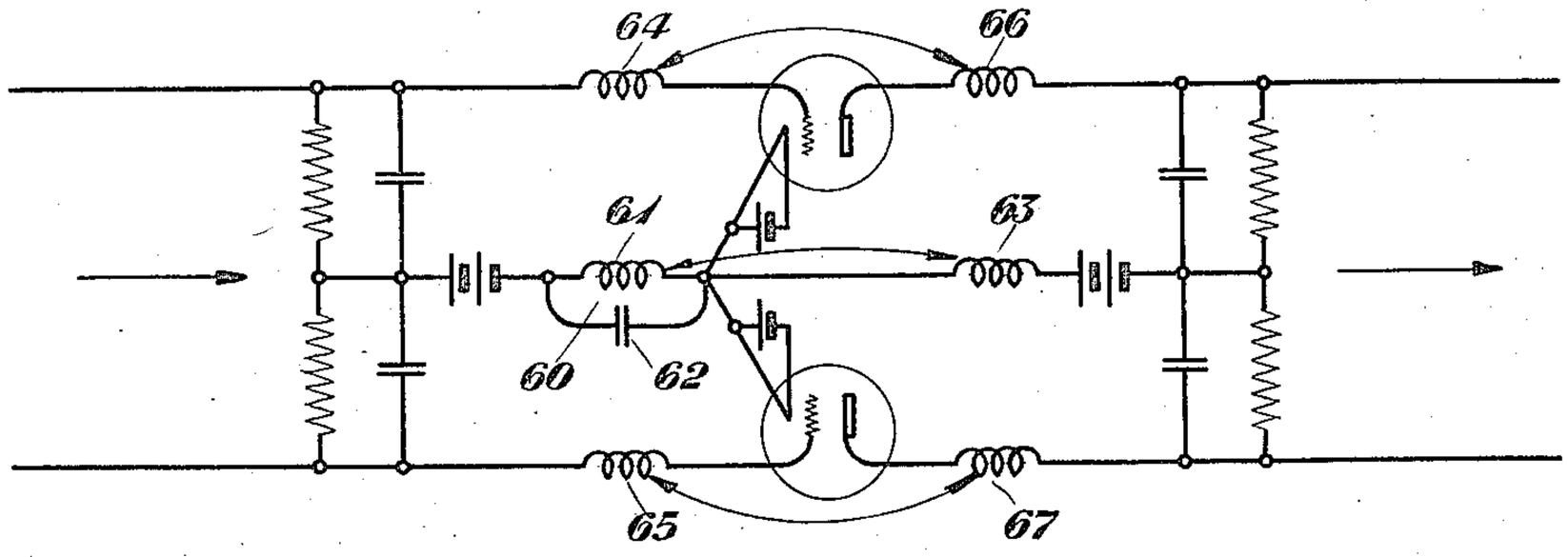

Fig. 4

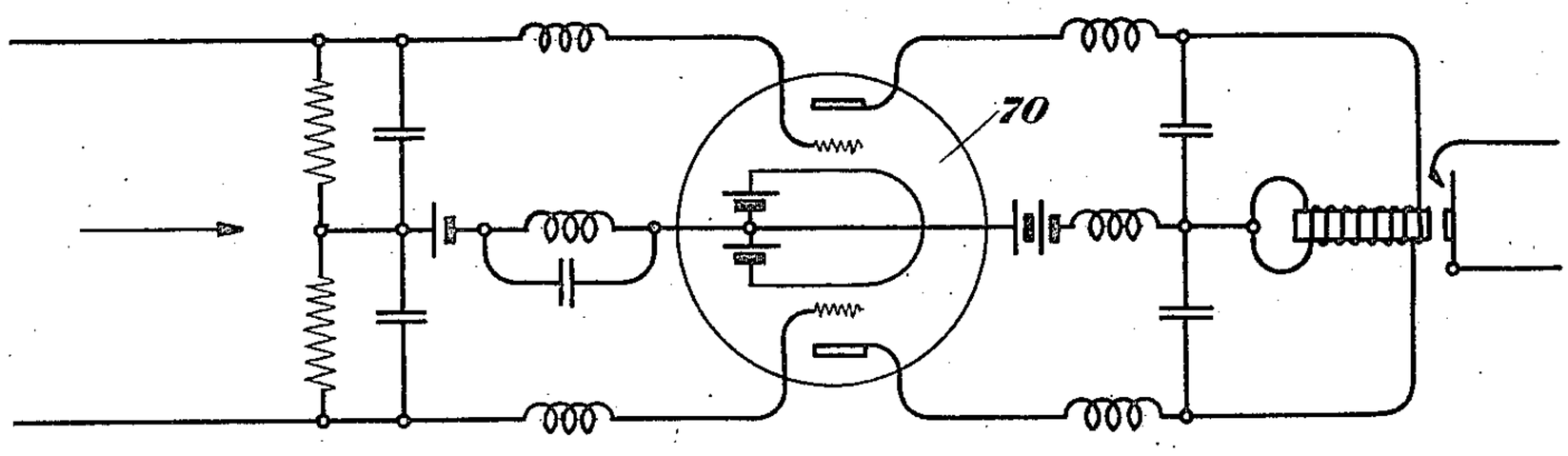

Fig. 5

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Patented Sept. 5, 1922. 1,428,156

UNITED STATES PATENT OFFICE.

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

LOW-FREQUENCY AMPLIFIER.

Application filed September 26, 1919. Serial No. 326,526.

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 Low-Frequency Amplifiers, of which the following is a specification.

This invention relates to the amplification of low frequency signals, such, for example, as ocean cable, telegraph signals or those emanating from the propeller or engine noises in submarine detection. Such signals have a large or predominating direct current or very low frequency component which is not transmitted or inefficiently transmitted through the ordinary repeating coils used in the local circuits of thermionic amplifiers. An object of the present invention is to provide an arrangement for amplifying signals of this character which will amplify all low frequencies, including the direct current, without the necessity of a metallic connection between the successive stages of the amplifier and without the attendant difficulty of preventing the output battery of one stage from affecting the input circuit of the succeeding stage. The invention in many of its aspects is equally applicable to the amplification of signals in any order of frequency. For example, it may even be found advantageous to amplify the voice frequencies of ordinary telephone currents by means herein described.

A further object of the invention is to increase the amplification to telephone currents or to carrier currents over that obtainable by the usual vacuum tube amplifying circuits, by the use of feed-back circuits.

In general, the invention consists in the modulation of an alternating current, of a frequency say of 1,000 cycles per second or higher, by the incoming signal impulses, the amplication of the modulated alternating current and the demodulation of the amplified current.

In the accompanying drawings, Figure 1 illustrates diagrammatically one embodiment of the invention. Figure 2 shows a modification in which the amplifying and demodulating functions are combined, and Figure 3 a modification in which the three functions are accomplished by a single duplex tube. The Figures 4 and 5 represent modifications of the arrangement shown in Figure 3.

In Fig. 1, an alternating current of a readily amplifiable frequency is modulated by the incoming signals in the circuit of the duplex tube 16. This circuit comprises the two tubes 17 and 18, each having its grid connected to one side of the line and its filament connected to a neutral point provided by the resistances 19 and 20 connected across the line, and the condensers 21 and 22 connected in parallel with said resistances; and each having its plate connected to a winding, 23—24, whose other terminal is connected to the filament through the battery B, the two windings constituting the primary of a transformer 25. The battery C for adjusting the potential of the grids of the tube 17 and 18 may be connected in the common portion of their input circuit as shown.

The secondary of the transformer 25 comprises two windings 30 and 31, each having one terminal connected to a grid of a duplex amplifier 32, and its other terminal connected to the filaments of the two tubes through a common conductor which may contain a battery C′ for controlling the grid potentials of the two tubes 33 and 34 of the duplex amplifier. The output circuits of the tubes 33 and 34 contain the two windings 35 and 36 acting as the primary of transformer 37, whose secondary consists of the two coils 38 and 39 which are respectively in the input circuits of the tubes 40 and 41, these tubes being connected in the opposite sides of a duplex circuit, in general similar to the circuit containing the tubes 33 and 34, but with the output circuit connected directly to the line conductors for forwarding the amplified signals. In this output circuit the common point for the connection to the filaments in the battery B″ is provided by equal resistances 42 and 43 connected across the line and condensers 44 and 45 connected in parallel with the resistances.

A resistance 46 is inserted in the common portion of the input circuit of the tubes 17 and 18 and a similar resistance 47 is inserted in the common portion of the input circuits of the tubes 40 and 41, and the source of alternating current 48 of any convenient frequency, say 1,000, is connected across a part or all of each of the resistances 46 and 47. The connection to each resistance is preferably made adjustable, as indicated.

In the operation of the circuit shown in Fig. 1, the current from the alternating

source 48 is normally ineffective in the transformer 25 due to its equal and opposite effect in the windings 23 and 24. When, however, this current is modulated by an incoming signal, the balance of the windings 23 and 24 is disturbed and a modulated alternating current is transmitted to the duplex amplifier 32, and the amplified current is passed on through the transformer 37 to the duplex demodulating tube, 40—41. The combined effect of the alternating current applied from the source 48, through the resistance 47 and the modulated alternating current received through the transformer 37, is to eliminate the alternating current of the frequency derived from the source 48, leaving in the output of the tubes 40 and 41 only a signal current of precisely the form arriving at the input of the tubes 17 and 18, but amplified.

It will be understood that a certain amount of amplification is secured in each of the three sets of tubes shown in Figure 1. By properly arranging and proportioning the circuit one or more of the sets of tubes there shown may be eliminated. Thus in Figure 2, the amplifying and demodulating is accomplished in a single duplex circuit 50. The modulation and demodulation is accomplished here in the same way as in Figure 2 and the circuits are the same and therefore require no special description. The amplification is increased to the desired point by providing the feed-back circuits 51 and 52 for the tubes 53 and 54 respectively. This circuit in itself is not new and consists in a connection, here shown as inductive, between the input and output circuits of the tubes.

In Figure 3 the modulating, amplifying and demodulating is all accomplished by the single pair of tubes 55 and 56 connected in a duplex circuit comprising the input elements 19′, 20′, 21′, 22′, and the output elements 42′, 43′, 44′ and 45′, similar to the corresponding input and output elements at the opposite ends of the circuit shown in Figure 1. Feed-back circuits similar to those shown in Figure 2 are here used for increasing the amplification and in order that the modulation and demodulation may be secured through the same pair of tubes, two windings such as 57 and 57′ forming the connections for each feed-back circuit should also be inductively related, and the two sets of windings for the two tubes may be likewise related, as indicated by the arrows. The windings should be so mutually poled and the coupling so proportioned as to establish a transverse non-oscillating feed-back circuit. Since the modulation and demodulation is accomplished in the same pair of tubes, a single connection only is necessary between the duplex circuit, the alternating source 48′. This is here shown as inductive though a direct connection as in Figure 2 may be used.

Figure 4 shows a circuit similar to Figure 3, except that it is arranged to generate its own alternating current by using the tubes as oscillators. This is accomplished by properly tuning the circuit 60 containing inductance 61 and capacity 62, and here shown as in the input circuits of the tube. The inductance 61 is in inductive relation to the inductance 63 in the output circuit of the tubes. This connection causes the circuit to oscillate longitudinally with the two tubes operating in division and in the same phase. The transverse and non-oscillating feed-back connection between the input and output circuits are formed by inductively relating windings 64 and 65 in the input circuits and windings 66 and 67 in the output circuits of the respective tubes.

Figure 5 corresponds to Figure 4, except that a single duplex tube 70 is used for the duplex circuit instead of the double duplex tube arrangement. The output circuit is here shown with a relay for either the local reception of the signals or the repetition of them into another line.

The circuit arrangements described above may be employed also for amplifying telephone currents, or carrier currents which carry as a modulation either telephone or telegraph signals. For such use it is necessary to employ in the amplifier a modulating-demodulating frequency high compared with the telephone or carrier currents to be amplified. By so doing the band of frequencies occupied by the signaling currents themselves is made small in reference to the carrier frequency employed internally in the amplifier, and the advantage of increased amplification given by feed-back circuits may be obtained without sensible distortion in the band of frequencies representing the signaling currents.

Various modifications of the circuits herein shown and described may manifestly be made without departing from the spirit of the invention.

What is claimed is:

1. An amplifying circuit for signalling currents comprising a modulating device connected to the incoming circuit, an amplifier having its input circuit operatively related to the output circuit of said modulating device, a demodulating device having its input circuit operatively related to the output circuit of said amplifier, and its output circuit connected to the outgoing line, and a source of alternating current of a frequency suitable for amplification in said amplifying device, connected to the input circuit of the modulating device, and to the output circuit of the demodulating device.

2. An amplifying circuit for signalling currents comprising a modulating device

connected to the incoming circuit, an amplifier having its input circuit inductively related to the output circuit of said modulating device, a demodulating device having its input circuit inductively related to the output circuit of said amplifier, and its output circuit connected to the outgoing line, and a source of alternating current of a frequency suitable for amplification in said amplifying device, connected to the input circuit of the modulating device, and to the output circuit of the demodulating device.

3. In an amplifier for low frequency or direct current signals, a vacuum tube modulating device connected to the incoming circuit, a vacuum tube amplifier having its input circuit inductively related to the output circuit of the modulating device, a demodulating vaccuum tube device having its input circuit inductively related to the output circuit of the amplifier and its output circuit connected to the outgoing line, and a source of alternating current connected to the input circuit of the modulating device and to the input circuit of the demodulating device.

In testimony whereof, I, have signed my name to this specification this 25th day of September, 1919.

LLOYD ESPENSCHIED.