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D. F. WHITING

WAVE TRANSMISSION SYSTEM

Filed March 22, 1926

Fig. 1

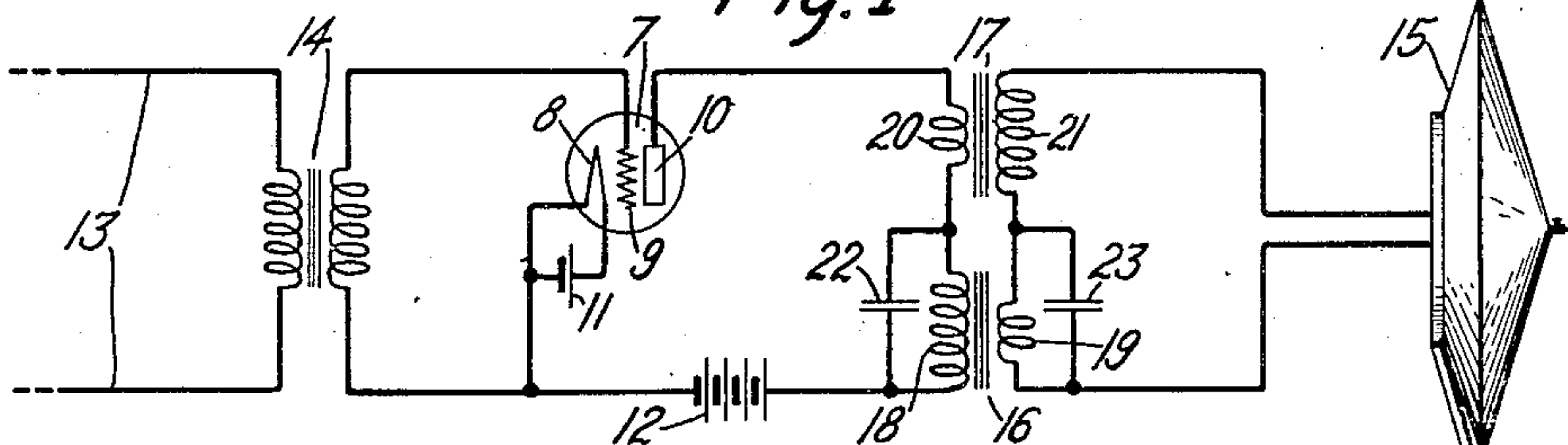


Fig. 2

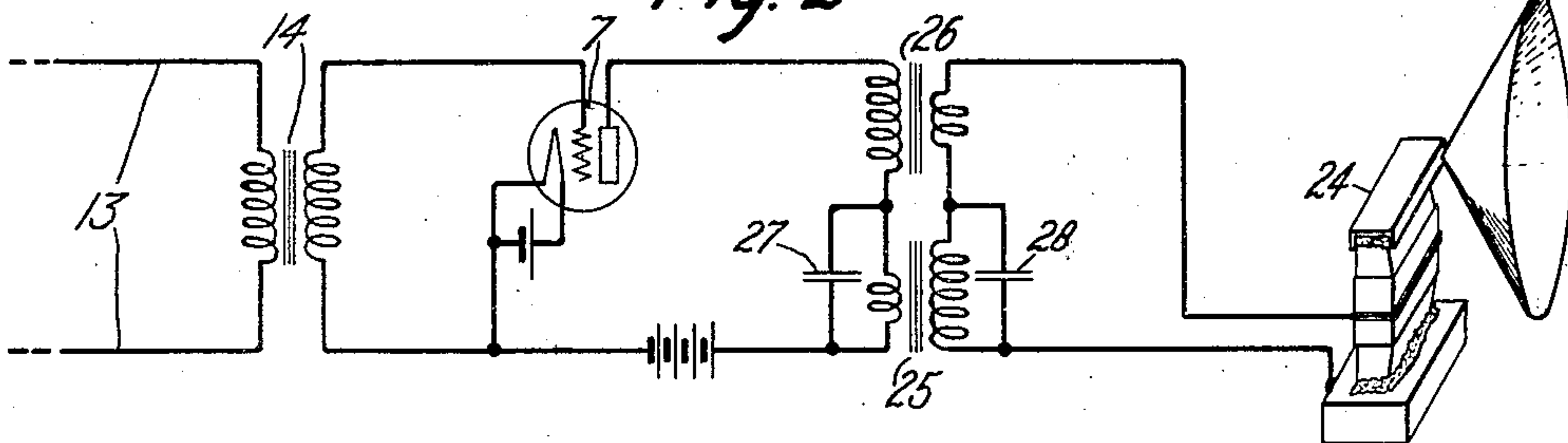


Fig. 3

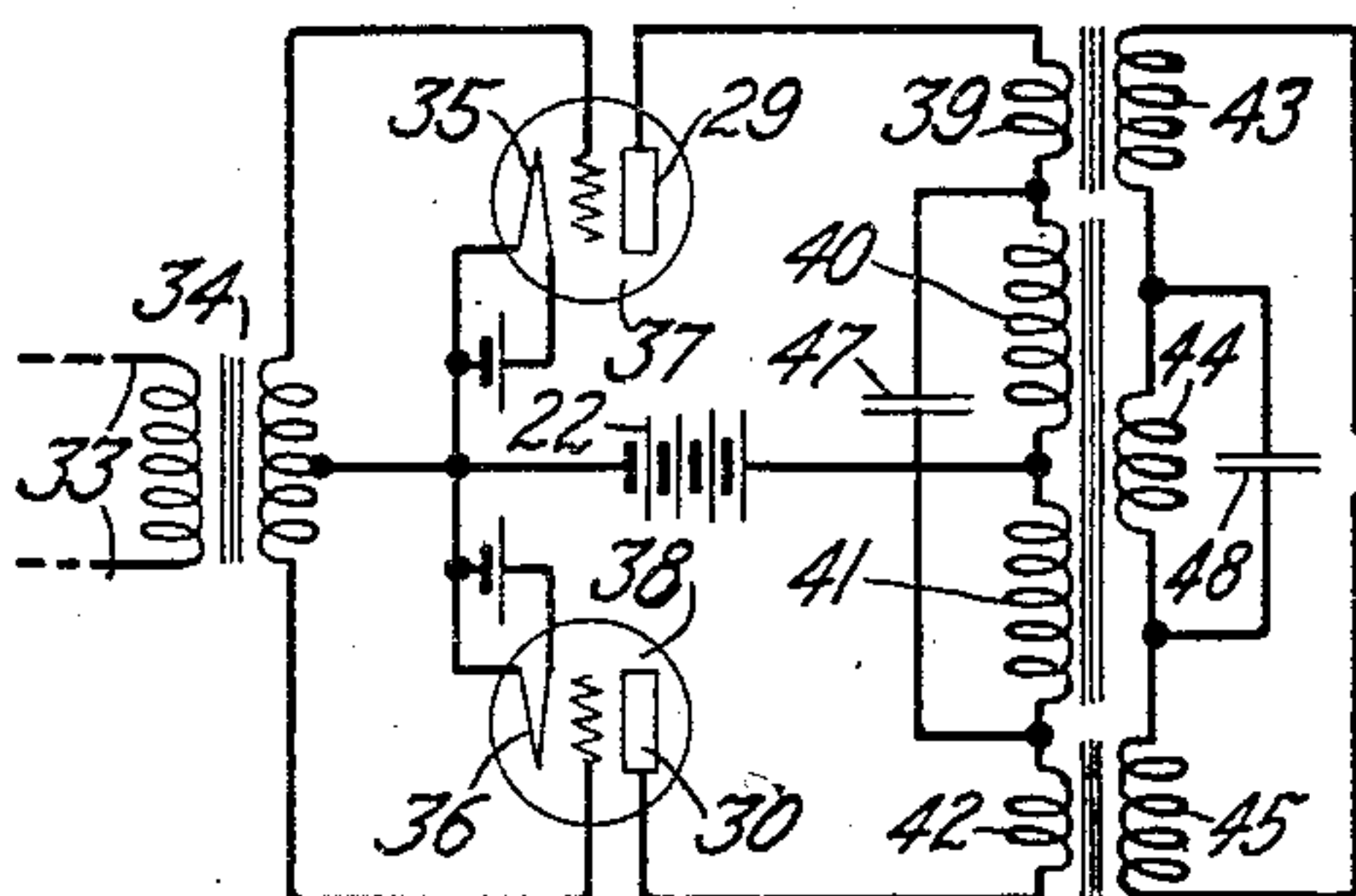


Fig. 4

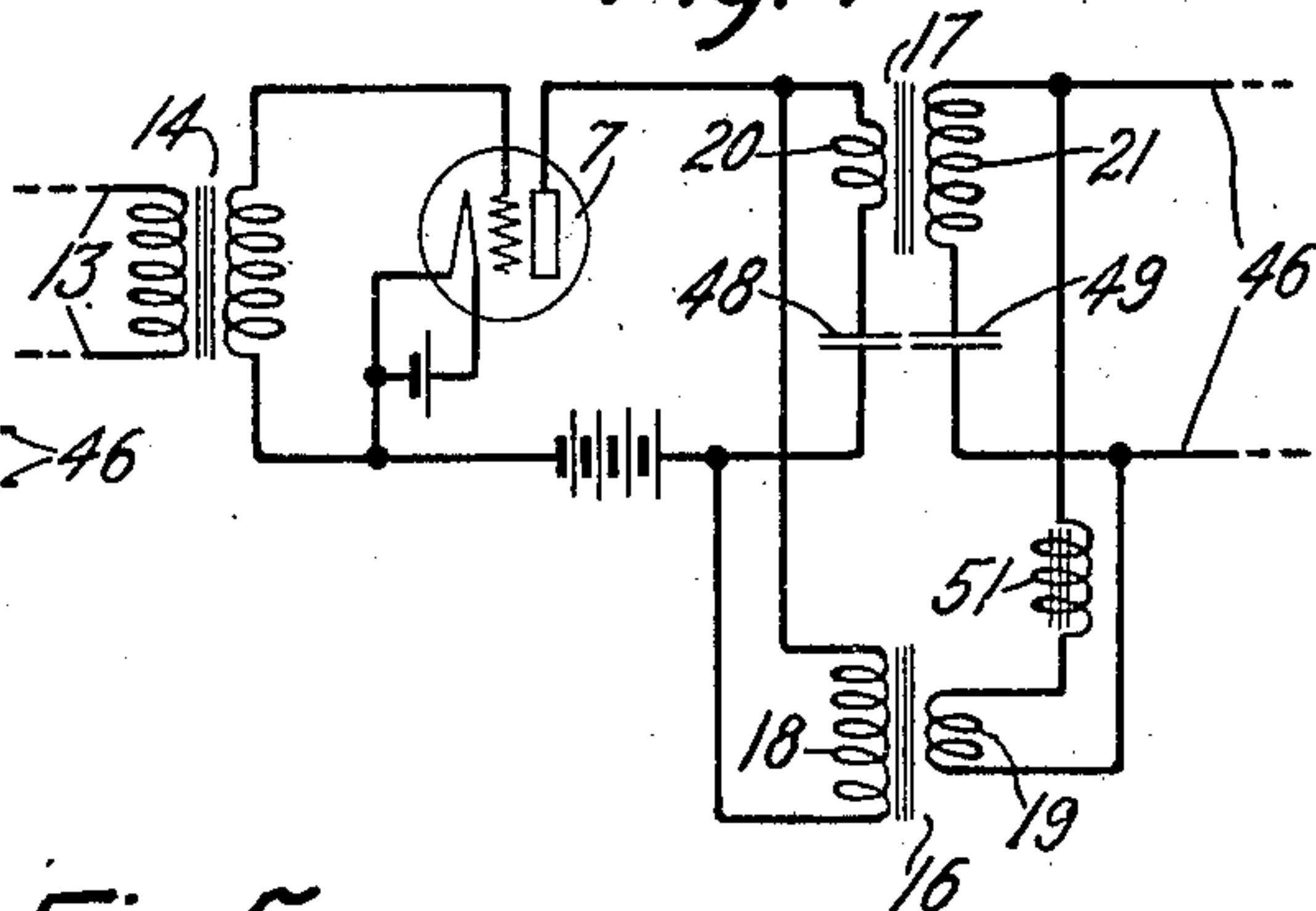
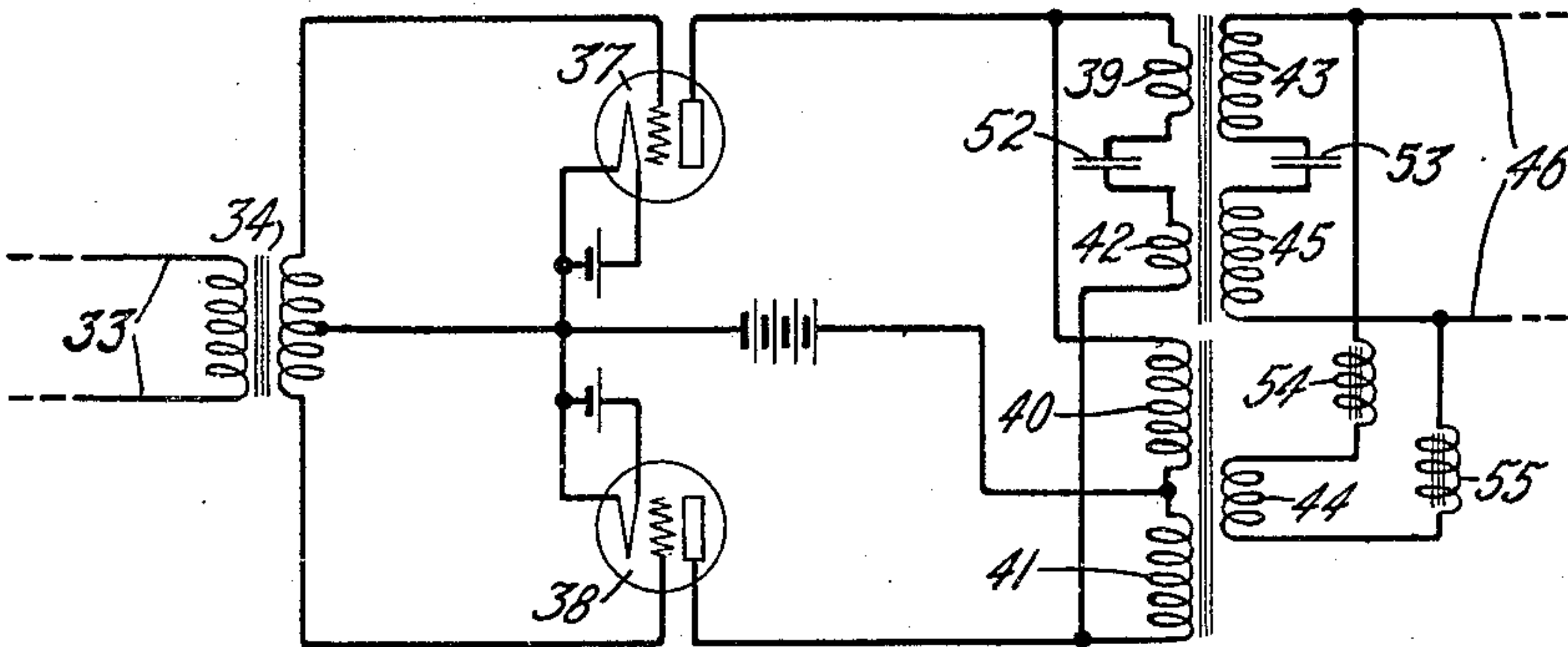


Fig. 5



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UNITED STATES PATENT OFFICE.

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WAVE TRANSMISSION SYSTEM.

Application filed March 22, 1926. Serial No. 96,418.

This invention relates to wave transmission, and relates particularly to transmitting complex waves, such as waves representing speech or music.

5 An object of the invention is simplicity and efficiency in transmitting waves of a plurality of frequencies without undue distortion, such as, for example, distortion created by generation of waves of other frequencies.

10 It is also an object of the invention to efficiently transmit complex waves, or waves having components which are of different frequencies, such as, the complex waves instanced above, without undue distortion either of the particular type just mentioned or other type, as for example, the type of distortion due to transmission of components having different frequencies with different degrees of transmission efficiency.

15 It is also an object of the invention to couple the output of an electron discharge device to a receiver circuit to efficiently transmit speech or music waves without distortion.

20 In high quality reproduction of speech and music it is necessary that the reproduced waves throughout a wide frequency range be essentially of the same relative amplitude as the original sound waves and also that no waves of frequencies which were not originally present be introduced. Consequently it is necessary not only that the circuit used should uniformly transmit waves of all frequencies within the desired range but also that no new frequencies be produced. When electron discharge devices are employed, it is therefore essential that they should not be overloaded so as to produce harmonic products of the waves transmitted.

25 The wave spectrums of speech and music contain ranges in the neighborhood of 170 cycles per second and 64 cycles per second respectively, in which the energy level is normally several times higher than that which obtains over the remaining portion of the spectrum. The electron tube circuits must therefore be designed so as not to overload at these frequencies which impress the greatest amplitude on the grid, while at the same time amplifying waves throughout the entire spectrum substantially uniformly.

30 As has been pointed out, for example, by

W. J. Brown on page 289 of the March 1924 issue of the "Journal of the Institution of Electrical Engineers", London, the maximum distortionless output of a vacuum tube is obtained when the tube is operating into a load having an impedance about double that of the tube. However, it is often necessary to use vacuum tubes in connection with output circuits having reactive impedances, such for example, as loud speaking receivers or transmission lines, and if this impedance ratio is set up for the low frequencies, at which the energy level is highest, a considerable undesired loss due to mismatched impedances will occur at the higher frequencies at which the load impedance is greatly different. If the impedance of the tube and load circuit be matched at some intermediate frequency there results premature overloading of the tube at the lower frequencies and still a considerable transition loss at the higher; and even if an equalizing arrangement be employed for matching the impedances throughout the larger portion of the range there still results a premature overload at the lower frequencies.

35 In accordance with one specific aspect of this invention there is provided a coupling means having such an impedance ratio at low frequencies that the impedance into which the tube works is preferably about double the impedance of the tube and having such a ratio at high frequencies that the impedance into which the tube works is preferably about equal to its own impedance. Other objects, aspects and features of the invention will be apparent from the following description of specific examples of systems utilizing features of the invention, taken in connection with the claims and with the drawings.

40 Figs. 1, 3, 4 and 5 show transformer arrangements according to this invention for coupling a tube to a load having an inductive impedance, and Fig. 2 shows a transformer arrangement for coupling a tube to a load having a capacity impedance.

45 Fig. 1 shows a vacuum tube 7 having a cathode 8, a grid 9 and plate 10. The cathode is heated in the usual manner by current supplied from a battery 11. A second battery 12 is connected in the plate circuit for supplying plate current. The waves to

be amplified are impressed from the line 13 through an input transformer 14 onto the grid circuit. The amplified waves are impressed on an electromagnetic loud speaking receiver 15. Two transformers 16 and 17 having their primary windings 18 and 20 connected in series to the plate circuit of the tube and their secondary windings 19 and 21 connected in series to the receiver are provided for coupling the tube to the receiver. Transformer 16 is designed to have the proper impedance ratio at low frequencies to prevent premature overloading at those frequencies. Condensers 22 and 23 are connected in shunt to the primary and secondary windings, respectively, of this transformer, to provide shunt paths for the high frequency currents. Transformer 17 is designed to give good transmission at the higher frequencies and to have the proper impedance ratio to prevent transition loss in that range.

To aid in the understanding of the invention values typical of those which may be found in practice will be assigned to the various circuit elements. Accordingly, it may be assumed that the vacuum tube has a plate impedance of 4000 ohms and operates into a receiver having an impedance varying from 2000 ohms at the lower frequencies to be transmitted to approximately 50,000 ohms at the higher. In such a circuit, transformers 16 and 17 should have impedance ratios of $\frac{8000}{2000}$ and $\frac{4000}{50000}$ respectively.

Although at the low frequencies the impedance into which the tube works be such as to give the maximum energy output from the tube for those frequencies that is possible without introduction of distortion, and, on the other hand at the high frequencies the impedance into which the tube works be such as to give the maximum possible energy output from the tube, this difference will not cause material distortion of the speech or music by causing the relative amplitudes of the low frequencies and the high frequencies, after reproduction, to be materially different from their relative amplitudes when they are impressed on the system. The transmission loss, or loss of gain, at the low frequencies that is due to the use of the transformer ratio which gives the maximum possible distortionless output from a tube for those frequencies instead of the maximum possible output from the tube for those frequencies, is of the order of one-half transmission unit, which represents a change in the energy of sound not noticeable by the average ear. Thus, ordinarily no compensation or adjustment for the system would be required for the purpose of obtaining substantially uniform transmission efficiency for the low and the high frequencies because of the transformer ratio in the case of the low

frequencies being the ratio for maximum possible distortionless output from the tube at those frequencies and the ratio for the high frequencies being the ratio for maximum possible output from the tube at the high frequencies.

Fig. 2 shows a circuit similar to that of Fig. 1 except that the tube is operating into a loud speaking receiver having a capacity impedance such as for example a piezo-electric loud speaker of the type disclosed in the application of A. M. Nicolson, Serial No. 683,643, filed December 31, 1923. The transformers 25 and 26 are connected in series to the circuit of Fig. 1 in the same manner as the transformers 16 and 17. Transformer 25 is designed to have the proper impedance ratio to prevent overloading at the lower frequency, and its windings are shunted by the condensers 27 and 28 in the same manner as transformer 16. Assuming in this case that the same type of vacuum tube having a plate impedance of 4000 ohms is used and that the impedance of the receiver varies from 50,000 ohms at the lower frequencies to be transmitted, to 2000 ohms at the higher frequencies, transformer 25 should have an impedance ratio of $\frac{8000}{50000}$ and transformer 26 should have an impedance ratio of $\frac{4000}{2000}$.

Fig. 3 shows an amplifier of the push-pull type employing two tubes 37 and 38 connected in the usual manner to receive waves from an input transformer 34. The plate circuits of the tubes are connected to the primary windings 39, 40, 41 and 42 and are in series between the plates 29 and 30 of the tubes 37 and 38 respectively. Windings 39 and 42 together with their corresponding secondary windings 43 and 45 may be mounted on a common core while the windings 40 and 41 and their secondary winding 44 may be mounted on a separate core. A connection is made from the cathodes 35 and 36 of the tubes 37 and 38 to the plate battery 22 to the common connection of windings 40 and 41 so that the output transformer arrangement is symmetrical with respect to the two tubes. The secondary windings 43, 44 and 45 are connected in series to the load circuit 46 which may be a loud speaking receiver such as that shown in Fig. 1 for example. The transformer 40, 41, 44 is designed to give the proper impedance ratio at low frequencies. As condenser 47 is connected in shunt to the primary windings 40 and 41, similarly a condenser 48 is connected in shunt to the secondary winding 44. These condensers provide paths for the high frequency currents. The couplings 39 and 43 and 42 and 45 are designed to give good transmission at the higher frequencies and to have the proper impedance ratio to prevent transition loss

in that range. If the tubes 37 and 38 are similar to those assumed for Figs. 1 and 2, namely, each having a plate impedance of 4000 ohms or an impedance of 8000 ohms for the two, and if an electromagnet receiver having an impedance characteristic such as was assumed for the receiver of Fig. 1 is connected to the load circuit 46, the couplings 39, 42 and 43, 45 should have an impedance ratio of $\frac{8000}{50000}$ while the impedance ratio of the transformer 40, 41 and 44 should be $\frac{16000}{2000}$.

The circuit shown in Fig. 4 employs a single vacuum tube as in Fig. 1 but the transformers 16 and 17 instead of being connected in series are connected in parallel between the plate circuit of the tube and the load circuit 46. Condensers 48 and 49 are connected in series with the primary 20 and secondary 21, respectively, of the transformer 17 to provide high impedance for the low frequency currents. While inductance coil 51 is connected in series with the secondary winding 19 of the transformer 16 to provide a high impedance for the high frequency currents. A separate inductance for this purpose need not necessarily be used but instead the transformer winding may be designed to have high leakage inductance. If the same type of tube and receiver is used as was assumed for the circuit of Fig. 1, the impedance ratios of the transformers should be the same as was used in connection with the transformers of that circuit.

Fig. 5 shows a circuit employing tubes arranged in push-pull relation as in Fig. 3 except that in this case the transformers are connected in parallel rather than in series. A condenser 52 is connected between the windings 39 and 42 and condenser 53 between the windings 43 and 45 to provide a high impedance to low frequency currents. Inductance coils 54 and 55 are connected in series with the secondary winding 44 to provide a high impedance for high frequency currents. Two coils may be used to keep the circuit balanced or this result may also be obtained if the two windings 54 and 55 are wound on the same core. In the low frequency transformer the balanced arrangement is maintained by connecting the condensers between the halves of the primary and secondary windings. Assuming the same circuit conditions as was assumed for Fig. 3, the transformers should have the same impedance ratios as was specified for that circuit.

In the description of the circuits of Figs. 4 and 5, the reference numerals which have been used to designate the circuit elements are the same as those by which similar circuit elements have been designated in the circuit of Figs. 1 and 3 respectively.

While several embodiments of the invention have been shown they may be variously modified without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. In a circuit for the transmission of waves of a band of frequencies having waves in one portion normally at a higher energy level than waves in the remainder of the band, an electron discharge device, an output circuit for said device, transformer means for coupling said device to said circuit, said means having at the frequencies in said portion of the band at which the energy level is normally high an impedance ratio equal to substantially twice the impedance ratio of the coupled circuits at said frequency so that said device works into an impedance substantially equal to twice its output impedance, said transformer means having at frequencies in the remainder of said band an impedance ratio substantially equal to the impedance ratio of said coupled circuits.

2. In a circuit for the transmission of waves in the audible frequency range, an electron discharge device, an output circuit for said device having a reactive impedance, transformer means for coupling said device to said circuit, said means being responsive to waves of frequencies in the lower portion of the audible frequency range and having an impedance ratio equal to substantially twice the ratio of the impedances of the coupled circuits at said frequencies so that said device works into an impedance substantially equal to twice its output impedance, and transformer means for coupling said device to said circuit, said means being responsive to waves of frequencies in the upper portion of the audible frequency range and having an impedance ratio substantially equal to the impedance ratio of the coupled circuits at said frequencies.

3. The combination according to claim 2 in which each of the transformer means have primary and secondary windings connected in series to said electron discharge device and said circuit, respectively, and condensers connected in shunt to both the primary and secondary windings of said first transformer means.

4. In a circuit for the transmission of waves in the audible frequency range, a vacuum tube amplifier, an output circuit for said amplifier having a reactive impedance, transformers for coupling said amplifier to said output circuit, one of said transformers having primary and secondary windings divided into halves and the other of said transformers having primary and secondary windings connected between the two halves of the windings of said first transformer and condensers connected in shunt to the

primary and secondary windings of said second transformer, said first transformer having at frequencies in the upper portion of the audible frequency range an impedance ratio substantially equal to the ratio of the impedances of said amplifier and said output circuit at said frequency, and said other transformer having at frequencies in the lower portion of the audible frequency range, an impedance ratio substantially equal to twice the ratio of the impedances of said amplifier and said output circuit.

5. In combination, a translating device, a load whose impedance is relatively low at one portion of the frequency range to be transmitted and relatively high at another

portion to be transmitted, and a plurality of transformers, certain of said transformers serving to transmit the first mentioned portion of said frequency range and having an impedance ratio such as to give substantially maximum distortionless output from said device to said load, and certain other of said transformers serving to transmit the other mentioned portion of said frequency range and having an impedance ratio such as to give substantially maximum output from said device to said load.

In witness whereof, I hereunto subscribe my name this 18 day of March A. D., 1926.

DONALD F. WHITING.