R. V. L. HARTLEY.

MODULATOR OR DETECTOR.

APPLICATION FILED SEPT. 29, 1919.

1,419,562. Patented June 13, 1922.

Fig. 1.

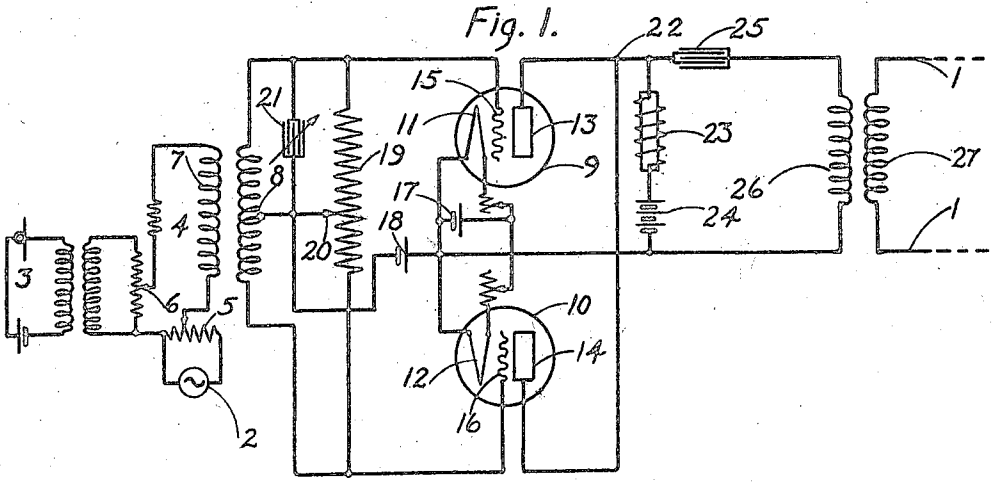
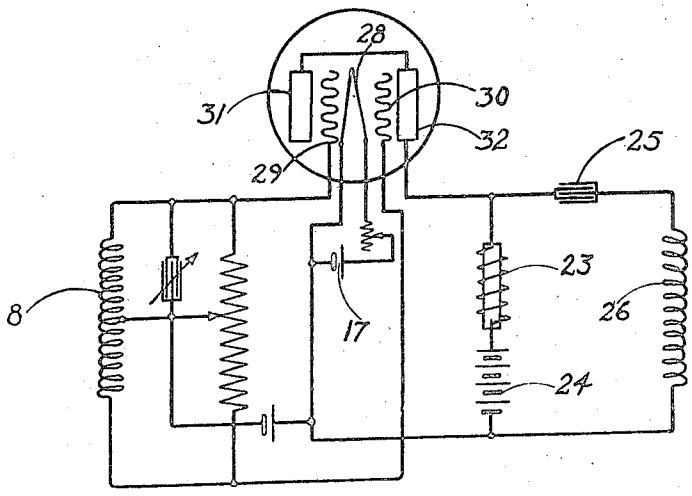


Fig. 2.



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by C.A. Sprague Atty.

UNITED STATES PATENT OFFICE.

RALPH V. L. HARTLEY, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

MODULATOR OR DETECTOR.

1,419,562. Specification of Letters Patent. Patented June 13, 1922.

Application filed September 29, 1919. Serial No. 327,331.

To all whom it may concern:

Be it known that I, RALPH V. L. HARTLEY, a citizen of the United States, residing at East Orange, in the county of Essex, State of New Jersey, have invented certain new and useful Improvements in Modulators or Detectors, of which the following is a full, clear, concise, and exact description.

The present invention relates to a simplified circuit for the control of one wave by another for signaling or other purposes. Circuit arrangements of this general type are commonly known in the art as modulators, demodulators or detectors, according to the use to which they are put.

The invention relates particularly to a novel form of balanced modulator or detector in which preferably a pair of three electrode discharge devices are connected so as to emphasize the production of certain wave components and to neutralize the production of other components.

In the British Patent No. 102,503 there is disclosed a type of balanced modulator for suppressing the transmission of each of the input waves and for producing in the output of the modulator only waves which represent the combination frequencies and the double frequencies of the impressed waves. The mathematical analysis given in that patent applies equally as well to the modulator to be disclosed herein, and since the principle of operation of balanced modulators of this general type is now well known, the detailed exposition of this principle will not be here repeated except so far as it is considered an aid in pointing out distinctions between the device of the present invention and other devices of this general character.

According to the analysis given in said British patent, the current in the output circuit of a three-electrode electron discharge tube is assumed to be capable of representation by a power series having as an independent variable the voltage impressed upon the input circuit. That is, I_1, the output current from one such discharge device due to an input voltage v_1, may be completely represented by $I_1=av_1+bv_1^2+cv_1^3+\text{—}$ in which a, b, c, etc., are constants depending upon the tube characteristics. If another discharge tube having substantially the same constants, a, b, c, etc., be chosen, the output I_2 from this discharge device, due to a similar impressed wave, will be substantially $I_2=av_1+bv_1^2+cv_1^3+\text{—}$. It is found in practice that all terms in this series after the second power term bv_1^2 may be neglected for most purposes. It is also obvious that the first term which simply represents the repeating property of the device without any frequency modification, plays no part in the modulation process. The property represented by the square term, bv_1^2, however, is commonly made use of for effecting the modulation of one input wave by another and for demodulating or detecting by combining input wave components. Since one object of using a balanced modulator is to suppress the transmission of the unmodified frequencies which represent the impressed waves uncombined with each other and otherwise unchanged, the two discharge devices are to be so connected relative to the impressed waves as to cause the wave of unmodified frequency that is transmitted by one of the discharge devices to be neutralized by that transmitted by the other. If the input wave v_1 impressed on one electron discharge device is reversed in sign relative to that impressed on the other, that is, if the two waves have a phase difference of 180°, and the output currents are then added, the desired result is accomplished as is indicated in the following equation, in which the relatively unimportant higher power terms are neglected:

$$\begin{aligned} I_1&=av_1+bv_1^2 \\ I_2&=-av_1+bv_1^2 \\ \hline I_1+I_2&=2bv_1^2 \end{aligned}$$

The completeness of this action is dependent, however, upon the tubes being identical as to the properties represented by the constants a and b in the equation, and it is also dependent upon the current I_1 being completely added to the current I_2. Since this addition of the two output currents represents in part really the cancelation of the undesired component represented by the first power term av_1, even if the current I_1 from the first tube is exactly equal to I_2 but if the adding function does not completely involve both I_1 and I_2, there will be a residue of the component av_1 appearing in the output of the tube combination.

It is an object of the present invention not only to provide a simplified circuit arrangement for a balanced modulator or detector, but to provide a circuit in which the addition of the output current from the respective electron discharge tubes completely involves the said output current.

Further objects and features of the invention will appear from the more detailed description given below in connection with the accompanying drawing, in which Fig. 1 illustrates a preferred form which the invention may take, and Fig. 2 shows a modification.

In Fig. 1, a modulator according to the invention is shown situated between a work circuit 1, for any desired purpose, and wave sources which are indicated by way of example as a source 2 of sustained high frequency waves and a source of voice current produced in the circuit 3 for modulating the high frequency or carrier waves from source 2. The frequency of source 2 is preferably near but higher than the highest essential voice frequency in the system shown, although this is not necessary if the waves produced in circuit 3 are not to be speech waves. Both the carrier or high frequency waves from source 2 and the speech waves are impressed on the same circuit 4, which contains potentiometer resistances 5 and 6 for permitting adjustment of the respective amplitudes of the waves so impressed. Circuit 4 also contains a coil 7 by which it is coupled to the modulator through the medium of coil 8.

The modulator comprises the two discharge devices or electron tubes 9 and 10, which may be of well known construction and which should, for the best operation, be carefully chosen to have so far as possible identical characteristics, as has already been pointed out in connection with the equations above given. The discharge devices or electron relays comprise preferably highly evacuated enclosures containing the respective heated filaments 11, 12, the respective anodes 13, 14, and the respective grids or impedance controlling elements 15, 16, the filaments being heated by current from the source 17 through regulating resistances shown.

The grids 15 and 16 are connected respectively to the opposite terminals of coil 8 and the filaments are connected in common to the mid-point of coil 8. Voltages induced in coil 8 from coil 7, therefore, affect the potential of the grids oppositely with respect to their common filament potential. The battery 18 is shown for fixing the normal potential of the grids. Across the terminals of coil 8 is a resistance 19 having a sliding contact 20 connected to the common filament connection. A variable condenser 21 is also shown in shunt of one-half of the coil 8. The purpose of elements 19, 20 and 21 is to compensate for any differences in the two halves of coil 8 and to secure a more perfect balance of the two sides of the circuit with respect to the common filament terminal which is usually grounded. However, elements 19, 20 and 21 are not essential to the present invention and may be omitted particularly where the coil 8 is to a high degree symmetrical with respect to the common filament terminal. The anodes or plates 13 and 14 are connected at point 22 directly together by means of a conductive connection of substantially zero reactance and connection is made from this point to the common filament terminal through two circuit branches. One of the two branches includes the choke coil 23 and space current source 24, and is substantially a constant current branch, while the other circuit branch includes the large condenser 25 and the output primary coil 26 and serves as a path for the variable wave components. The latter branch is coupled to coil 27 in the work circuit 1.

It will be observed that the connection between the anodes 13 and 14 contains no coils or condensers and is, therefore, non-reactive. Consequently, those output wave components of electron relay 9, which are at all times 180° out of phase with those from relay 10, are immediately neutralized in the connection 13, 22, 14. Wave components of the same phase from the two tubes, however, pass into the circuit 25, 26, and are impressed on the work circuit 1. Since the output connections for the two tubes are not separate but may be considered as only one circuit from the common output terminal 22 to the common filament terminal, it is obvious that the output current of each tube is completely added to that of the other and such addition is not dependent upon the symmetrical relation of coils or the like.

Since, according to the invention, the two anodes or plates are tied directly together, the invention may conveniently make use of a double electron discharge device having one heated filament 28, as shown in Fig. 2, two grids 29, 30, and two plates 31, 32, which may be one piece of metal extending from one side of one grid around to the opposite side of the other grid. By using a metallic plate of this type, or by connecting the two plates or anodes together within the container itself, which is usually a glass bulb, one less lead need be taken through the bulb than if the anodes were connected externally of the bulb. The external connections indicated are substantially the same as those in Fig 1.

The invention has been described as a modulator, but it may equally well be used as a demodulator or a detector in case the wave in circuit 3 is a modulated wave to be detected. In either case it is the usual practice to include suitable selective circuits in the work circuit for selecting the desired

wave component, but such circuits being well known and forming no part of the present invention, are not illustrated.

While preferred forms of embodiment of the invention have been shown and described, it is to be understood that the scope of the invention is not to be restricted to the particular forms disclosed but is defined in the appended claims.

What is claimed is:

1. A balanced modulator comprising two similar discharge devices each having a cathode, a control element and an anode, said cathodes being connected directly together, a circuit for causing equal and opposite instantaneous variations of the potentials of said control elements by a wave to be modulated and a modulating wave, and a single substantially non-reactive connection between said circuit and said cathodes.

2. A balanced modulator or demodulator comprising two similar electron discharge tubes each having a cathode, an impedance controlling element and an anode, said cathodes being connected together and said anodes being connected together, an input circuit individual to each tube connected between its impedance controlling element and said cathodes, and a common output circuit for said tubes, one terminal being connected to both cathodes and the other terminal to both anodes.

3. A balanced modulator or demodulator comprising two similar electron discharge tubes each having a cathode, an impedance controlling element and an anode, said cathodes being connected together and said anodes being connected together, an input circuit individual to each tube connected between its impedance controlling element and said cathodes, a common output circuit for said tubes, one terminal being connected to both cathodes and the other terminals to both anodes, sources of waves for said modulator or demodulator, and circuit connections for simultaneously impressing each of said waves in opposite phase upon said input circuits.

4. A balanced modulator or demodulator comprising two similar electron tubes each having input and output terminals, a plurality of sources of waves for said modulator or demodulator, connections for impressing said waves on the input terminals of each tube simultaneously in opposite phase, the respective output terminals of said tubes being connected conductively together, and a common output circuit for said tubes, the terminals being connected respectively to said conductively connected output terminals.

5. A balanced modulator or demodulator comprising a pair of three-electrode discharge devices, two of the electrodes of one device being non-reactively connected respectively to the corresponding electrodes of the other device, an output circuit common to both devices connected between the respective non-reactively connected electrodes, a source of waves for said modulator or demodulator, and connections for simultaneously impressing said waves oppositely on the two remaining electrodes of said devices.

6. A modulator or demodulator comprising a pair of similar electron discharge devices each having a cathode, a controlling element and an anode, circuits of substantially zero reactance connecting said cathodes together and said anodes together, sources of waves for said modulator or demodulator, circuit connections for impressing said waves simultaneously in opposite phase relation upon the respective controlling elements relative to the common cathode connection, and an output circuit for said modulator or demodulator connected between said anodes in common and said cathodes in common.

7. A modulator or demodulator comprising a source of direct current, a pair of asymmetrically conducting devices connected in parallel with each other and in series with said source, impedance controlling elements for said devices, sources of waves each acting oppositely upon said control elements to vary the impedance of said devices complementally, and an output circuit for said modulator or demodulator connected in series with said devices.

8. A modulator or demodulator comprising a source of direct current, a pair of asymmetrically conducting devices connected in parallel with each other and in series with said source, impedance controlling elements for said devices, sources of waves each acting oppositely upon said control elements to vary the impedance of said devices complementally, and an output circuit for said modulator or demodulator connected in series with said devices and in parallel with said source of direct current.

In witness whereof, I hereunto subscribe my name this 27th day of September A. D., 1919.

RALPH V. L. HARTLEY.