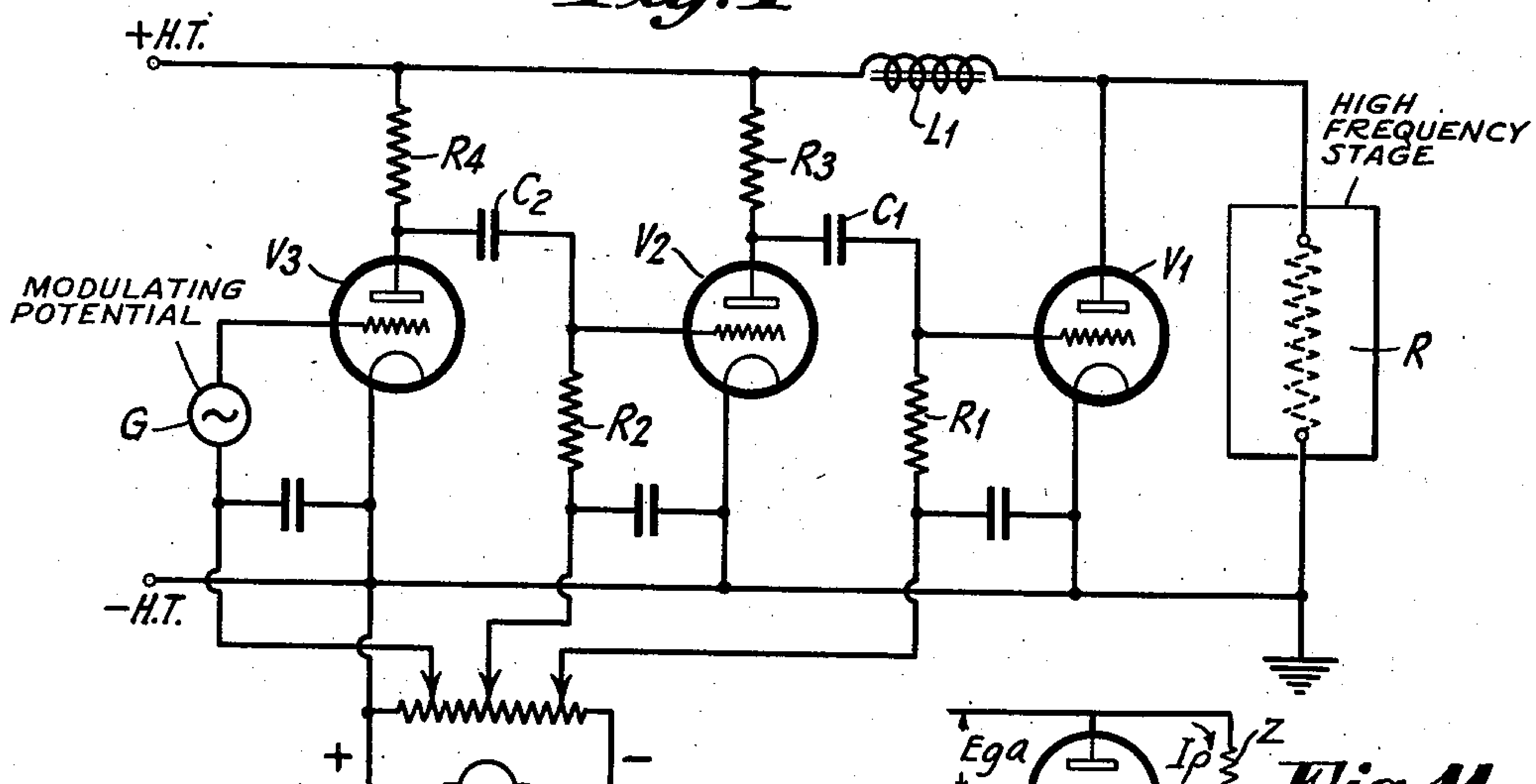
Dec. 19, 1939. E. GREEN ET AL 2,183,865

MODULATED CARRIER WAVE TRANSMITTER

Filed Feb. 10, 1937 4 Sheets-Sheet 1

Fig. 1



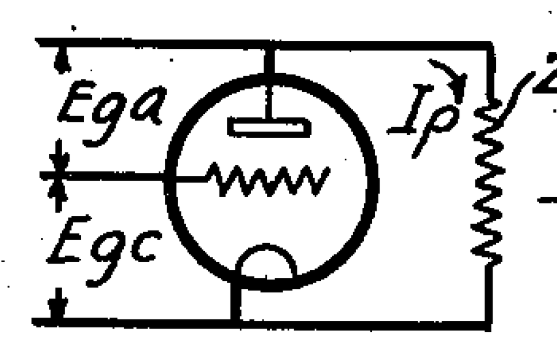


Fig. 11

Fig. 2

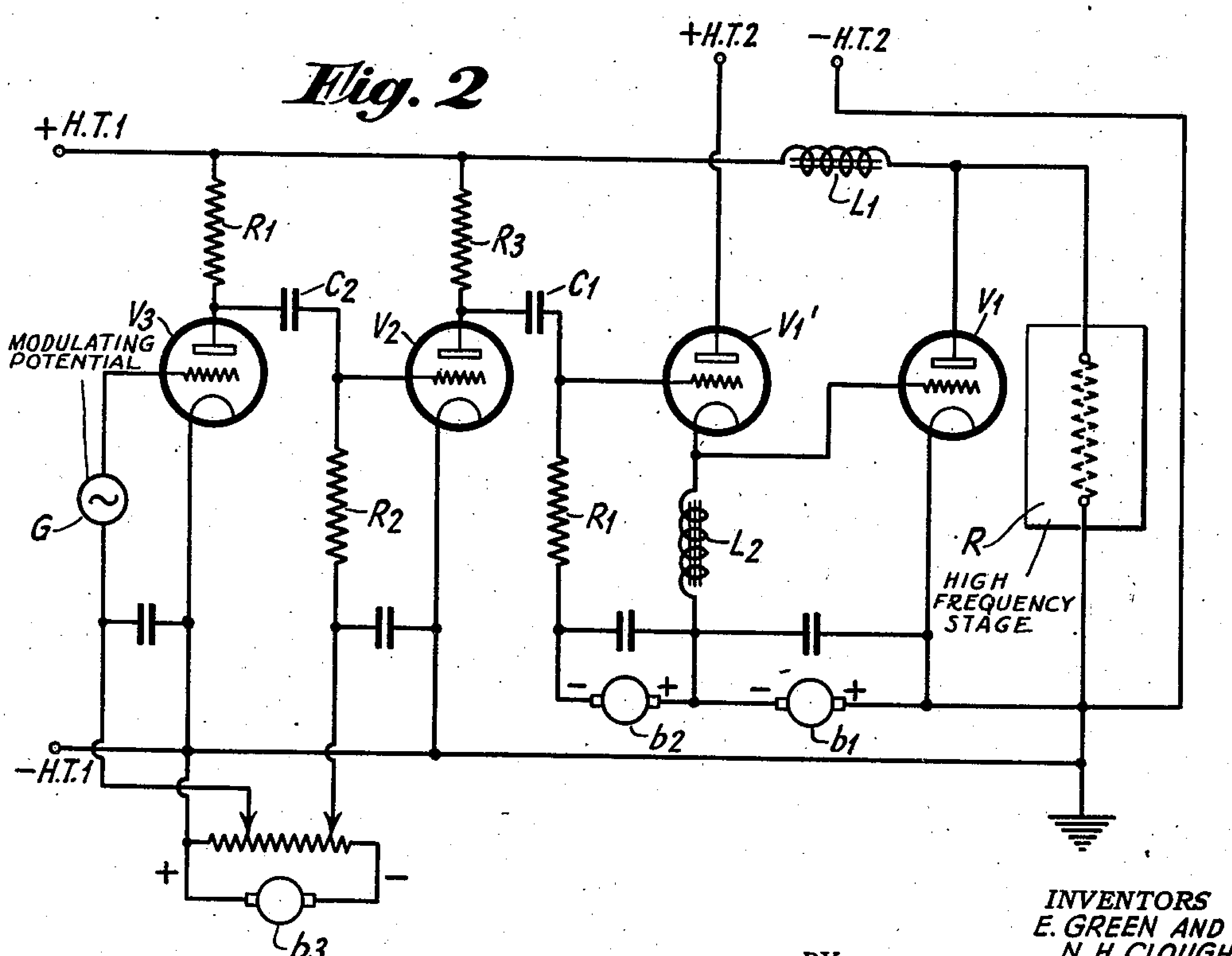


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Fig. 3

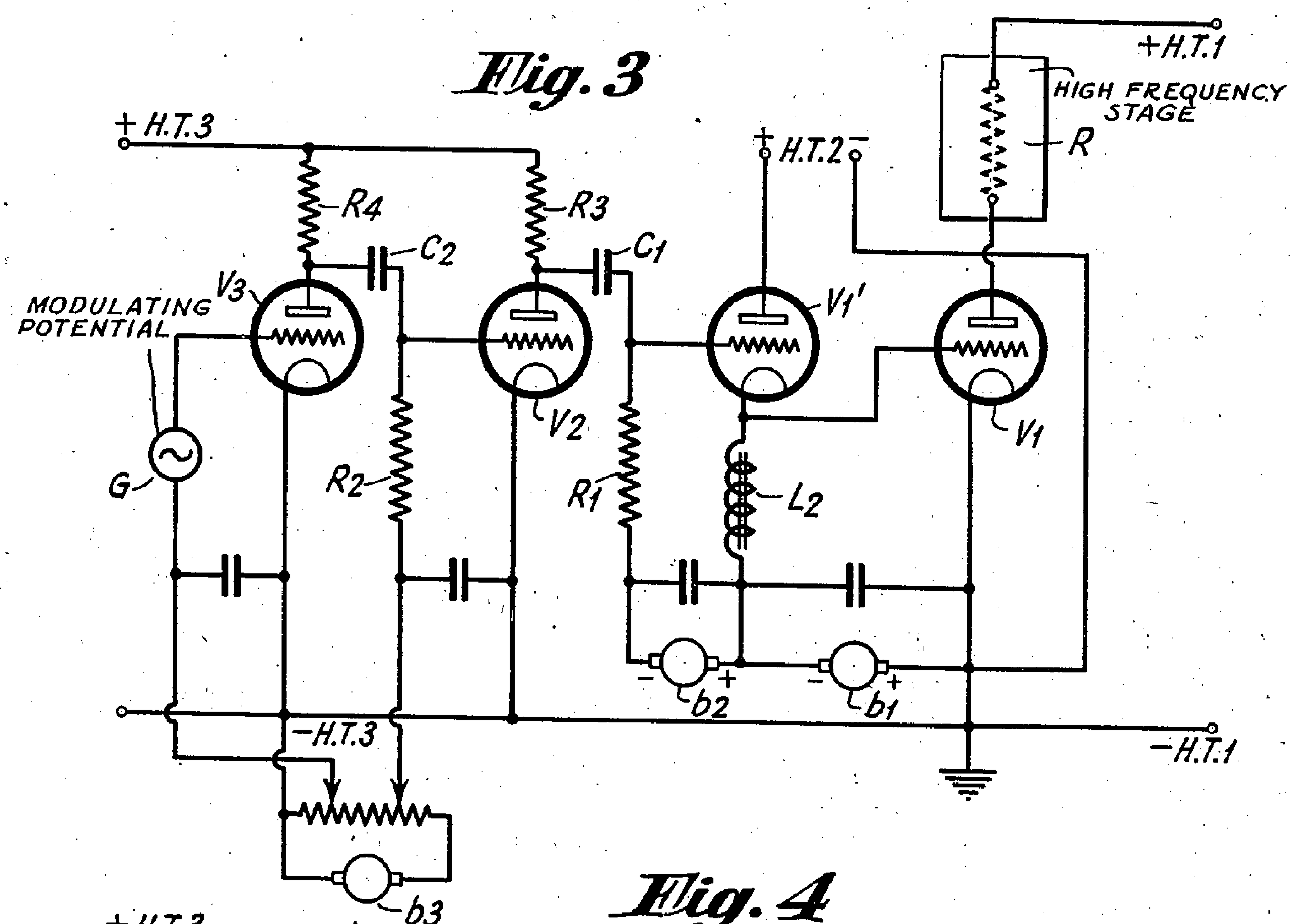
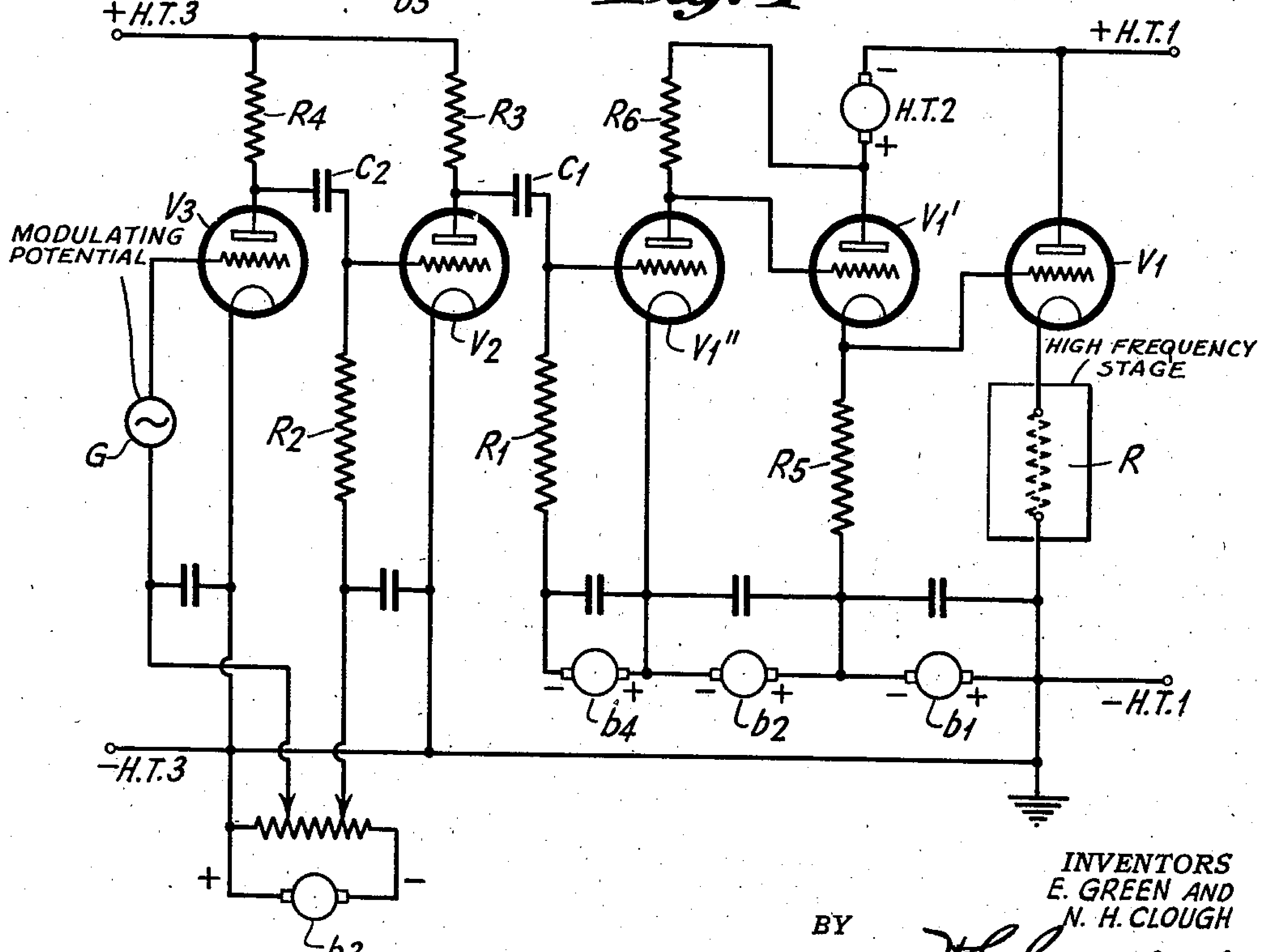


Fig. 4



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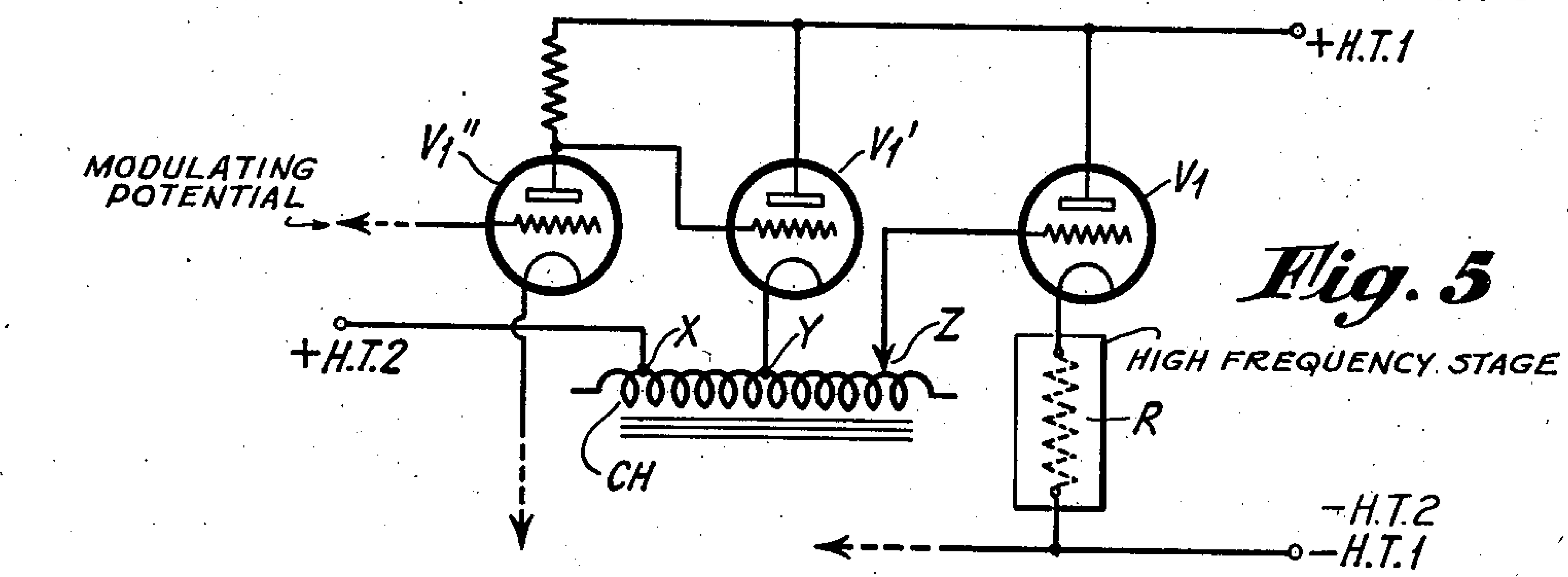

Fig. 5

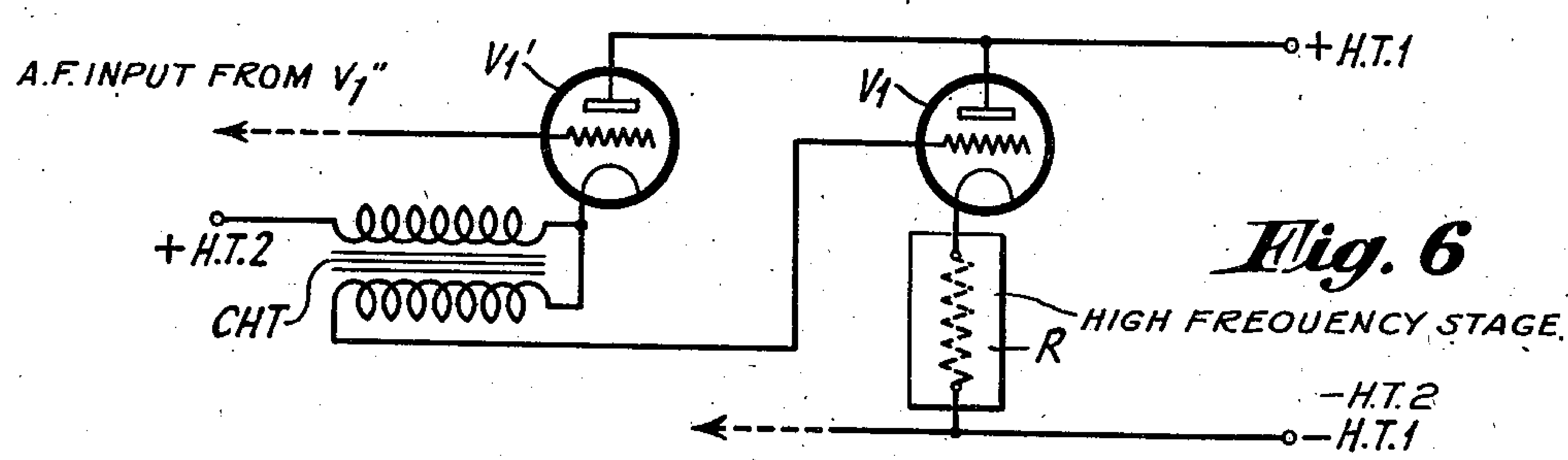

Fig. 6

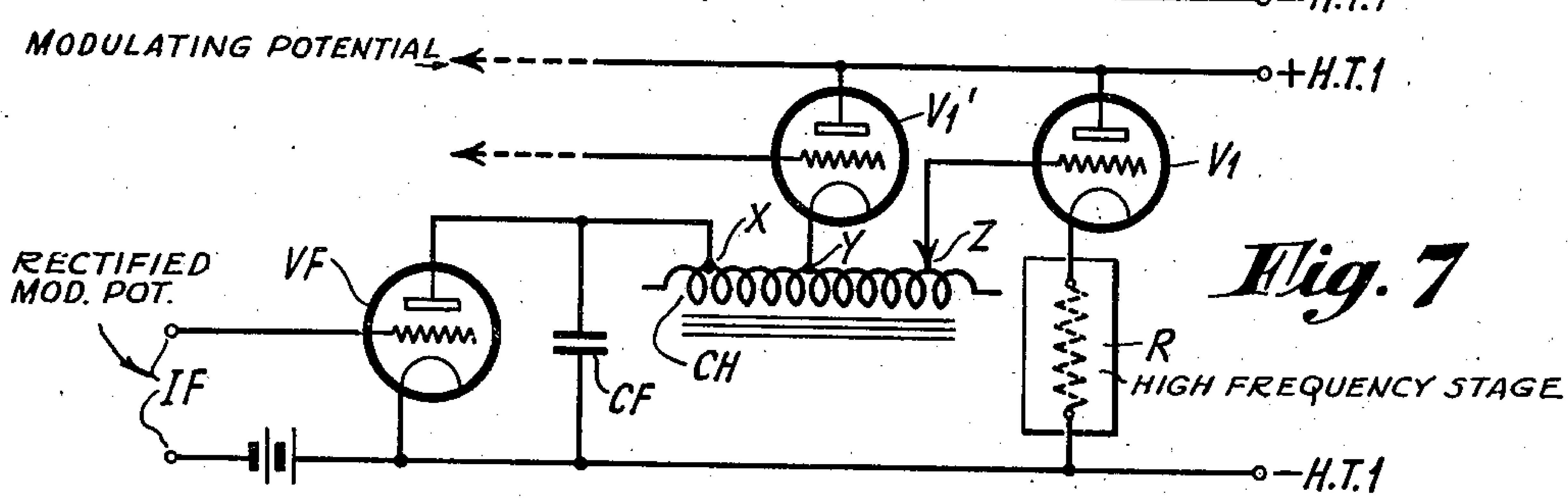

Fig. 7

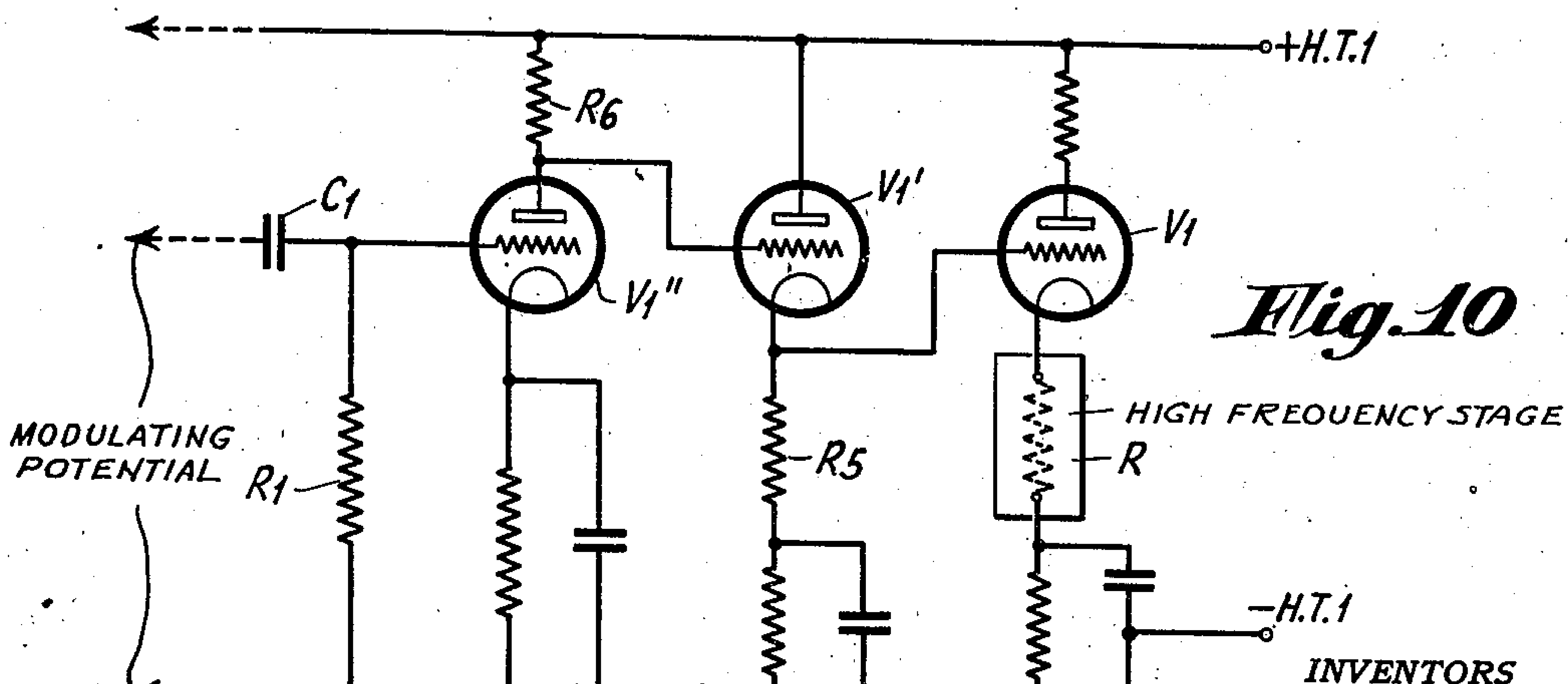

Fig. 10

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Fig. 8

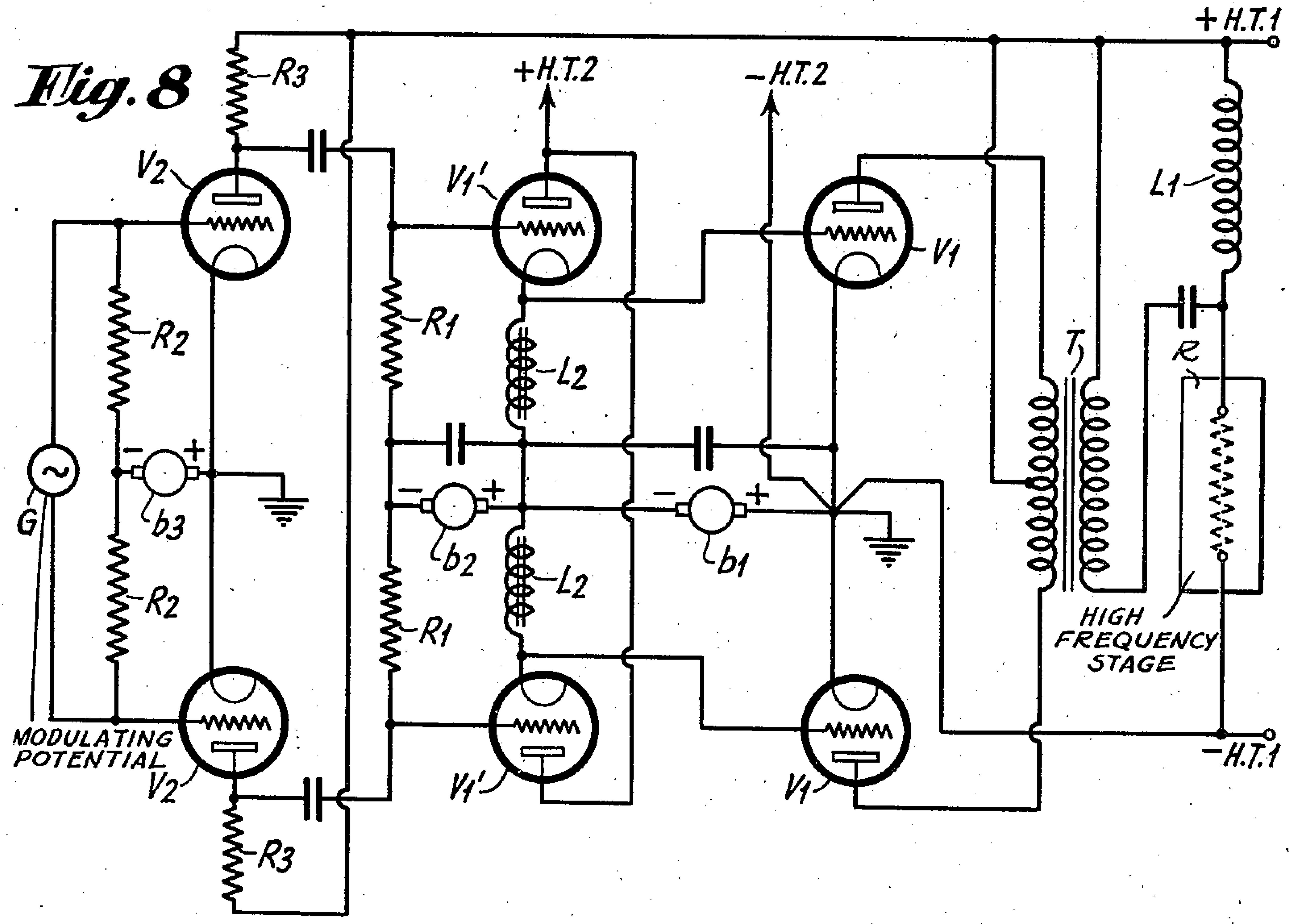
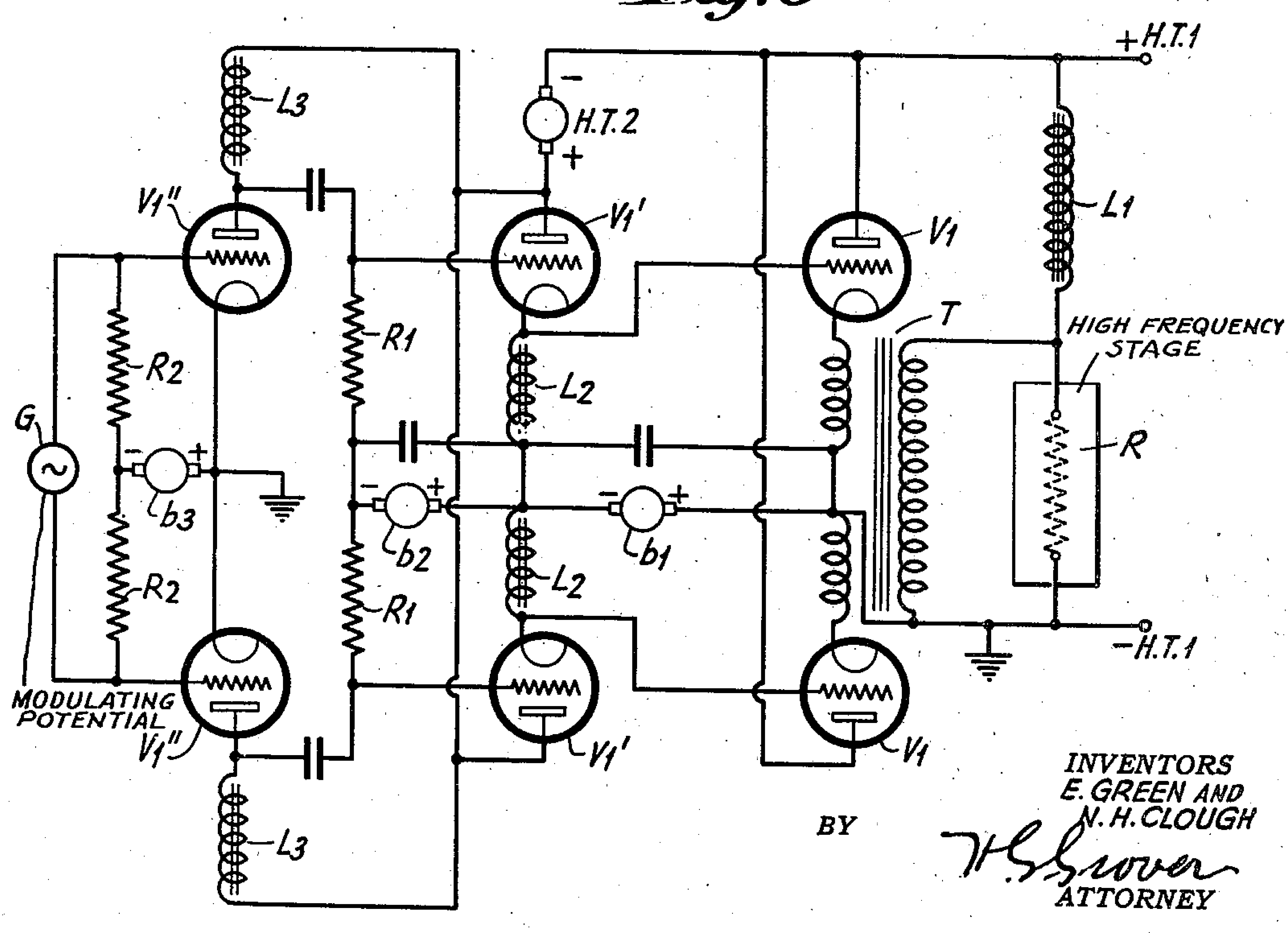


Fig. 9



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MODULATED CARRIER WAVE TRANSMITTER

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Application February 10, 1937, Serial No. 124,994
In Great Britain February 27, 1936

7 Claims. (Cl. 179—171.5)

This invention relates to modulated carrier wave transmitters.

Figure 1 of the drawings accompanying this specification, shows diagrammatically a well known form of resistance capacity coupled modulator arrangement such as is normally employed for a high power modulator system of the choke type. In Figure 1 the high or carrier frequency stage to be modulated is represented by a resistance R and L1 is the modulation choke, high tension supply being made at the terminals +HT and —HT. The main or final tube is the tube V1 and this tube is preceded by two tubes V2 V3 in cascade. Modulation from a source represented at G is applied to the grid of the tube V3 which is resistance capacity coupled by means of the elements R4, C2 and R2 to the grid of the tube V2 which in turn is resistance capacity coupled by means of the elements R3, C1 and R1 to the grid of the following tube V1. Grid bias is applied to the three tubes V1, V2 and V3 from a potentiometer resistance which is shunted as shown across a suitable source of direct current potential shown as constituted by a generator *b1*.

The difficulty of a known arrangement as shown in Figure 1 and of similar arrangements is that the main modulator tube V1 must be operated in the region of zero grid current for if any attempt be made to drive the said tube V1 into grid current the said current will flow through the resistance R1 thus altering the grid bias and producing distortion. The limitation that the tube V1 must be operated in the region of zero grid current of course involves inefficiency. The principal object of the present invention is to avoid this defect and enable large modulation inputs to be handled without serious distortion.

Although in the preceding description the stages including the tubes V1, V2 and V3 have been shown as single tube stages, of course any of these tubes (and, in practice generally the tube V1) may be replaced by a number of tubes in parallel.

According to this invention the final modulator tube of a modulating system is coupled to the preceding apparatus by an interposed coupling tube stage not designed to provide amplification but so arranged as to behave as a generator of low internal resistance for supplying grid current. In this way the final modulator tube may be allowed to run into grid current without producing appreciable distortion.

The invention is illustrated in Figures 2 to 11 inclusive of the drawings accompanying this specification which show diagrammatically various embodiments thereof. Each embodiment includes low impedance means for supplying grid current to the modulator tube to permit the same to draw grid current without causing appreciable distortion. Figure 11 is a simplified diagram used to illustrate the manner in which the grid current is supplied by the low impedance means.

Figure 2 shows an arrangement of the general type illustrated in Figure 1 but modified to bring it into accord with this invention. In Figure 2 it will be seen that the tube V1 is preceded by a coupling tube V1′ which is not arranged to provide amplification but is the tube provided in accordance with this invention to permit the tube V1 to be run into a grid current. The main high tension supply is made at the terminals +HT1 and —HT1, and a second high tension supply is made at the terminals +HT2 and —HT2. The positive terminal +HT2 is connected to the anode of the tube V1′ the cathode of which is connected to the grid of the tube V1 and also through a large choke L2 to the junction point of the two direct current sources *b1* and *b2*, the positive terminal of the source *b2* being connected to the negative terminal *b1*. The positive terminal of the source *b1* is grounded and connected to the cathode of the tube V1 and the negative terminal of the source *b2* is connected through the resistance R1 to the grid of the tube V1′. The preceding stages including the tubes V2 and V3 are arranged in much the same way as in Figure 1 but receive their bias from a potentiometer shunted across a further source *b3*. Shunt condensers are provided across the sources *b1* and *b2*.

It will be seen that in this arrangement the grid bias to the tube V1 is fed from the source *b1* through the choke L2, the cathode of tube V1′ being connected to the grid end of the said choke. The source *b1* also provides part of the high tension supply to the tube V1′, the remainder being supplied from the auxiliary source connected at +HT2 and —HT2. The cathode of the tube V1′ can be energized from any suitable insulated machine or transformer (not shown). In operation the tube V1′ provides no amplification of voltage but behaves as a generator of low internal resistance for supplying grid current for the main tube V1. It will be noticed that this grid current does not flow through the choke L2, or through the source *b1* but is supplied from the auxiliary high tension supply only through the tube V1′. As a consequence the tube V1 can be operated in the region of grid current thus giving increased efficiency but at the same time there will be substantially no distortion due to the flow of grid current.

This operation will be clear from the following mathematical discussion thereof made in connection with Figure 11, which shows a tube operating in the manner V1′ is operated.

In a triode valve if the input is applied between grid and anode, the resistance of the equivalent generator is

$$\frac{R_a}{m+1}$$

and the magnification factor is

$$\frac{m}{m+1}$$

This statement is proved as follows:

In Figure 11 let

$\overline{Z}$=Impedance of load.

R_a=A. C. resistance of triode.

m=magnification factor of triode.

$\overline{I_p}$=A. C. component of plate current.

$\overline{E_{gc}}$=A. C. voltage between grid and cathode.

$\overline{E_{ga}}$=A. C. voltage between grid and anode.

Then relative to input between grid and cathode we know that the valve behaves as a generator of internal EMF=mE_{gc} and resistance R_a. This is expressed by the equation

$$m\overline{E_{gc}}=(\overline{R_a}+\overline{Z})\overline{I_p} \quad (1)$$

But if we are considering the input between grid and anode we have

$$\overline{E_{ga}}=\overline{E_{gc}}+\overline{Z}.\overline{I_p} \quad (2)$$

Substituting for E_{gc} in (1)

$$m(E_{ga}-\overline{Z}\overline{I_p})=(\overline{R_a}+\overline{Z})\overline{I_p} \quad (3)$$

rearranging

$$m\overline{E_{ga}}=(\overline{R_a}+(m+1)\overline{Z})\overline{I_p}$$

dividing by $(m+1)$

$$\frac{m}{m+1}\overline{E_{ga}}=\left(\frac{\overline{R_a}}{m+1}+\overline{Z}\right)\overline{I_p} \quad (4)$$

This equation is of the same form as (1) with

E_{ga} in place of E_{gc}

$\frac{m}{m+1}$ in place of m

and $\frac{R_a}{m+1}$ in place of R_a

Hence relative to input between grid and anode, the valve behaves as a generator with internal

$$EMF\frac{m}{m+1}E_{ga}$$

and internal resistance

$$\frac{1}{m+1}R_a$$

In the modification shown in Figure 3 the modulation system is of the series type instead of the choke type, the final tube V1 being on the low potential side of the high frequency stage represented by the resistance R. Corresponding parts are indicated in Figures 2 and 3 by corresponding references and accordingly detailed description of Figure 3 will, it is thought, be unnecessary. It will be observed that the stages including the tubes V2 and V3 receive high tension potential from a separate source whose terminals are indicated at +HT3 and −HT3. This is usually more convenient.

Figure 4 shows another series modulation system embodying the present invention but in this case the final tube V1 is on the high potential side of the carrier frequency stage represented by the resistance R. In this case the choke L2 of Figures 2 and 3 is replaced by a resistance R5 to provide the grid bias for the main modulator tube V1 and an additional tube V1″ gives coupling between the tube V1′ and the tube V2. The elements R3 C1 R1 couple the anode of the tube V2 to the grid of the tube V1″ and R6 is the anode resistance of the tube V1″. In Figure 4 the source of anode potential for the tube V1′ is represented by a machine HT2 instead of by terminals and the additional direct current source b4 provides grid bias for the tube V1″. Variable grid bias may be applied to the grid of the tube V1″ in order to provide "floating carrier" action, as known per se. As this obtaining of floating carrier action forms no part of the present invention, it will not be described herein, and the apparatus for producing it, other than the tube V1″ is not illustrated in Figure 4.

Figure 5 is a diagram showing part of a modification of an arrangement as illustrated in Figure 4, only such parts being shown in Figure 5 as are necessary to an understanding of the modification in question. As will be obvious, the steady anode potential applied to the tube V1′ is equal to the difference between the potentials applied at +HT1 and +HT2. The supply source (not shown) connected at +HT2 can usefully be employed to feed earlier stages (not shown in Figure 5) so that the current demand on this source can be reduced owing to the opposition of feed currents. The cathode choke or auto-transformer CH has three taps X, Y and Z thereon as shown. The intercept X—Y is chosen sufficiently high to insure substantially no diminution in volume of the lowest frequency required to be passed by the system. If the tap Z for the grid of the tube V1 be positioned (as shown) to the right (in Figure 5) of point Y audio frequency voltage magnification will occur, but if the grid loading (grid current or capacity current) of the tube V1 is high it may be desirable to move the point Z to Y or even to some position between X and Y.

In some circumstances it may be desired to have the currents in V1′ and V′ in phase opposition or at least with a phase difference in excess of 90°. For this result the point Z must not be to the right (in Figure 5) of X but to the left thereof. Where, however, this result is required it is preferred to use a double wound transformer CHT in place of the auto-transformer CH of Figure 5, the essential connections being then as shown in Figure 6. The grid of the tube V1′ may be driven in any convenient manner (e. g., as shown in Figure 5) its potential, in the zero modulation condition, being somewhat below the potential supplied at +HT2.

If desired, in the arrangement of Figures 5 and 6 "floating bias" for "floating carrier" action may be added, e. g., as shown in Figure 7 which shows one way of adding floating bias to the arrangement of Figure 5. In Figure 7 there is applied between the input terminals IF of the added tube VF unidirectional potentials derived by rectifying the audio frequency. In Figure 7 the condenser CF should be large enough to by-pass the audio frequency cathode currents of the tube V1' but not large enough to impose too much delay on the change of anode potential of VF resultant upon a change in rectified audio frequency potential applied at IF. Obviously a separate source +HT2 is not required in Figure 7. The choke CH may be replaced by a resistance if magnification is not required and if complete carrier extinction is required in the quiescent conditions suitable bias must be applied either in the grid lead to the tube V1 or in the cathode lead to the tube VF.

The invention is of great advantage as applied to quiescent and other push-pull systems. One push-pull circuit in accordance with this invention is illustrated in Figure 8 and it will be observed that Figure 8 is substantially a push-pull duplication of the circuit of Figure 2 the only major difference beyond such duplication being that the output from the final modulator stage including the two tubes V1, is fed through a transformer T. In Figure 8 similar references are applied to similar parts in the two halves of the push-pull system. In some cases the two chokes L2 may be wound on a common core so that they will function as a transformer. In either case the grid connection of the tubes V1 may be made either above or below the cathode connection of the tubes V1' so as to provide a step-up or step-down transformer action as may be required.

Figure 9 shows a further push-pull arrangement in accordance with this invention. In Figure 9 the primary of the output transformer T is connected between the cathodes of the tubes V1 instead of, as in Figure 8, between the anodes thereof. This arrangement has the advantage of improving rectilinearity. The only other difference of substance between Figure 9 and Figure 8 is that the tubes preceding the tubes V1' receive anode potential from the source HT2 through chokes L3 as indicated. The arrangement of the stage preceding the stage including the tubes V1' may be regarded as approximately a push-pull duplication of that stage of Figure 4 which includes the tube V1'' and accordingly the said tubes (in Figure 9) preceding the tubes V1' are denoted by the references V1''.

The invention is not limited to the precise circuit arrangements shown. For example, fixed bias for the main modulator tube may be applied in the grid lead of that tube instead of in the cathode lead of the tube immediately preceding it. Again any other methods well known per se may be resorted to for obtaining desired biases on the various tubes and desired variations in anode potential from tube to tube—for example, the feed circuits for the last three tubes of Figure 4 could be arranged as shown in Figure 10, which figure, it is thought will be found self-explanatory.

Where a plurality of main modulator tubes in parallel are employed individual biases therefor may be obtained in various different ways. For example, each grid may be tapped upon a resistance in the cathode lead of the immediately preceding tube; or they may be tapped upon a separate bias potentiometer resistance (connected at one end to a point in the cathode lead of the immediately preceding tube—e. g., to the cathode) which is shunted by a bias source; or they may be tapped upon a resistance connected between the cathode of the immediately preceding tube and the anode potential source.

In any of the illustrated circuits "floating carrier" action may be obtained by superimposing "floating bias" in any convenient way known per se. Figure 7 is but one example of a circuit in which such action is obtained.

Any of the above described circuits employing resistance couplings and deriving its operating direct current potentials from external sources (i. e., not employing so-called automatic biasing or high tension voltage dropping resistances) may be employed for telegraphy and like purposes.

We claim:

1. In a transmitting system a radio frequency stage to be modulated, a source of modulating potentials, a modulator tube having input and output electrodes, means connecting the output electrodes of said modulator tube to said radio frequency stage to modulate the same, a source of direct current potential, a coupling tube having an anode, a cathode, and a control grid, an impedance connecting the cathode of said coupling tube to one terminal of said source of direct current potential, a coupling between said impedance and the input electrodes of said modulator tube, a connection between the other terminal of said source of direct current potential and the anode of said coupling tube, said impedance being of a value high enough to materially impede the flow of modulating potentials and means for applying modulating potentials to the control grid and cathode of said coupling tube.

2. In a transmitter system, a high frequency stage to be modulated, a modulator tube having input and output electrodes, means coupling the output electrodes of said modulator tube in series with said high frequentcy stage and with a source of direct current potential, said high frequency stage being in the high potential side of said connection, a source of modulating potentials, a coupling tube having a control grid, a cathode, and an anode, a second source of potential, an impedance connecting the cathode of said coupling tube to one terminal of said second source of potential, a connection between the anode of said coupling tube and a point on said second source of potential, a connection between the input electrodes of said modulator tube and said impedance, said impedance being of a value high enough to materially impede the flow of modulating potentials and means for impressing biasing potential between the control grid and cathode of said coupling tube and modulating potentials from said source on the control grid and cathode of said coupling tube.

3. A system as recited in claim 1 wherein an additional source of direct current potential controlled in accordance with said modulating potentials is coupled with said coupling tube to provide a floating carrier action.

4. In a transmitter system, a high frequency stage to be modulated, a source of modulating potentials, a pair of electron discharge devices having output electrodes coupled to said high frequency stage to modulate the same. said discharge devices having input electrodes, a pair of coupling tubes each having an anode, a cathode, and a control grid, impedances coupling the cathodes of said coupling tubes together, means connecting the input electrodes of said discharge devices in shunt to said impedances, said impedances being of values high enough to materially impede the flow of modulating potentials and means for applying modulating potentials from said source of modulating potentials to the control grids and cathodes of said coupling tubes.

5. A system as recited in claim 4 wherein the output electrodes of said modulator tubes are connected in push-pull by the primary winding of a transformer, the secondary winding of which is coupled to said high frequency stage.

6. A system as recited in claim 4 wherein the output electrodes of said modulator tubes include anode and cathode electrodes and wherein the cathode electrodes of said modulator tubes are connected together by the primary windings of a transformer the secondary winding of which is coupled to said high frequency stage.

7. In a transmitting system, a high frequency transmitter stage, a source of modulating potentials, a modulation frequency relay tube having input electrodes coupled through a modulation frequency amplifier system to said source of modulating potentials and output electrodes coupled to said high frequency transmitter stage to modulate the same in accordance with modulating potentials from said source and means for preventing peak modulation potentials which produce current flow in the input circuit of said modulator stage from causing appreciable distortion in the modulated output of said transmitter comprising a coupling tube having a control grid, an anode, and a cathode, means for connecting the control grid and cathode of said coupling tube through said amplifier system to said source of modulating potentials, an impedance connected between the anode and cathode of said coupling tube, said impedance being of a value high enough to materially impede the flow of modulating potentials and circuits connecting the input electrodes of said relay tube in shunt to a portion of said impedance whereby said coupling tube acts as a generator of low internal resistance supplying grid current to said relay tube input circuit.

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