Nov. 10, 1931. H. A. WHEELER 1,831,431

ELECTRIC COUPLING CIRCUITS

Filed Jan. 16, 1931

Fig. 1.

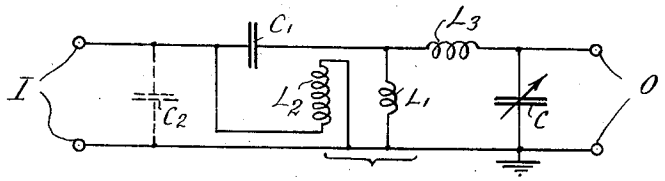


Fig. 2.

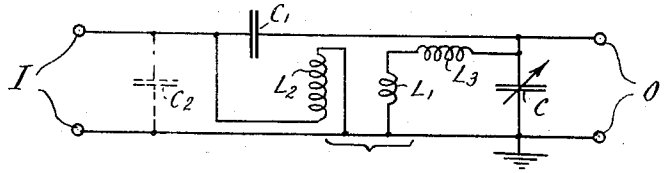


Fig. 3.

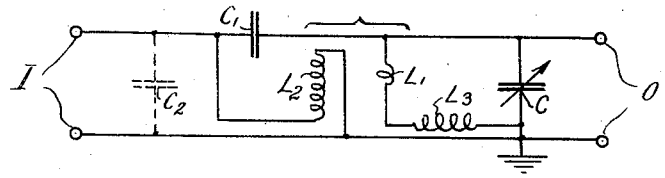


Fig. 4.

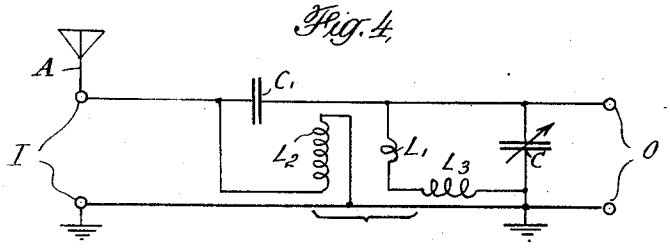
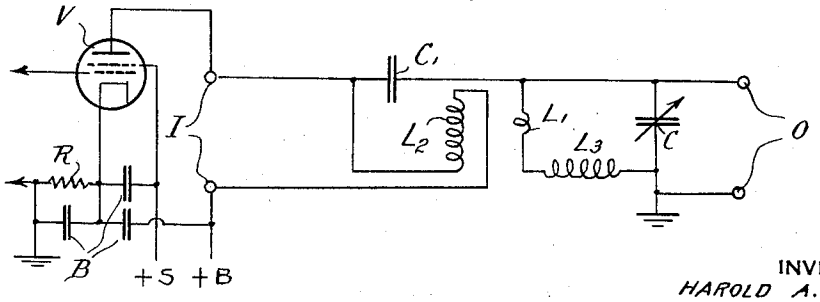


Fig. 5.



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ELECTRIC COUPLING CIRCUITS

Application filed January 16, 1931. Serial No. 509,115.

This invention relates to high frequency electric coupling circuits tunable over a range in frequency and adapted more especially for interconnecting successive elements of a high frequency thermionic amplifier or a radio system.

The coupling circuits of the present invention are characterized in that the voltage ratio produced thereby is caused to vary automatically with the frequency of tuning in a manner which is under the control of the designer; the design in general being preferably such as to produce a substantially constant resultant amplification, i. e., uniform sensitivity throughout the tunable frequency range.

The subject matter of this invention has been published in a paper entitled "Theory and operation of tuned radio frequency coupling systems" by H. A. Wheeler and W. A. MacDonald. This paper was presented and distributed in printed form at the 1930 Convention of the Institute of Radio Engineers held at Toronto, Canada.

With an elementary type of high frequency coupling circuit of which a two-winding transformer having a tunable secondary is a typical example, the variation of amplification with frequency is not under the control of the designer, but increases with frequency throughout the tunable range in a manner well understood, with consequent detrimental effects on the amplification, selectivity and stability of the system.

In the elementary type of coupling circuit referred to above there exists between the primary and tunable secondary circuits a coefficient of coupling which is substantially constant throughout the frequency range, a condition which is partially responsible for the mentioned increase in amplification with frequency. The present invention avoids the above noted objections by proper cooperation of different reactance elements in the primary circuit. These provide an effective coupling between input and tunable output circuits which automatically decreases with increase in the tuned frequency, and may be proportioned to offset wholly or in part the factors operative to produce an increase in amplification with frequency.

Coupling circuits broadly operative in accordance with the principles disclosed herein but differing from the present invention as regards both the circuit connection utilized and the specific modes of operation thereof, are set forth in Patent No. 1,763,380 issued to C. E. Trube, and in his copending application Serial No. 101,906, filed April 14, 1926, and Serial No. 120,045, filed July 2, 1926.

The coupling circuits of the present invention embody the following essential elements, namely, a fixed inductance and the secondary coil of a high frequency transformer serially connected between an output terminal and a common or grounded terminal, a variable tuning condenser likewise connected between the output and grounded terminals, a primary transformer coil inductively related to the secondary connected between an input terminal and the common or a grounded terminal, and a fixed coupling condenser connected from the ungrounded terminal of the primary coil to a point in secondary circuit of opposite alternating current polarity thereto.

The mentioned connection of elements provides a pair of parallel paths between the input and grounded terminals; one path containing the fixed capacity and at least a portion of the secondary circuit, whereas the other path contains only the primary transformer coil.

Thus the coupling circuit of the present invention comprises an input circuit coupled both capacitively and magnetically to a tunable secondary circuit. These couplings may be proportioned to provide a resultant coupling between primary and secondary circuits which automatically falls off as the frequency in tuning is increased but at a rate proportioned to produce a desired variation in amplification and selectivity with frequency; and also to control the variation in input impedance of the circuit in such manner as to insure stability of operation when utilized in conjunction with thermionic elements.

In order to render the resultant coupling

of maximum effect at the low frequency end of the tunable range, the inductance of the primary coil is by association of suitable capacities including that of the coupling condenser, rendered resonant at a frequency lower, but not greatly lower, than the lowest frequency within the tunable range. To this end an additional fixed capacity may be connected between the input and ground terminals, or in the operation of the circuit capacity may exist between these terminals sufficient in magnitude to effect the desired low resonance frequency of the primary circuit. Such capacity may for example be present in the form of the antenna-to-ground capacity of an antenna circuit connected to the input and ground terminals of the coupling circuit, or in the form of the anode-to-ground capacity of a thermionic element connected thereto.

Referring now to the drawings:

Figs. 1, 2 and 3 show diagrammatically elementary coupling circuits in accordance with the present invention;

Fig. 4 shows the coupling circuit of Fig. 3 in association with an antenna circuit connected to the input portion thereof; while

Fig. 5 discloses the manner of connecting the anode circuit of a thermionic element to the input portion of the Fig. 3 modification.

Like elements are similarly designated in several figures.

The coupling circuit of Fig. 1 comprises a variable tuning condenser C shunted by the series connection consisting of a fixed inductance L_2 and a secondary transformer coil L_1 bridged between output terminals O, the lower terminal of which is conductively connected to the lower of a pair of input terminals I in order to provide a common or ground connection. Inductively related to the secondary coil L_1 is a primary coil L_2 connected between input terminals I. A fixed coupling condenser C_1 extends between the ungrounded terminals of coils L_1 and L_2 respectively. Coil L_2 is so poled relative to coil L_1 that the coupling condenser C_1 is connected between points of opposite alternating current polarity in order that, with the circuit elements properly proportioned as explained, the capacitive coupling due to element C_1 will aid the magnetic coupling existing between coils L_1 and L_2 throughout the tunable frequency range.

The capacity C_2, shown dotted, is intended to represent the entire capacity effectively bridged between the input terminals I while the circuit is in operation, and in conjunction with capacity C_1 and any additional capacities which may be associated with the primary coil L_2, should be such as to render the primary circuit resonant at the mentioned frequency slightly below the tunable range of the secondary circuit. It is not essential to the operation of the circuit that a capacity C_2 exists between the input terminals I. In the event that capacity C_2 is zero however, capacity C_1 should be of such magnitude as to insure the desired low frequency resonance condition of the primary circuit.

The capacity C_1 is sufficiently small that the path between the input terminals I which contains elements C_1 and L_1 is capacitively reactive throughout the tunable range and hence of decreasing impedance for an increase in the tuned frequency; whereas reactance of element L_2 must increase in magnitude with the tuned frequency. It will thus be apparent that elements C_1 and L_2 produce effects in the secondary circuit which vary in opposite fashion with the tuning adjustment, the resultant effect being proportioned to produce a resultant coupling between primary and secondary circuit which automatically falls off in a desired rate as the frequency of tuning increases.

Since the instantaneous current flowing in the coupling condenser C_1 is in phase opposition to that flowing in coil L_2, it is necessary in order that the capacitive aid the magnetic coupling, to connect the condenser C_1 between points in the primary and secondary circuits which are of opposite alternating current polarity.

The circuit of Fig. 2 constitutes a slight modification over that of Fig. 1 in that the coupling condenser C_1 is connected between the ungrounded terminal of the primary coil L_2 and the undgrounded terminal of the secondary tuning condenser C. This modification requires different circuit constants to obtain the same results as are obtained by the circuit of Fig. 1, but in other respects the two modifications are practically equivalent.

The circuit of Fig. 3 which is electrically equivalent to Fig. 2 differs therefrom in the connection of the fixed inductance L_2 between the lower terminal of the secondary coil L_1 and the condenser C rather than between the upper terminal of the secondary coil and the condenser as is the case in Fig. 2.

In Fig. 4 an antenna circuit A is connected to the input terminals I of the Fig. 3 modification. The capacity C_2 in this instance comprises the antenna-to-ground capacity effectively bridged between the input terminals, and in conjunction with capacity C_1 should be such as to render the primary circuit resonant at the mentioned frequency below the tuning range.

In Fig. 5 the upper input terminal of the circuit of Fig. 3, is connected directly to the anode of a thermionic element V whereas the lower input terminal is connected to the +B lead extending to a space-current supply source for supplying the anode circuit of the tube through coil L_2.

Tube V is of the screen grid type wherein the screen grid electrode is connected to a

suitable source of biasing potential over lead +S. A grid biasing resistor R shunted by a high frequency by-passing condenser B is connected between cathode and ground for applying a suitable negative potential to the grid electrode of the tube in accordance with the usual present day practice.

The lower input terminal is not in this instance connected directly to the lower output terminal as this would result in grounding the +B terminal of the space-current supply source at the grounded rotor element of condenser C. Instead the connection between these terminals is traced through the by-pass condensers to ground and thence directly to the grounded output terminal.

The capacity C_2 comprises the anode-to-ground capacity of tube V which in association with capacity C_1 provides the desired resonance condition for the primary circuit.

While the circuits of Figs. 4 and 5 depict the modification of Fig. 3 connected to an antenna circuit and to a thermionic element respectively, it will be apparent that the modifications of Figs. 1 and 2 could be effectively employed in the same manner.

All of the circuit modifications are of such nature as to permit a direct grounding of the rotor element of the variable tuning condenser. This is desirable in that it prevents undesired couplings otherwise occurring between the rotor element and different parts of the circuit.

In this invention, especially in Figs. 3, 4 and 5, the capacity C_1 can easily be secured as inherent capacity between coils L_1 and L_2.

What is claimed is:

1. A high frequency electric coupling circuit tunable throughout a range in frequency comprising a secondary circuit including a variable condenser bridged between an output and a common ground terminal, a fixed inductance in series with a secondary transformer coil connected in shunt to said condenser, a primary transformer coil inductively related to said secondary connected between said ground terminal and an input terminal, and a fixed capacity connecting the ungrounded end of said primary coil to a point in said secondary circuit of opposite open-circuit alternating current polarity, the inductance of said primary coil together with the associated capacities in the operation of said circuit being resonant at a frequency slightly below said tunable range.

2. A high frequency electric coupling circuit tunable throughout a range in frequency comprising a secondary circuit containing a variable condenser bridged between an output and a common terminal, a fixed inductance in series with a secondary transformer coil connected in shunt to said condenser, a primary transformer coil inductively related to said secondary connected between said ground terminal and an input terminal, and a fixed capacity connecting the ungrounded end of said primary coil to a point in said secondary circuit of opposite open-circuit alternating current polarity, a fixed capacity existing in the operation of said circuit between said input and ground terminals, the inductance of said primary coil together with the said capacities associated therewith being such as to render the primary circuit resonant at a frequency slightly below the tunable range for providing uniformly high sensitivity and selectivity throughout said tunable range.

3. In a tuned radio frequency receiving system the combination of an electric coupling circuit having an input, an output and a ground terminal, a variable tuning condenser shunted by a fixed inductance and a secondary transformer coil in series connected between said output and ground terminals, a primary coil inductively related to said secondary coil connected between said input and ground terminals, a fixed capacity connected from the ungrounded terminal of said primary coil to a point in said secondary circuit of opposite open-circuit alternating current polarity, and an antenna circuit associated with said input and ground terminals, the inductance of said primary coil together with the associated capacities including said fixed capacity and the antenna-to-ground capacity of said antenna circuit being resonant at a frequency slightly below the tuning range of said variable condenser for effecting in said system uniformly high sensitivity and selectivity throughout said range.

4. In a high frequency thermionic amplifying system, the combination of an electric coupling circuit having an input, an output and a ground terminal, a variable tuning condenser connected between said output and ground terminal and shunted by a fixed inductance and a secondary transformer coil in series, a primary coil connected between said input and ground terminals and inductively related to said secondary coil, a fixed capacity connected from the ungrounded terminal of said primary coil to a point in said secondary circuit of opposite open-circuit alternating current polarity, and a thermionic tube having anode and cathode connected to said input and ground terminals respectively, the inductance of said primary coil together with the associated capacity including said fixed capacity and the anode-to-ground capacity of said thermionic tube being resonant at a frequency slightly below the tuning range of said variable condenser for effecting in said system a uniformly high sensitivity, selectivity and stability throughout said tunable frequency range.

In testimony whereof I affix my signature.

HAROLD A. WHEELER.