Nov. 10, 1931. W. VAN B. ROBERTS 1,831,640

TUNED RADIO FREQUENCY COUPLING DEVICE

Filed Feb. 13, 1928

Fig.1

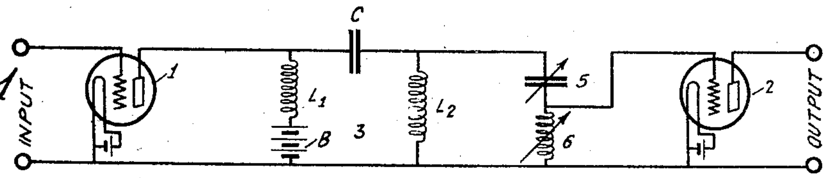


Fig.2

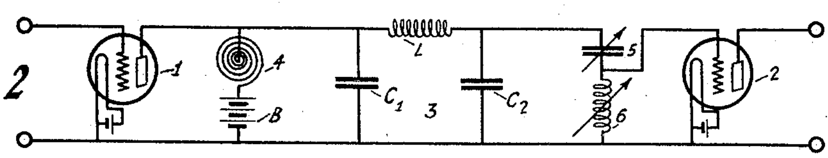


Fig.3

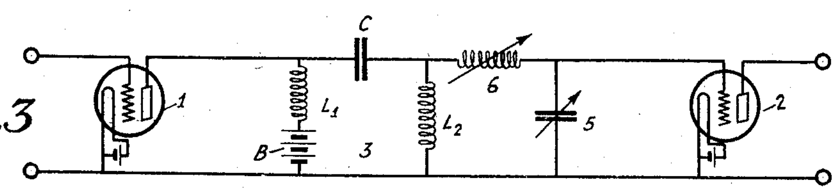


Fig.4

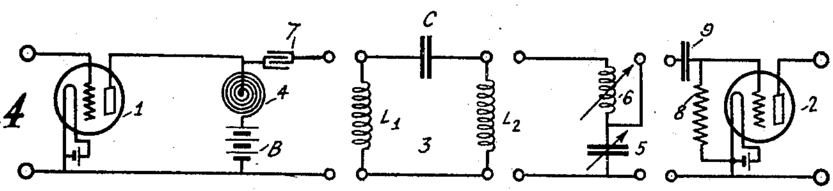


Fig. 5a

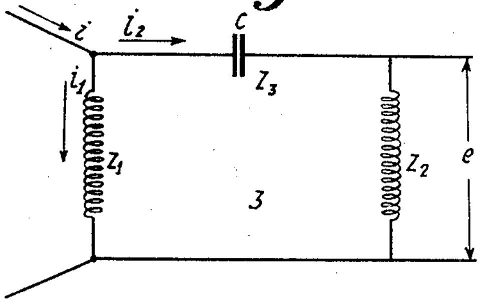
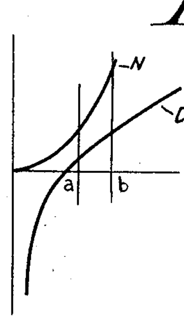


Fig. 5b



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UNITED STATES PATENT OFFICE

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TUNED RADIO FREQUENCY COUPLING DEVICE

Application filed February 13, 1928. Serial No. 253,831.

One of the difficulties encountered in modern radio practice is the fact that unless numerous adjustments are provided, uniform results will not be obtained when receiving signals over the usual frequency range. It has been found that this is due mostly to the fact that the ordinary coupling means now in use have changing characteristics with changing of frequencies of current. It is, therefore, one of the objects of this invention to have a coupling device which allows approximately uniform results to be obtained over the usual frequency range without other adjustments being necessary than the tuning means.

Another object of the invention is the obtaining of uniform selectivity throughout the broadcasting range.

Still another object of the invention is to obtain uniform amplification throughout the broadcast range.

Other objects of the invention will be apparent in the description of the device when read in connection with the drawings in which;

Fig. 1 shows a preferred embodiment of the invention;

Fig. 2 illustrates a modification of the invention slightly differing in detail from Fig. 1;

Fig. 3 is similar to Fig. 1 except that the arrangement therein disclosed allows for the grounding of the rotor of the variable condenser;

Fig. 4 shows a circuit incorporating the invention broken up into its constituent parts;

Fig. 5*a* shows the coupling circuit of Fig. 1 detached and;

Fig. 5*b* shows curves for certain conditions existing in the circuit of Fig. 5*a*.

Briefly this invention deals with the design of a constant coupling circuit for vacuum tubes arranged in cascade relation. In prior circuits, known in the art, when producing approximately constant coupling for a certain range of frequencies, circuits have been designed in which the coupling between the tubes is the sum of an inductive and a capacitive coupling. The purpose of this dual coupling effect is that upon a change in frequency the loss in the coupling value of the capacitive coupling would be made up by the increase in inductive coupling, or vice versa, so that in reality the result obtained would be the algebraic sum of the coupling effects of the two couplings, which by the proper choice of constants and electrical values of the component parts could be made approximately constant for a certain band of predetermined frequencies.

The present invention differs therefrom in that the total coupling effect is not a simple sum of two simple couplings but is a quantity which mathematical analysis shows to be determined by the ratio of two other quantities (neither of them couplings in their own right) each of which is a function of frequency, and which ratio is kept constant by choosing circuit elements such that as one quantity increases with frequency, the other also increases in approximate proportion.

In a word the old system utilizes the constancy of a sum of two quantities one going up as the other goes down, while the present invention utilizes the constancy obtainable in a ratio of two quantities which vary proportionately.

In the drawings, Fig. 1, two thermionic tubes 1 and 2 of a cascade circuit are shown coupled together by circuit 3, consisting of the inductances L_1 and L_2 and the capacity C all of which are preferably units of fixed value. An extremity of each inductance is connected to the filament circuit and the opposite extremities are connected to the opposite terminals of the capacity C. The plate battery B may be connected to energize the plate in any suitable manner for example in series with the coil L_1 as shown. Coupling circuit 3 is tuned to a frequency outside the rings, in this case, lower than any frequency to be received by properly selecting the values of units C, L_1 and L_2. A series resonant circuit consisting of condenser 5 and inductance 6 is connected in parallel with inductance L_2. Either or both of the elements 5, 6 may be made adjustable for tuning.

Fig. 2 shows a different method of coupling in which 3 as before represents the coupling circuit composed of the fixed condensers C_1

and C_2 and the fixed inductance L. This modification, it will be noted, replaces the inductances of the coupling circuit of Fig. 1 by capacities and the capacity by an inductance. In Fig. 2 because of the arrangement a direct current path must be provided in the plate filament circuit which path is shown by choke coil 4 and battery B. In this circuit the coupling device is tuned by means of C_1, L and C_2 to a frequency above any to be received. Mutual inductance between the various coils in Figs. 1 and 2 is not necessary, but may be present without detriment if not excessive.

In the two circuit arrangements just discussed it will be noted that the rotor of the variable condenser 5 is not grounded. In case this is desired the apparatus may be arranged as shown in Fig. 3 which is similar to Fig. 1, except that the tuning inductance 6 in the variable condenser 5 have been transposed.

The inductance 6 has been shown variable as it would be preferable to do at least part of the tuning by varying the inductance, or otherwise the tuning range might not be sufficient and the voltage amplification might become relatively too large at the high frequency end of the scale. However, if necessary the tuning may be done entirely by either variable inductances or variable condensers.

The component parts and further details of the circuit are shown for purposes of further explanation in Fig. 4 in which a circuit according to the invention is broken up into its fundamental constituent parts. In this figure the plate circuit of the tube 1 is energized in the manner shown in Fig. 2 and a blocking condenser 7 of large capacity is utilized to prevent short circuit through inductance L_1. The input circuit of tube 2 is provided with a grid leak 8 and grid condenser 9 for enabling the tube to act as a detector in a well-known manner. The input vacuum tube 1 acts as if it were an alternating current generator having definite internal resistance. Next comes, a so-called transducer or coupling circuit 3, made up of inductances L_1 and L_2 and capacity C. The term "transducer" is used to designate any network of impedances which receives energy in one pair of terminals and delivers it usually at a different voltage out of another pair of terminals. The output terminals of the transducer are connected to the series combination inductance 6 and capacity 5. This series combination is utilized for the purpose of producing high voltage by passage of the current through large reactances and to select or tune by insuring that there is only one frequency at which this resonance voltage occurs. The last fundamental constituent is the input circuit of the next vacuum tube 2 which may be connected across any two points of the series resonant circuit 5—6 having a large potential difference therebetween.

The theory of operation of the network or transducer 3 (Fig. 5a) can best be explained by means of the curves shown in Fig. 5b.

In Fig. 5a, a current (i) applied at the input as shown will divide up as is well known into two components, one of which will go through Z_3 and Z_2 and the other component through Z_1. The part going through Z_3, Z_2 will be say, i_2, and the part through Z_1 will be i_1. From well-known formulæ:—

$$i_2 = i\frac{Z_1}{Z_1+Z_2+Z_3} \quad (1)$$

But

$$e = i_2 Z_2 \quad (2)$$

therefore:

$$e = i\frac{Z_1}{Z_1+Z_2+Z_3}Z_2 \quad (3)$$

Let us designate by the word "transducance" the voltage appearing between the output terminals per ampere flowing into the input, the output terminals being supposedly unconnected to anything.

Therefore, from above:—

$$\text{Transducance} = \frac{e}{i} = \frac{Z_1 Z_2}{Z_1+Z_2+Z_3}$$

or, in Fig. 5a:

$$\text{Transducance} = \frac{j\omega L_1 j\omega L_2}{j\omega L_1 + j\omega L_2 - j\frac{1}{\omega C}}$$
$$= j\frac{\omega^2 L_1 L_2}{\omega(L_1+L_2) - \frac{1}{\omega C}}$$

Plotting separately the values of the numerator and the value of the denominator in the above equation for a range of different frequencies

$$\frac{\omega}{2\pi},$$

the two curves N and D shown in Figs. 5–6 will be obtained, remembering always, of course, that for purposes of the curves certain values of L_1 and L_2 have been chosen and that they remain constant throughout the curves. For other values of the constants, the values obtained from the curve would have to be multiplied by certain constants.

By means of Thevenin's theorem, it can be proven that the uniformity of selectivity and amplification depends very approximately upon the transducance. To illustrate, suppose that the desired result is to have the same current flowing through the tuning elements at all frequencies and further suppose that the resistance of the tuning elements does not vary with frequency. Then, the so-called transducance should remain constant in order to receive the desired result. If other results are desired, the transducance should vary with frequencies in a definite fashion.

Now in many cases, it would be desirable to have this transducance remain approximately constant. If a transducer is used such as shown in Figs. 1 or 2, the expression for the transducance takes the form of a ratio such as shown above by Equation (3) and that by suitable choice of constants the numerator and denominator can be made to vary almost proportionately over the desired frequency range such as 50 to 150 kcs. so that the transducance remains substantially constant over the range. Such a condition would approximately exist for the frequencies shown between the points *a* and *b* of Fig. 5*b*. It will be seen from that portion of the two curves that the values increase almost proportionately which means that the transducance will remain approximately equal for that range.

It is not intended to limit the invention to the particular construction and arrangement of parts shown, since many modifications may be made therein without departing from the invention and the appended claims should be construed to cover all such modifications.

I claim:

1. In combination a thermionic valve having input and output circuits said output circuit comprising a choke coil, a current source in series therewith and a capacity across said choke coil and said source, a second thermionic valve having input and output circuits, said input circuit comprising a pair of condensers in series and an inductance in parallel therewith, and means for connecting one of said last named condensers to said first mentioned condenser comprising a circuit including an inductance.

2. In an amplifier system for amplifying electrical impulses of radio frequency, the frequency of which may vary within specified limits, a source of radio frequency energy, a space discharge device having input and output circuits, a transducer for coupling said source and said space discharge device and maintaining a constant coupling relationship therebetween irrespective of whichever frequency within said limits is being transferred therethrough, said transducer having an input side and an output side, said output side being connected to a series combination of inductance and capacitance at least one of which is adjustable for tuning said series combination to any frequency within said specified limits, the input of said space discharge device being connected across two points of said series combination having a difference of potential between them, said transducer comprising two reactances of like sign and one reactance of opposite sign connected in series, said reactances of like sign and said reactance of unlike sign being tuned in combination to a frequency outside said specified limits, said output side of the transducer being formed across two points of one of said first mentioned like reactances, and said input side being formed across two points of the other reactances of like sign.

3. A system for coupling a source of alternating current to the input of a space discharge device, adapted to maintain a constant coupling therebetween irrespective of the frequency transferred within a certain frequency band to be received, which comprises three reactances two of like sign and one of unlike sign forming a series circuit, the total reactance of said circuit vanishing at a frequency outside said band of frequencies to be received, means for coupling the source of alternating current to one of the two reactances of like sign, means for coupling the other reactance of similar sign to a series combination of unlike reactances one of which is adjustable for selection purposes and means for coupling one of the last named reactances to the input electrodes of the space discharge device.

4. A system for coupling a source of alternating current to the input of a space discharge device, adapted to maintain constant coupling irrespective of the frequency transferred therethrough within a frequency band to be received which comprises a pair of terminals for input energy an inductive reactance connected in shunt, a capacitive reactance in series, another inductive reactance in shunt and a series pair of reactances of opposite signs, one thereof being adjustable, in shunt with said second inductive reactance the input electrodes of said space discharge device being tapped across one of said series pair of unlike reactances, said first three named reactances being chosen to have the sum of their reactances vanish at a frequency below the range of frequencies to be received.

5. The combination of elements as recited in claim 4 in which the magnitudes of each of the first named three reactances are such that the impedance measured across the third mentioned reactance when said three reactances are connected to the source of current, is small compared to the impedance of the series pair of reactances of opposite signs.

6. A system for coupling a source of alternating current to the input of a space discharge device adapted to maintain constant coupling irrespective of the frequency within a frequency band to be received transferred therethrough, which comprises a pair of input terminals, a capacitive reactance connected in shunt, an inductive reactance in series, another capacitive reactance in shunt and a series pair of reactances of opposite signs, one thereof being adjustable, in shunt with said second capacitive reactance, the input electrodes of said space discharge device be-

ing tapped across one of said series pair of reactances, said first three named reactances being so proportioned that the sum of their reactances vanish at a frequency above the range of frequencies to be received.

7. The combination as recited in claim 6 in which the magnitudes of each of the first three named reactances are such that the impedance measured across the mentioned reactance when said three reactances are connected to the source of current is small compared to the impedance of either of the series pair of reactances.

WALTER VAN B. ROBERTS.

DISCLAIMER

1,831,640.—*Walter Van B. Roberts*, Princeton, N. J. TUNED RADIO FREQUENCY COUPLING DEVICE. Patent dated November 10, 1931. Disclaimer filed February 3, 1933, by the assignee, *Radio Corporation of America.*

Therefore, enters the following disclaimer:

In claim 3, no claim is made to the combination recited except where the resonant frequency of the combination of the first-named reactance of unlike sign and that reactance of like sign which is coupled to the series combination of unlike reactances is higher than the lowest frequency of the range to be received.

[*Official Gazette February 21, 1933.*]