July 28, 1936. P. O. FARNHAM 2,048,737

AMPLIFIER CIRCUIT

Filed Sept. 23, 1931

Fig. 1.

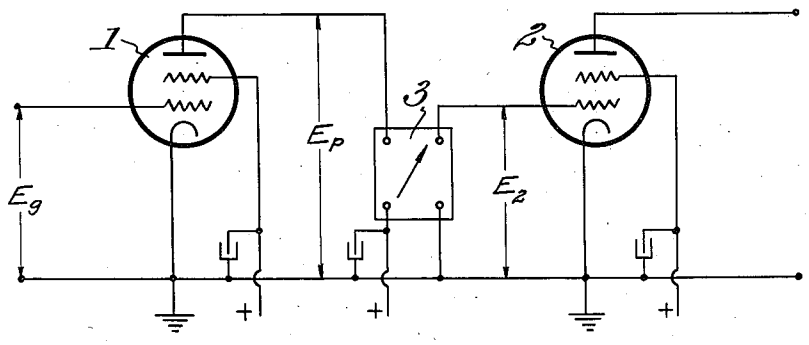


Fig. 2.

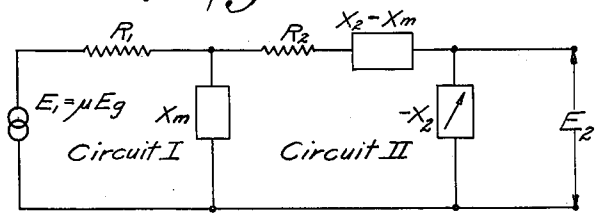


Fig. 3.

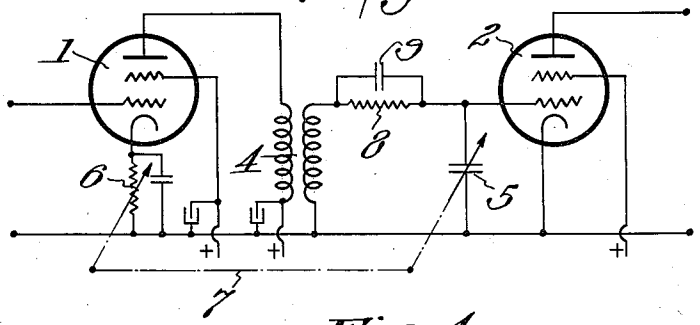
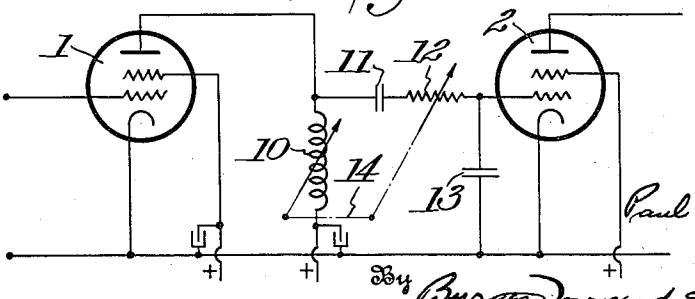


Fig. 4.



Inventor:
Paul O. Farnham,
By Byrnes Townsend & Potter,
Attorneys.

Patented July 28, 1936

2,048,737

UNITED STATES PATENT OFFICE

2,048,737

AMPLIFIER CIRCUIT

Paul O. Farnham, Boonton, N. J., assignor, by mesne assignments, to Radio Corporation of America, New York, N. Y., a corporation of Delaware

Application September 23, 1931, Serial No. 564,675

11 Claims. (Cl. 178—44)

This invention relates to audion amplifier circuits, and more particularly to tuned amplifier circuits in which the gain and selectivity bear a desired relationship to the frequency to which the amplifier is tuned.

It may be stated that, in general, the most satisfactory tuned amplifier circuit will exhibit a constant gain and a constant selectivity as it is tuned over the frequency band. In the following specification, "selectivity" is to be understood as the ratio of transmission at the resonant frequency to the transmission at a constant frequency interval off resonance. In the simpler amplifier stages in which the coupling consists of a transformer tuned by a variable condenser, the gain increases linearly with increasing frequency and the selectivity varies inversely with the frequency. Unfortunately, the previous attempts to improve one of these characteristics of a transmission system including tuned amplifier stages have reacted unfavorably upon the other characteristic of the system.

An object of the present invention is to provide a tuned amplifier stage which reduces the variation of gain and of selectivity with frequency, which reduction of variation may, in one special case, result in constant gain and constant selectivity over the entire frequency band. A further object is to provide an amplifier stage having a coupling system so designed and constructed that the impedances of circuit elements are varied automatically as the coupling system is tuned over the frequency band, the variations being so related to frequency changes that the gain and the selectivity of the amplifier both remain constant or approximately constant throughout the tuning range of the amplifier.

These and other objects of the invention will be apparent from the following specification when taken with the accompanying drawing, in which,

Fig. 1 is a schematic view of an amplifier including tuned coupling between successive tubes,

Fig. 2 is a circuit diagram of an equivalent network, and

Figs. 3 and 4 are circuit diagrams of embodiments of the invention.

In the drawing, the reference numerals 1, 2 identify successive tubes in an amplifier system, the plate circuit of tube 1 being coupled to the control grid or input circuit of tube 2 by means of a tuned coupling 3. The remaining circuit connections for energizing the tubes may be of any desired appropriate type. Through the amplifier action of tube 1, an alternating voltage $E_1=\mu E_g$ is established in the plate circuit, identified in Fig. 2 by the legend "Circuit I", and the coupling 3 between circuit I and the grid circuit, II, of tube 2 sets up an alternating potential E_2 between the control grid and cathode of tube 2.

A generalized net work equivalent to the coupled amplifier circuits is shown in Fig. 2, in which circuit I includes a voltage source E_1, in series with a resistance R_1 equal to the plate resistance of tube 1 and a coupling impedance X_m. Circuit II includes, in series, the coupling reactance X_m, a resistance R_2 equal to the resistance of the grid circuit of tube 2, a reactance $X_2—X_m$ of the same type as the coupling reactance, and a variable reactance, $-X_2$, for tuning the circuit II. That is, X_2 is the sum of the reactances of a sign opposite to that of the tuning element and, in one special case, X_m may be equal to X_2, i. e., the total reactance of a sign opposite that of the tuning reactance may be embodied in the coupling reactance. E_2 is the voltage developed across the tunable element of circuit II when the circuit is adjusted for maximum E_2 at the frequency of the desired signal.

A mathematical study of the Fig. 2 network will show that for constant gain and for constant selectivity over the frequency band certain relationships between the magnitudes of the circuit elements must be satisfied. To secure a gain and a selectivity independent of frequency the following three equations must be satisfied.

$$\frac{X_m^2}{R_1R_2}=K, \text{ a constant} \quad (1)$$

$$\frac{X_2}{X_m}=K_1, \text{ a constant} \quad (2)$$

$$\frac{X_2}{\omega R_2}=K_2, \text{ a constant} \quad (3)$$

Equations (1) and (2) are necessary and sufficient conditions for the gain to be independent of frequency. Equations (1) and (3) are necessary and sufficient conditions for the selectivity to be independent of frequency.

To obtain both constant gain and selectivity, an examination of these equations indicates that, for capacitive tuning, i. e., when $-X_2$ takes the form of an adjustable condenser, the resistance R_2 of the circuit II must remain constant throughout the frequency band while R_1, the plate resistance of tube 1, must vary as the square of the frequency; and that, for inductive tuning, R_2 must vary as the reciprocal of the

square of the frequency while R_1 remains constant.

Amplifier circuits which satisfy these conditions are shown in Figs. 3 and 4.

As shown in Fig. 3, the coupling between the tubes includes a transformer 4 and tuning condenser 5 across the transformer secondary. To secure the desired increase of plate resistance as the system is tuned to higher frequencies, a variable cathode resistance 6 is included in the circuit of tube 1, and the control element of the resistance is mechanically connected to the movable element of condenser 5, as indicated by bar 7. The total resistance, R_2, of the grid circuit of tube 2 may be maintained substantially constant over the frequency band by the insertion in the circuit of a network of fixed impedances comprising a series resistance 8 shunted by a condenser 9. As the resonant frequency is increased, the effect of resistance 8 upon the circuit resistance decreases automatically and the values of resistance 8 and condenser 9 are so chosen that the total resistance of the grid circuit does not vary appreciably with frequency. The resistance 8 may have a value of about 120 ohms with a condenser 9 of about 0.007 microfarad.

One possible arrangement of an inductively tuned coupling system is shown, in Fig. 4, as including a tuned plate inductance 10 coupled, by condenser 11, to the grid circuit which includes a variable resistance 12 and capacity 13 between the control grid and cathode of tube 2. The adjustable elements of tuning inductance 10 and the resistance 12 are mechanically linked, as indicated by bar 14, to secure such variation of the resistance with tuning that the total resistance of the grid circuit varies inversely with the square of the frequency. The plate resistance of tube 1 remains constant throughout the tuning range.

It will be apparent that a plurality of stages embodying the invention may be cascaded in the usual manner, and that the particular circuits herein described and illustrated are illustrative of two particular networks based upon the generalized network shown in Fig. 2. Other adaptations of that general network will occur to those familiar with the design of electrical circuits.

While the foregoing explanation has dealt with the securing of constant gain and constant selectivity over the frequency band, it is to be understood that the invention is not restricted to methods or circuit arrangements which maintain both the gain and the selectivity absolutely constant. The invention provides a general method for the control of the frequency variation of gain and of selectivity and, for various reasons, it may be desirable to construct amplifier circuits in which the usual frequency variation of one or both of these characteristics is altered, but is not completely eliminated.

I claim:

1. In a transmission system, a pair of circuits serially arranged in the path of signal transmission and coupled by a capacitive reactance, an adjustable resistance in one of said circuits, an adjustable inductive reactance in one of said circuits for tuning the same over a band of frequencies, and means for simultaneously adjusting said adjustable tuning reactance and said adjustable resistance, said adjustable resistance being a series element in the second of said circuits.

2. In an amplifier, the combination with a pair of vacuum tubes, an inductively tuned output circuit for the first tube, capacitive means coupling the input circuit of said second tube to the output circuit of said first tube, an adjustable resistance included in said input circuit, and means automatically decreasing the effective magnitude of said resistance as said output circuit is tuned to higher frequencies.

3. In a transmission system, the combination with a circuit in which a signal voltage is developed, a second circuit inductively coupled to said first circuit and including an adjustable condenser for tuning said second circuit over a band of frequencies, of resistive impedance in said second circuit, and means comprising a network of fixed impedances for automatically maintaining the effective value of said resistive impedance substantially constant as the resonant frequency of said second circuit is increased.

4. The invention as set forth in claim 3, in combination with resistance in said first circuit, and means automatically increasing the said resistance as the resonant frequency of said second circuit is increased.

5. In an alternating current transmission system, the combination with two circuits, reactance coupling said circuits, and reactive means for tuning one of said circuits over a band of frequencies, of resistance in one of said circuits, and means operative automatically with adjustment of said reactive tuning means to vary said resistance to substantially match the impedance of both said circuits throughout the tuning range and thereby maintain the gain and selectivity of said coupled circuits substantially independent of the frequency to which said system is tuned.

6. A vacuum tube amplifier of the type including two vacuum tubes, and a condenser tuned transformer coupling said tubes, of means automatically increasing the resistance of the primary circuit of said transformer and automatically reducing the increase in resistance of the transformer secondary circuit as the transformer is tuned to higher frequencies.

7. In the operation of a tuned amplifier of the type in which two tubes are cascaded by coupling the plate circuit of one tube to the input circuit of the second tube by a coupling reactance of one type and a tuning reactance of the opposite type included in one of said circuits, the method of controlling both the amplifier gain and the amplifier selectivity as a function of the resonant frequency, which comprises automatically varying the resistance of one of said circuits while maintaining the resistance of the other circuit substantially constant as the amplifier is tuned over its frequency band.

8. The invention as set forth in claim 7, wherein the rates of variation of the resistances of said circuits are so related to the resonant frequency that the product of the resistances of the respective circuits maintains a constant ratio to the square of the coupling reactance throughout the frequency band.

9. In the operation of an amplifier of the type in which the plate circuit of one tube is inductively coupled to the input circuit of the succeeding tube, and one of said circuits includes an adjustable condenser for tuning the amplifier over a frequency band, the method which comprises automatically maintaining the resistance of the input circuit substantially constant over the frequency band while varying the plate circuit resistance as the square of the frequency of the amplifier is tuned over its frequency band.

10. In the operation of a tuned amplifier including two tubes cascaded by a capacitive coupling system, the method of reducing the frequency variation of gain and of selectivity which comprises tuning said coupling system by adjusting the magnitude of an inductive reactance therein, and simultaneously varying the resistance of the input circuit of the second tube inversely as the square of the resonant frequency.

11. In an alternating current transmission system, the combination with two circuits, inductive impedance coupling said circuits, and capacitive means for tuning one of said circuits over a band of frequencies, of an impedance in one of said circuits, and means operative automatically with adjustments of said capacitive means to vary one of said impedances to substantially match the impedance of both said circuits throughout the tuning range and thereby maintain the gain and the selectivity of said coupled circuits substantially independent of the adjustment of said capacitive means.

PAUL O. FARNHAM.