June 22, 1937. R. A. BRADEN 2,084,475

HIGH FREQUENCY AMPLIFIER

Filed Dec. 29, 1934

Fig. 1.

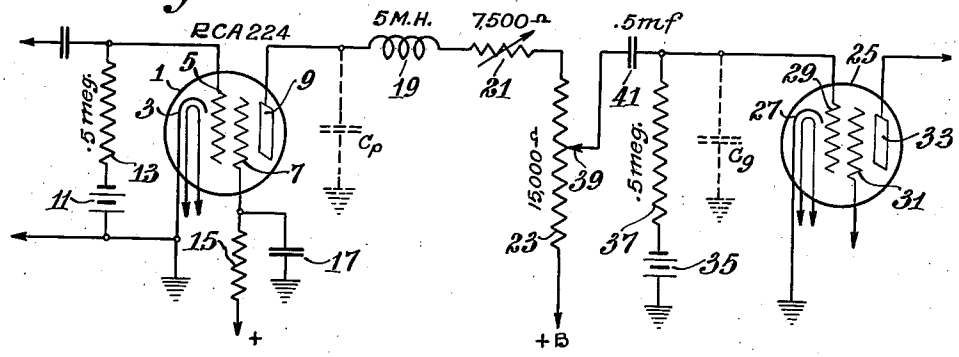


Fig. 2.

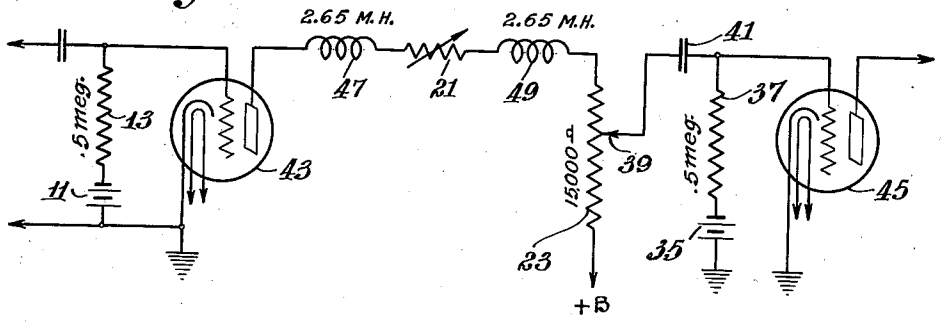
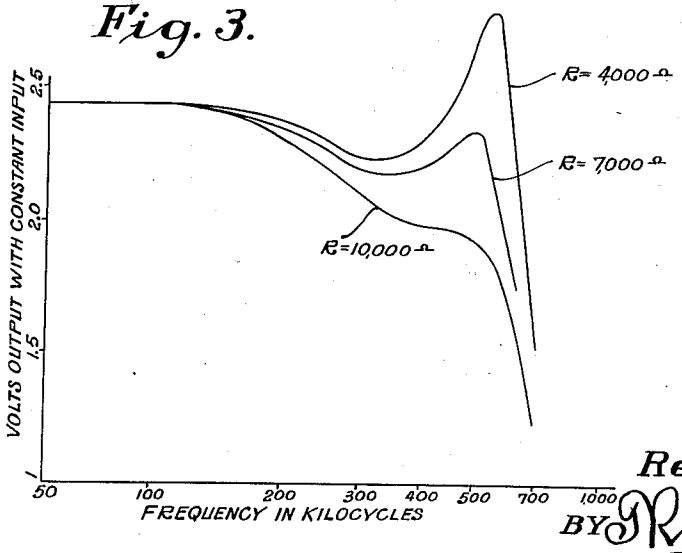


Fig. 3.



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HIGH FREQUENCY AMPLIFIER

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6 Claims. (Cl. 179—171)

My invention relates to high-frequency amplifiers, and particularly to amplifiers adapted to amplify uniformly all signal frequency components included within a wide frequency range.

An object of my invention is to provide an improved high-frequency amplifier having satisfactory gain at the high frequency end of the band of frequency components to be amplified.

A further object of my invention is to provide an improved circuit whereby the range of uniform amplification may be extended to higher frequencies than can be done with previously known circuits.

A still further object of my invention is to provide an improved amplifier of the above mentioned type having gain control means which may be adjusted without appreciably changing the amplifier frequency response characteristic.

My amplifier circuit resembles the circuit shown in the U. S. patent to Round #1,841,383 in that an inductance coil is resonated with tube capacity at the high frequency end of the amplifier's frequency range. In my amplifier, however, the inductance coil is made to resonate with the tube output capacity rather than the tube input capacity as in the Round circuit, and the output voltage is taken off a resistor in the resonant plate circuit by means of a variable tap. By adjusting this tap, the gain of the amplifier as a whole may be varied without changing the amplifier characteristics appreciably.

Other objects, features and advantages of my invention will appear from the following description taken in connection with the accompanying drawing, in which

Figure 1 is a circuit diagram of an amplifier embodying my invention;

Fig. 2 is a circuit diagram of another embodiment of my invention; and

Fig. 3 is a group of curves showing certain characteristics of the amplifier shown in Fig. 1.

Referring to the embodiment of my invention shown in Fig. 1, the amplifier comprises an amplifier tube 1 which may be a vacuum tube of the screen grid type having a cathode 3, a control grid 5, a screen grid 7 and a plate 9. In the specific amplifier illustrated, the vacuum tube is an RCA 224. The control grid 5 is biased to a suitable operating potential in any suitable manner as by means of a biasing battery 11 and grid resistor 13.

A suitable positive potential is applied to the screen grid 7 through a resistor 15 in the usual manner, the screen grid being maintained at substantially ground potential for alternating currents by means of the usual by-pass condenser 17. As indicated at C_p by the dotted lines, the plate 9 has a certain amount of capacity to ground. The greater part of this capacity is the capacity between the plate 9 and the screen grid 7. As is well understood in the art, capacity shunting an amplifier circuit in this manner tends to by-pass the higher frequency components of the signals to be amplified whereby the gain of the amplifier tends to drop at the high frequency end. This is especially true where such high frequencies as those employed in television systems are involved.

In accordance with my invention, I apply the usual positive potential to the plate 9 through a plate circuit which includes an inductance coil 19 positioned adjacent to the plate. The plate circuit also includes in series with the inductance coil 19 a variable damping resistor 21 for adjusting the damping of the plate circuit, and a load resistor 23 across which appears the voltage to be impressed upon the succeeding amplifier tube 25.

The succeeding amplifier tube 25 may be of any suitable type, such as a screen grid tube having a cathode 27, a control grid 29, a screen grid 31 and a plate 33. As indicated at C_g by the dotted lines, the control grid 29 has a certain amount of capacity to ground which, like the capacity C_p, has a shunting effect on the high frequency components of the signals. The control grid 29 may be biased to a suitable operating potential in any suitable manner as by means of the biasing battery 35 and grid resistor 37.

The output circuit of the first amplifier tube 1 is coupled to the input circuit of the succeeding tube 25 by means of a connection from a variable tap 39 on the resistor 23 through a coupling condenser 41 to the control grid 29. It will be evident that the voltage appearing across the portion of the resistor 23 below the variable tap 39 is impressed upon the input circuit of the amplifier tube 25, and that the magnitude of this impressed voltage may be changed by adjusting the variable tap whereby the gain of the amplifier may be controlled.

As previously mentioned, the inductance coil 19 is given a value of inductance such that it resonates with the capacity C_p at the high-frequency end of the amplifier's frequency range. Therefore, the plate circuit is resonant at this selected frequency and the height of the resonant peak may be changed by adjusting the variable resistor 21. This will be seen by referring to Fig. 3, where the frequency response characteristic of the

amplifier is shown for three values of the resistor 21.

It should be noted that the input circuit of the amplifier tube 25 is not coupled across any portion of the plate circuit containing reactance. For this reason the voltage applied to the input circuit is directly proportional to the current flowing in the plate circuit and through the resistor 23. Consequently, the frequency response characteristic of the amplifier as a whole remains substantially unchanged when the position of the variable tap 39 is changed. The only change that is produced is that caused by a slight change in the loading of the plate circuit.

Without the plate inductance 19, the capacity C_p and the capacity C_g are in parallel, and in shunt to the load resistance 23, causing the load impedance to decrease at high frequencies, and thus causing the amplification to decrease. If tube 1 is a screen grid tube, its plate impedance is so high in comparison with the load impedance 23 that the above mentioned variation of the load impedance at high frequencies has no effect on the output current, which therefore remains constant when the frequency is varied.

The effect of the inductance 19 in the circuit can be partly explained by noting that it separates C_p and C_g, and only C_g is directly across the load resistance. Since C_g is generally about half the size of C_p, the capacity C_g alone has only about $\frac{1}{3}$ of the effect of C_p and C_g together at high frequencies. At the same time the capacity C_p resonates with the inserted coil at the upper limiting frequency of the amplified band. The effect of this is to increase the current flowing through the load impedance (comprising resistor 23 and capacity C_g in parallel) by adding to the output current of the tube 1 a circulating current component flowing through C_p, coil 19, and resistors 21 and 23, thus increasing the voltage developed aross the load resistance 23. This effect becomes more pronounced, of course, as the frequency increases, until the resonance frequency is reached. Above this frequency the effect is reversed and the amplification is reduced very sharply.

When the circuit is suitably proportioned, the shunting effect of C_g and the current resonating effect of C_p increase at approximately the same rate, so that as the load impedance decreases with increasing frequency, the current through it increases at the proper rate to keep the voltage across the load impedance substantially constant. Suitable proportions include, among other things, the right amount of damping resistance 21, as this resistance controls the amount of circulating current, and the rate at which this varies with frequency. If this resistor is too small, the current through the load resistor will rise to a high value at the resonant frequency, and the frequency response curve will have a peak at this frequency as shown in Fig. 3.

The capacity C_g has no effect on the resonant frequency of C_p and coil 19, since C_g is shunted by the load resistor 23, which is a low resistance relative to the reactance of C_g. At the same time, resistor 23 provides a comparatively small amount of damping for the resonant circuit when the tap 39 is in its maximum gain position because of C_g shunting it.

As tap 39 is moved to reduce the gain, the shunting action of C_g on resistor 23 is reduced whereby the high frequency response tends to improve; also, the portion of 23 above the tap becomes effective as damping resistance and hence reduces the effectiveness of the resonant action in increasing the high frequency response, these two effects working in opposite directions maintain the frequency characteristic substantially constant as the amplification is reduced.

In Figs. 1 and 2 like parts are indicated by the same reference numerals. In the amplifier shown in Fig. 2, three-element vacuum tubes 43 and 45 are employed and the single inductance coil 19 of Fig. 1 has been split into two sections 47 and 49, for the purpose of minimizing the effect of distributed capacity in the coil. Where three-element vacuum tubes are employed it may be desirable to omit the damping resistor 21, since the plate impedance of tubes of this type is low enough to cause considerable damping in the circuit.

On the drawing various circuit values have been indicated, by way of example, in ohms, millihenrys, and microfarads. It should be understood that the circuit values may be varied within rather wide limits, different values being desirable for different types of tubes.

From the foregoing description it will be apparent that various other modifications may be made in my invention without departing from the spirit and scope thereof, and I desire, therefore, that only such limitations shall be placed thereon as are necessitated by the prior art and are set forth in the appended claims.

I claim as my invention:

1. An amplifier comprising an electric discharge tube of the screen grid type having an output electrode which has a certain amount of capacity to ground, an output circuit connected to said electrode, said circuit including an inductance coil adjacent to said electrode and a resistor connected in series with said coil between the coil and a source of potential for said electrode, said coil and said capacity being resonant at the high frequency end of the amplifier's frequency range, a second electric discharge tube having an input circuit, means for impressing at least a portion of the voltage drop across said resistor upon said input circuit, and a damping resistor connected in series with said coil and said first resistor whereby said damping resistor is not shunted by the input capacity of said second tube.

2. An amplifier according to claim 1 characterized in that said means includes a variable tap on said resistor connected to the grid of the second tube whereby the gain of the amplifier may be controlled.

3. An amplifier comprising an electric discharge tube which includes output electrodes having a certain amount of capacity therebetween, an output circuit connected to said electrodes and including an inductance coil and a resistor connected in series, said coil having an inductance value such that it resonates with said capacity at the high frequency end of the amplifier's frequency range, a work circuit coupled across said resistor only, and a damping resistor connected in series with said coil and said first resistor whereby said damping resistor is not shunted by said work circuit.

4. Apparatus according to claim 3 characterized in that means is provided for varying the amount of resistance across which said work circuit is connected.

5. Apparatus according to claim 3 characterized in that said work circuit is connected to said resistor through a variable tap.

6. An amplifier comprising an electric dis-

charge tube which includes output electrodes having a certain amount of capacity therebetween, an output circuit connected to said electrodes and including an inductance coil, a damping resistor and a load resistor connected in series, said coil having an inductance value such that it resonates with said capacity at the high frequency end of the amplifier's frequency range, a work circuit, and means for coupling said work circuit across selected portions of said load resistance only.

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