April 25, 1933. H. F. ELLIOTT 1,905,826

HIGH FREQUENCY AMPLIFIER

Filed April 21, 1928 2 Sheets-Sheet 1

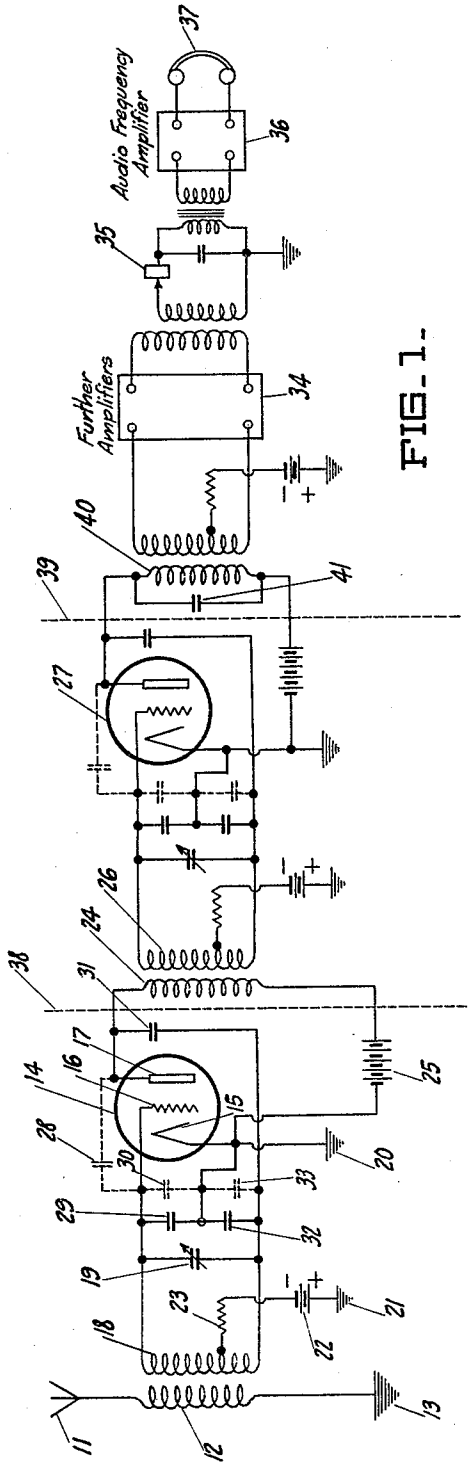


FIG. 1.

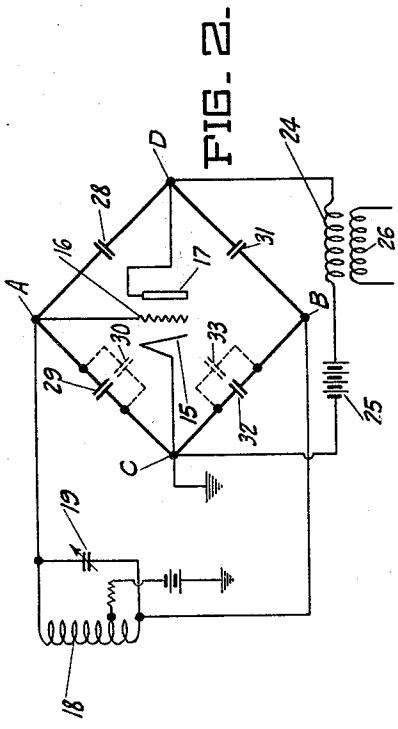


FIG. 2.

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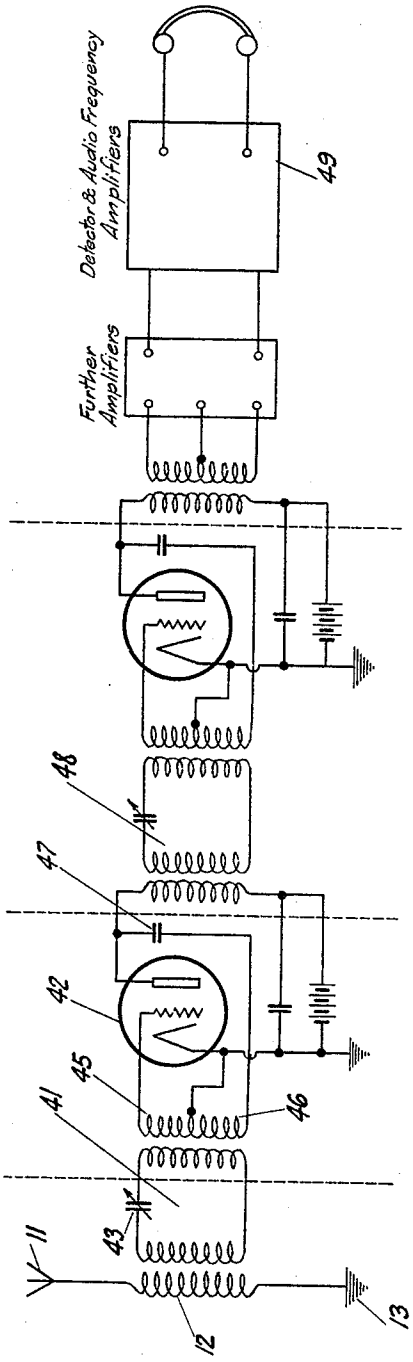


FIG. 3.

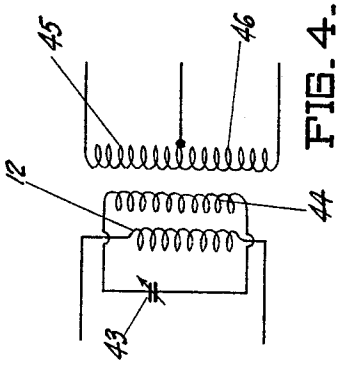


FIG. 4.

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UNITED STATES PATENT OFFICE

HAROLD F. ELLIOTT, OF PALO ALTO, CALIFORNIA, ASSIGNOR, BY MESNE ASSIGNMENTS, TO RADIO CORPORATION OF AMERICA, OF NEW YORK, N. Y., A CORPORATION OF DELAWARE

HIGH FREQUENCY AMPLIFIER

Application filed April 21, 1923. Serial No. 271,861.

This invention relates to electronic emission amplifiers, and particularly to a system of cascade amplification, such as are now in common use in connection with radio signaling.

This application is a continuation in part of my two prior applications; one having Serial #186,039, filed April 23, 1927, and entitled: "Electronic vacuum tube system"; and the other having Serial #175,500, filed March 15, 1927, and entitled: "Stabilized radio circuits".

Amplifiers utilizing electron emission are now well-known in the art of radio communication. Such amplifiers usually include an evacuated vessel in which there are a plurality of electrodes. One electrode serves as a source of electrons, and may for example, consist of a filament arranged to be heated by an electric current. The electrons are attracted to a plate electrode or anode, spaced from the electron emitting electrode and kept at a potential positive with respect to the said electron emitting electrode. This is accomplished by the aid of a circuit externally connecting these electrodes, and which is usually termed the output circuit.

The space current thus secured by the electron flow can be varied to a large extent by the aid of a control electrode, usually in the form of a grid interposed between the plate and the electron emitting electrode. Even minute variations in potential differences between the control electrode and the electron emitting electrode cause correspondingly large variations in the electron flow, and therefore in the space or output current. These large variations in the output current can be used successively to affect a series of succeeding amplifiers by causing the current variations in the output circuit to produce potential variations across the input electrodes of the succeeding amplifiers.

When using such a cascade system of amplifiers for very high frequency currents, such as in radio communication, it is found that the capacity effect between the electrodes, although negligible for low frequency currents, has a deleterious result, for by the aid of that effect, the input and output sides of the amplifier improperly affect each other; and succeeding stages react by its aid, upon the preceding stages.

It is one of the objects of my invention to reduce these disadvantageous effects to a negligible value, and especially by the aid of capacitities so arranged as to form with the interelectrode capacities, a bridge circuit that isolates the stages and the input circuits from the output circuits.

It is another object of my invention to make it possible to provide uniform overall amplification for the entire system for the entire range of frequency under which the system operates.

My invention possesses many other advantages, and has other objects which may be made more easily apparent from a consideration of several embodiments of my invention. For this purpose I have shown a few forms in the drawings accompanying and forming part of the present specification. I shall now proceed to describe these forms in detail, which illustrate the general principles of my invention; but it is to be understood that this detailed description is not to be taken in a limiting sense, since the scope of my invention is best defined by the appended claims.

Referring to the drawings:

Figure 1 is a wiring diagram showing one embodiment of my invention;

Fig. 2 is an explanatory diagram of a stage of amplification shown in Fig. 1;

Fig. 3 is a diagram of a modified form of my invention; and

Fig. 4 is a detail diagram showing a portion of the system illustrated in Fig. 3.

Referring to Fig. 1, I show my invention as embodied in a radio receiving system. There is a pick-up circuit including antenna 11, loading coil 12, and ground 13. The energy picked up in this circuit is caused to affect the first amplifier tube 14, having an electron emitting electrode 15, control electrode 16, and plate or anode 17.

The pick-up circuit is shown as coupled to a coil 18 which forms with a variable condenser 19, a tunable radio frequency circuit. By proper manipulation of the condenser 19, the circuit 18—19 is caused to respond, in

a well-understood manner, most strongly to the frequency of the signals desired to be received, and within the range of operation of the system. The control electrode 16 is connected directly to the upper terminal of coil 18, and filament 15 is connected to an intermediate point on coil 18, through ground connections 20, 21, grid bias battery 22, and an impedance, such as a resistance 23. Also, capacities 29—30 and 32—33 are arranged so that one half or more of the potential across circuit 18—19 is applied between the control electrode 16 and cathode 15. Variations in potential difference between the electrodes 15 and 16 due to these connections, cause variations in the space current flow. These variations are impressed on an external circuit, including plate or anode 17, a coupling coil 24 forming the primary of a radio frequency transformer, plate battery or other source of direct current 25, back to filament 15.

The primary 24 is used to transfer the amplified signaling impulses to a succeeding stage, as by being inductively coupled to the secondary coil 26, which can be connected to a succeeding amplifier 27 in the same manner as coil 18 is connected to amplifier 14.

It is evident that without further precautions, variations in the coil 24 induced therein from the succeeding stages, can affect the circuit 18—19 through the parasitic capacity coupling 28 between the control electrode 16 and plate 17. Furthermore, this parasitic coupling could also serve to pass energy from circuit 18—19 to the output side of the device. If uncorrected, parasitic oscillations and other disturbing influences may result, especially in a multistage system.

In order to obviate this, I arrange a bridge circuit, formed entirely of capacities and so connected to the output circuit 24—25, and the input circuit 18—19 that no substantial energy transfer can occur between them. For this purpose, I provide a four arm bridge, most clearly shown in the diagram of Fig. 2. The first arm is formed by a capacity 29 and capacity 30 in parallel. Capacity 30 represents the stray capacity, such as between the leads and the electrodes 15 and 16, and capacity 29 may be omitted if this stray capacity is of sufficient value.

The second arm is formed by the capacity 28 between the electrodes 16 and 17. The third arm is formed by a capacity 31. The fourth arm is formed by capacities 32 and 33 in parallel. Capacity 33 represents the stray capacity; such as of the leads and the condenser plates to earth. Capacity 32 may be omitted if this stray capacity is of sufficient value.

The input electrodes 15 and 16 connect to two of the corners of this bridge, such as the terminals of the first arm 29—30; the plate electrode connects to one of the other corners, as between arms 28 and 31. The output circuit 24—25 connects to diagonally opposite points; one terminal for example between arms 29—30, and 32—33; and the other, between arms 28 and 31. The input circuit 18—19 connects across the other diagonal; that is, one terminal connects between arms 29—30 and 28; and the other terminal, between arm 32—33 and arm 31.

It can readily be shown mathematically that if capacity 29—30 has the same ratio to capacity 32—33 that capacity 28 has to capacity 31, then there can be no energy transfer, through the bridge, between circuits 18—19 and 24—25; in other words, any potential difference across circuit 24—25 makes points A and B equipotential; and, vice versa, any potential difference across circuit 18—19 makes points C and D equipotential. In order to secure a large drop between filament 15 and grid 16, I prefer to make capacity 32—33 much larger than capacity 29—30; preferably about twice as large. Similarly, capacity 31 will be also twice as large as capacity 28.

The resistance 23 may be of the order of 0.1 megohm to 1.0 megohm; and it is tapped into coil 18 at a point substantially at earth potential. That is, if the combined capacity of 29—30 is half that of 32—33, as suggested hereinbefore, then resistance 23 should be tapped into coil 18 one-third of the way up from the lower terminal. The battery 22 provides the usual grid bias.

The succeeding radio frequency stages are arranged substantially like the first stage. One succeeding amplifier is indicated at 27; and rectangle 34 indicates additional amplifiers. The last of the seris of radio frequency amplifiers can be coupled to a detector circuit, such as one that includes a rectifying crystal 35. One or more audio frequency amplifiers 36 can be used to amplify the detected signals, and thereafter the signals are passed to a translating device, such as a loud speaker or phones 37.

The radio frequency stages are preferably shielded from one another, as indicated by lines 38, 39.

It is desirable that the system provide the same amplification constant for the range of frequency of operation. For example, in the broadcast range, between 550 and 1500 kilocycles, if no attention be paid to this, the efficiency of the system may be much higher near one limit than near the other. To correct this, I provide that some of the stages of amplification will have a capacitive reactance effect on the succeeding ones, while others will have an inductive reactance effect on the succeeding stage. The couplings of capacitive reactance increase the amplification as the frequency decreases; and the couplings of inductive reactance increase the amplification as the frequency increases; and by proper choice of constants, these couplings

will produce an overall constant amplification.

Thus in Fig. 1, I show the primary coil 40 in the output of one of the stages as paralleled by a capacity 41 of such value that the circuit 40—41 has a natural period below the lowest operating frequency. This causes a capacitive reactance coupling; and as many of the audio or radio frequency stages can be provided with such capacitive couplings as necessary. The other stages, omitting the capacity have natural periods above the highest operating frequency and therefore have an inductive reactance coupling.

Another form of the invention in which this constancy of amplification is secured is illustrated in Fig. 3. The pick-up system 11—12—13 is the same as before. A circuit 41 is interposed between the pick-up circuit and the first amplifier 42. This circuit can be an ordinary tunable link circuit, tuned by condenser 43, or else it can include only one coil such as 44 shown in Fig. 4, which is coupled both to the amplifier coils 45 and 46 as well as to the coil 12. This can be effected by interwinding these coils, or winding them on a common spool.

The amplifier stages can be neutralized in any well-known manner, as by the use of neutralizing circuits, including coil 46 and condenser 47. By proper choice of the constants of the circuits 41, 45, 46, 47, 48, etc., the inductive and capacitive reactance effects can be secured.

Thus for example, the first coupling circuit 41 may be made to have an inductive reactance effect by combining it with coils 45 and 46 so that it will have a resonance period between 550 and 150 kilocycles, depending on the setting of condenser 43; and also a resonance period of a value higher than 1500 kilocycles; for example, 1800 kilocycles. Similarly, circuit 48 may be made to provide a capacity reactance coupling, by giving it two degrees of freedom; one in the range of the system, and the other much below the range, say about 400 kilocycles. Or, if desired, each coupling circuit may be made to have three degrees of freedom so as to obtain both the inductive and capacitive reactions in the single circuit. For example, the circuit including inductor 12 may be given a period below the operating range of the system and the circuit including 45 and 46 a period above the range, while circuit 41 serves to tune the combination within the desired operating range. The design of coupled circuits to secure these effects is well understood.

Similar coupling effects can be secured in the audio frequency amplifiers indicated by rectangle 49; for example, one or more interstage couplings can have a natural frequency below the audio range, say 8000 cycles. Of course in the audio frequency amplifiers, the condenser corresponding to condensers 43 are fixed instead of variable.

Other schemes for securing capacitive and reactive couplings can also be used, and it is not considered necessary to detail these here. The important factor is their choice so that the combined effect is to produce a substantially constant amplification for the entire frequency range of the system.

I claim:

1. In an amplifier system, an electronic emission amplifier having an electron emitting electrode, an anode, and a control electrode, means forming with the inherent capacities of the device, a four armed capacity bridge, the electron emitting electrode and the anode being connected to opposite corners of the bridge and the control electrode to one of the other two corners, an input circuit connected between said control electrode and the opposite corner, a circuit connected between the electron emitting electrode and the anode, the impedance of the arm between the electron emitting electrode and the control electrode being greater than that between the electron emitting electrode and the corner opposite the control electrode.

2. In an amplifier system, an electronic emission device having an electron emitting electrode, a control electrode and an anode, means forming with the inherent capacities of the device, a four armed capacitive bridge, the electron emitting electrode and the control electrode connecting to opposite sides of one arm, said electron emitting electrode being at earth potential, and input circuit connected between the control electrode and to an opposite arm of the bridge at a corner of the bridge opposite said control electrode, said input circuit including an impedance, a circuit connected between the electron emitting electrode and the anode, a third circuit connecting between the electron emitting electrode and an intermediate point on said impedance and an impedance in said last named circuit.

3. The combination as set forth in claim 2, in which the third circuit connects to such a point on the impedance so as to divide it into two parts, said point being substantially at earth potential, and said parts having the same ratio of impedance as the ratios of the two arms of the bridge across which the input circuit is connected.

4. In an amplifier system, an amplifier having a filament, plate and grid, means forming with the inherent capacity between the electrode a four armed capacity bridge, the filament and plate being connected to opposite corners of the bridge and the grid to one of the other two corners, an input circuit connected between said grid and said opposite corner, and output circuit connected between said filament and said plate, the capacity between the filament and grid being of the order

of one-half that between the filament and the corner opposite the grid.

5. In an amplifier system, an amplifier having a filament, a grid and plate, means forming with the inherent capacities of the amplifier a four armed capacitive bridge, the filament and grid being connected to opposite sides of one arm of the grid, an input circuit connected between the grid and a corner of the bridge opposite said arm, said input circuit including an impedance, a circuit connecting between the filament and plate, the impedance of the arm between the filament and grid being of the order of twice that of the arm between the filament and the corner opposite said arm, and a third circuit connecting between said filament and a point of said impedance so as to divide the latter into two parts having the same impedance ratio as the above ratio between the arms and the bridge.

6. In an amplifying system having a certain frequency range of operation, a plurality of cascade connected amplifiers, coupling transformers between successive amplifiers each including a primary coil connected in the output circuit of one amplifier and a secondary coil included in the input circuit of a second amplifier, and means associated with said coils forming resonant circuits having resonant frequencies above and below the operating range of the system.

7. In an amplifying system having a certain frequency range of operation, a plurality of cascade connected amplifiers each having an input inductance and an output inductance, and a turnable circuit interposed between each output inductance and the succeeding input inductance and interlinking successive amplifiers to transfer energy therebetween, certain of said turnable circuits having natural period above the operating range of the system and others having natural periods below said operating range.

8. In an amplifying system having a certain frequency range of operation, a plurality of cascade connected amplifiers, coupling means between successive amplifiers and including an inductance connected in the output circuit of one amplifier and an inductance connected in the input circuit of a succeeding amplifier, and a turnable circuit associated with each coupling means, one of said turnable circuits having a natural period above the operating range of the system and another having natural frequency below said operating range.

9. In an amplifying system having a certain frequency range of operation, the combination of a plurality of cascade connected amplifiers, a series of coupling transformers in said cascade connection interposed between the successive amplifiers, one of said transformers having a winding and means connected therewith providing a circuit having a resonant frequency below the operating range of the system, and another of said transformers having a winding and means connected therewith providing a second circuit resonant at a frequency above the operating range of the system.

10. In an amplifying system having a certain frequency range of operation, the combination of a plurality of cascade connected amplifiers, a series of coupling transformers in said cascade connection interposed between the successive amplifiers, one of said transformers having a winding, means electrically coupled with said winding providing a circuit having a resonant frequency below the operating range of the system, another of said transformers having a winding and means electrically coupled therewith providing a second circuit resonant at a frequency above the operating range of the system.

In testimony whereof I have hereunto set my hand.

HAROLD F. ELLIOTT.