Aug. 18, 1936. K. RATH 2,051,177

ELECTRON COUPLED CIRCUIT

Filed Feb. 13, 1935 2 Sheets-Sheet 1

Fig. 1

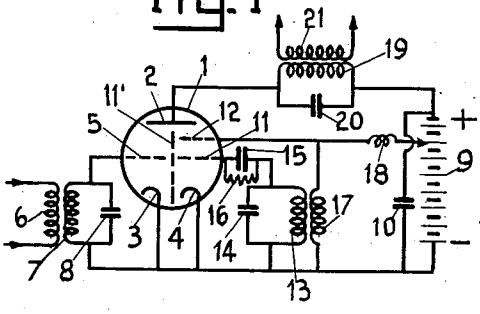


Fig 2

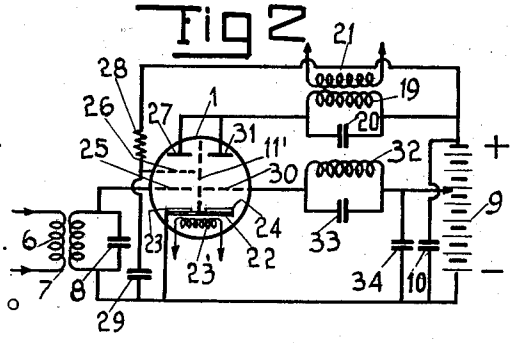


Fig. 3

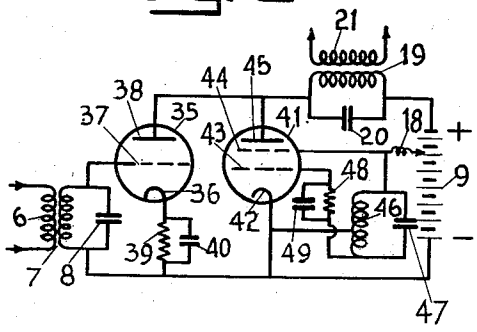


Fig. 4

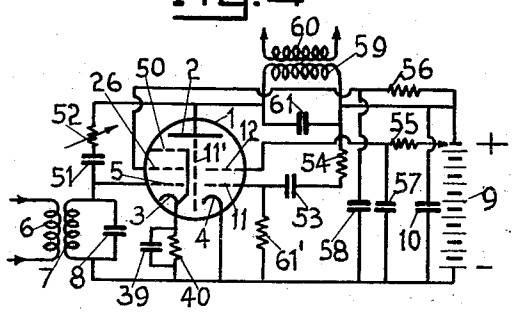


Fig. 5

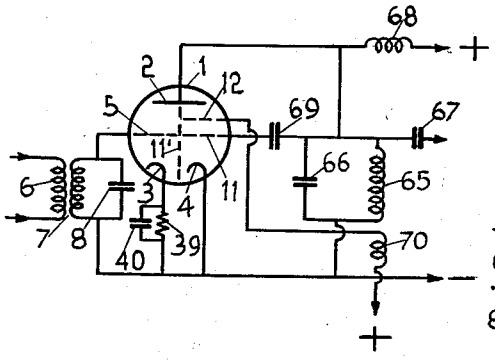
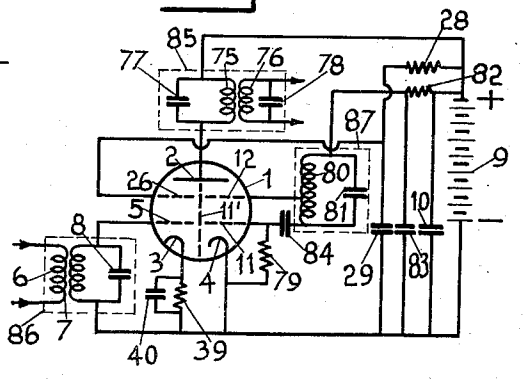


Fig. 6



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Fig. 7

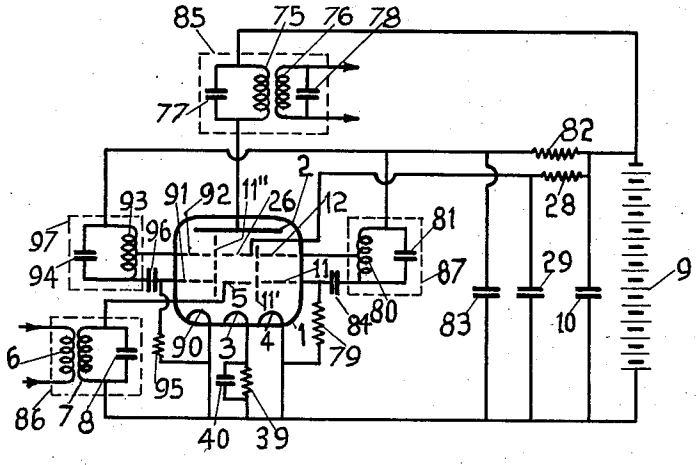


Fig. 8

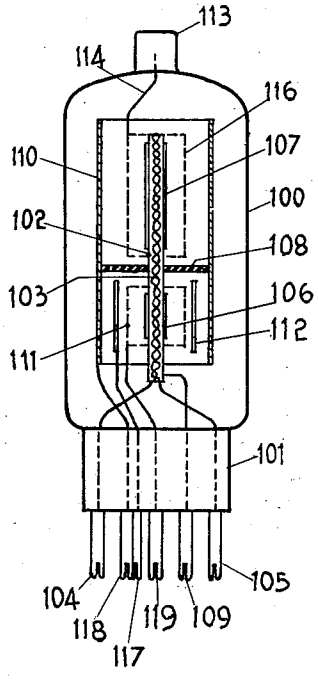
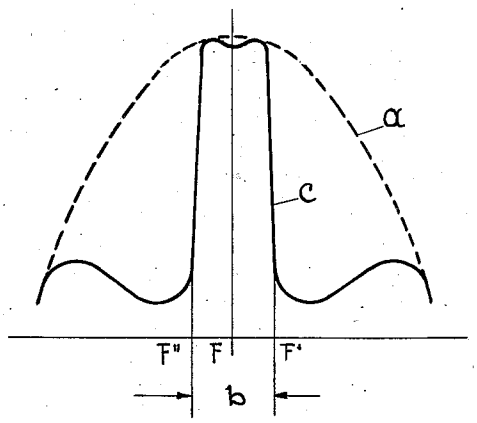


Fig. 9



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Patented Aug. 18, 1936 2,051,177

UNITED STATES PATENT OFFICE

2,051,177

ELECTRON COUPLED CIRCUIT

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Application February 13, 1935, Serial No. 6,286

13 Claims. (Cl. 250—20)

My invention relates to electric circuits, more particularly to electron coupled circuits for transmitting electrical energy from one circuit to another through an electron or ionic discharge stream serving substantially as the sole coupling element between the circuits.

Electron coupled circuits are known and used in the art primarily for combining or mixing oscillating currents of different frequencies to produce therefrom combination frequencies such as difference or intermediate frequency currents in superheterodyne systems for receiving high frequency signals.

One of the main advantages of electron coupled circuits in particular of the type according to the invention as compared with the usual coupling through a capacitative, inductive or ohmic impedance is the fact that the electron coupling besides being substantially independent of frequency is free from any undesired reaction between the circuits as well as inductive coupling frequencies liable to upset and disturb the proper adjustment and stability of operation of the circuits. In addition, the coupling, due to the use of an electron discharge stream as the coupling element, is uni-directional; that is, energy is passed from one circuit (input circuit) to another (output circuit) without reaction from the latter to the former as is the case in the ordinary impedance coupled systems, making it possible to adjust and regulate the current flow and operating conditions in the respective circuits substantially independently and without any interference. This insures a highly stable and constant energy transfer and a steady and undistorted current in the output or utilization circuit.

In the known type of electron coupled systems such as in the mixer or converter circuits used in superheterodyne systems for changing the receiving radio frequency signals into corresponding signals of intermediate frequency, a single electron stream is usually provided acted upon by the separate signals such as by means of grid or control electrodes suitably arranged in the common electron stream. Thus in the case of a mixer arrangement for superheterodyne receivers it is customary to provide at least two grid electrodes in a common electron discharge stream of a space discharge device such as an electronic relay or vacuum tube of known design. One of the grid electrodes is connected to the circuit carrying oscillating currents of one of the component frequencies, such as the incoming frequency of the received radio signals and the other grid electrode is connected to a source or circuit supplying currents of a different locally produced heterodyning or mixing frequency. In this manner the electron stream is acted upon or modulated in accordance with both frequencies and a combination frequency equal to the difference of the two mixing frequencies derived in the common output or anode circuit through the mixing operation of the tube in a well known manner.

A disadvantage of this known type of mixer arrangement is the fact that due to the use of a single electron stream simultaneously modulated in accordance with both component frequencies, it has been difficult to adjust the two components individually and independently to secure most favorable operating conditions and a steady energy transfer to the output or intermediate frequency circuit.

Accordingly it is an object of my invention to provide a new system of electron coupling for energy transfer between separate circuits which allows of an accurate and independent adjustment of the separate component currents and associated electron stream insuring a highly steady and stable combined result in a common output or utilization circuit.

Another object of my invention is to provide a novel type of composite electron tube and circuit connections for use in a mixer or frequency converter for combining currents of different or equal characteristics to secure therefrom a steady and stable resultant combined current of predetermined desired characteristics.

A specific object of my invention is to provide a composite mixer or converter electron discharge tube and circuit connections for combining currents of different frequencies to derive therefrom a current equal to the sum of difference frequency especially adapted for producing a steady and highly stable intermediate frequency current in super-heterodyne radio receiving systems.

A further object of the invention is to provide a novel type of composite electron discharge tube adapted for applying a neutralizing feed back potential to react purely electronically upon the electron stream controlled by an input signal for either stabilizing regeneration employed for increasing the signaling volume and selectivity or for balancing undesired inherent regeneration due to the interelectrode capacity or any other undesirable coupling between the input and output circuits of the tube.

Another object of my invention is the provision of a novel type of composite electron discharge tube and circuit connections therefor for securing reaction upon the electron stream connecting the input and the output circuits for modifying the frequency response characteristic of the energy transferred from the input to the output circuit.

The invention has further objects and advantages which will become more apparent as the following detailed description proceeds, taken with reference to the accompanying drawings wherein I have shown circuit arrangements and

a tube construction in accordance with the invention.

In the drawings, wherein like reference numerals identify like parts,

Figure 1 shows a basic mixer circuit embodying a mixer or converter tube according to the invention for changing one frequency to another frequency adapted especially for the production of the intermediate frequency current in superheterodyne radio receivers.

Figures 2 and 3 show modifications of a mixer or frequency converter according to Figure 1.

Figures 4 and 5 illustrate regenerative receiving circuits with means for stabilizing the regenerative action embodying the novel type of electron coupling according to the invention.

Figures 6 and 7 show filter circuits for transmitting modulated signal energy or energy comprising an extended band of component frequencies by means of electron coupled circuits according to the invention and adapted for modifying the frequency response characteristic or band width.

Figure 8 illustrates schematically a composite vacuum tube for use in electron coupled circuits shown in the preceding figures.

Figure 9 shows a resonance curve illustrative of the operation of the circuit according to Figure 7.

Referring more particularly to Figure 1 of the drawings, I have shown a mixer or converter circuit especially adapted for use in super-heterodyne radio receiving systems comprising a vacuum tube 1 including means for producing at least two separate electron discharge streams impinged upon a common anode 2. The electron streams are produced by separate cathodes 3 and 4. The stream between the cathode 3 and the anode 2 serves for receiving the incoming signals of radio frequency by means of a control or grid electrode 5 arranged in a known manner intermediate between the cathode 3 and anode 2. The incoming radio signals are impressed upon the grid 5 through a high frequency transformer having a primary winding 6 and a secondary winding 7 connected between the grid 5 and the cathode 3, in a known manner. The transformer secondary 7 is shunted by a condenser 8 serving for tuning the circuit to the frequency of the incoming signals in a known manner to secure a maximum control potential applied to the grid 5. If incoming signals are received by the circuit 7, 8, the action of the grid 5 will cause corresponding variations of the space current or the internal impedance of the discharge path between the cathode 3 and the anode 2, producing corresponding current variations in the output circuit of the tube completed through the high tension battery 9 or any other high tension source connected between the anode 2, and the cathode 3. The high tension source 9 is shunted by a bypass condenser 10 in a known manner. The second discharge section of the tube which is preferably isolated or shielded from the first section by a suitable shielding means such as a mica plate or a shield of other insulating material shown at 11' is comprised of a cathode 4, a first control grid 11, a second or anode grid 12, and the common anode 2. In the example shown, this second electron stream serves for producing the local oscillations having a frequency differing from the frequency of the incoming signaling oscillations impressed upon the primary 6 of the input transformer. For this purpose I have shown the grid 11 connected to an oscillatory circuit comprised of an inductance coil 13 and a parallel condenser 14 through a grid condenser 15, the other terminal of the oscillatory circuit being joined to ground or cathode potential. Numeral 16 represents a grid leak for securing the proper steady bias of the grid 11 during operation. In order to maintain sustained local oscillations in the circuit 13, 14 which, as pointed out, is tuned to a frequency differing from the frequency of the incoming signal oscillations, I have shown a feed back coil 17 inductively coupled with the coil 13 of the tuned circuit and connected between the second or oscillating grid 12 and the cathode. In order to supply the required oscillating energy and to cause oscillating potential variations to be impressed upon the anode 2, the grid 12 is further connected to the positive pole or a proper positive tap point of the high tension source 9. A choke coil 18 is placed in the connecting lead to the high potential source to prevent high frequency oscillations from entering the battery or other high potential source. In this manner local oscillations are produced by regenerative feed back action and corresponding variations impressed upon the electron stream passing from the cathode 4 to the anode 2 which in turn cause potential variation at the anode 2 through the action of the positive grid 12. Electrons attracted by the latter will be partly absorbed by it, while the rest will pass through its meshes or openings and be slowed down or decelerated by the attraction of the positive potential on the grid. This slowing down of the electron velocity is equivalent to an increase of the space charge close to the grid 12 within the space between the latter and the anode 2. This space charge or "virtual" cathode, as is understood, is not constant but varies in accordance with the oscillating frequency of the circuit 13, 14. As a result thereof, the anode 2 will be subjected to a varying potential in addition to the potential variations generated by the incoming signaling oscillations from the primary discharge path or section 3, 2 as described.

Since the two electron streams between the cathodes 3 and 4 in the common anode 2 are in parallel, a variation of one stream or a variation of the electrical impedance of the electron path will modulate the other stream, causing a resultant effect in the common output or anode circuit equal to a product function of the variations impressed upon the separate electron streams. In the example described where the variations impressed upon the separate streams are at different frequencies, a resultant current having a frequency equal to the difference of the individual frequencies will be set up in the output circuit which current may be utilized in any desired manner by means of a third tuned circuit comprising an inductance coil 19 and parallel condenser 20 inserted in the output circuit and tuned to the difference of the frequencies of the potential variations impressed upon the two electron streams. This intermediate frequency current may serve for further utilization, such as for amplification as in the case of an intermediate amplifier in a superheterodyne receiver connected to the secondary winding 21 inductively coupled with the winding 19 shown.

The operation of the electronic coupling or mixer circuit in the example shown is further understood by regarding the tuned circuit 19, 20 and the discharge path of section 4, 2 as the external circuit of the discharge path or section 3, 2, the circuit 19, 20 being in parallel to the section 4, 2. Thus any variation in the alter-

nating current resistance of the section 4, 2 alters the impedance of the external circuit. This in turn alters the ratio of the alternating current resistance of the section 3, 2 to the impedance of the external circuit, and so varies the power developed in the external circuit. Since the alternating current resistance of the section 4, 2 varies in accordance with the locally produced oscillations, the external impedance of the unit varies accordingly, and since the impedance of the section 3, 2 varies according to the incoming frequency oscillations, the resultant effect in the external circuits is a product function of the two variations (incoming and local oscillating frequencies), resulting in the production of sum and difference combination frequencies. This method may be termed electron coupling or mixing by absorption in that one electron stream varying according to one function absorbs energy from another stream varying according to another function with both streams being connected in a common output or utilization circuit in substantially parallel relationship.

As is understood, the provision of substantially separate electron streams constituting the only coupling link between the separate circuits allows of an individual, independent and accurate adjustment of the currents in the separate circuits without any disturbing mutual interference or reaction resulting in a highly steady and stable resultant or combined effect or resultant current in the output circuit. It is understood that in a system of the type as described, means should be provided to carefully prevent any outside or stray couplings, such as inductive coupling, between the separate circuits by the provision of efficient and proper shielding arrangements, bypassing or decoupling and blocking devices.

Referring to Figure 2, this shows a similar mixer or converter system adapted for use in super-heterodyne or similar circuits. I have again shown a composite or mixer tube provided with a common indirectly heated cathode 22. The latter may consist in a known manner of a metallic element or sleeve heated by a heating coil 23' supplied from either alternating or direct current heating source. The cathode element 22 has separate sections thereof covered with electron emissive material as shown at 23 and 24 serving as the separate emitters for the individual electron discharge streams which as described in Figure 1 are preferably isolated or shielded as by means of a suitable shield 11'. The first or input electron path is comprised of the emitter 23, input grid 25, screen grid 26, and anode 27. The input grid 25 is connected to the input circuit in a manner as described in Figure 1. The screen grid 26 is connected to the positive pole of the high potential source 9 through a voltage drop resistance 28 and shunted to ground through a de-coupling condenser 29 in a manner well known in the art. The second electron path or section is comprised of the emitter 24, grid 30, and anode 31. I have shown individual anodes 27 and 31 tied together in the output circuit so that the tubes of this construction may be used for purposes other than for mixing or converting as described, as separate discharge units for cascade connection or in any other suitable combination. The local oscillations are produced in the tuned circuit comprising an inductance coil 32 and parallel condenser 33 by virtue of a negative characteristic of the discharge path from the emitter 24 to the grid 30. For this purpose the grid 30 is connected through the tuned circuit 32, 33 to a point of suitable positive potential on the source 9. The negative characteristic is obtained in a known manner as follows: Electrons emitted by the cathode 24 and accelerated to a high speed by the positive potential of the grid 30 partly pass the meshes of the grid and are drawn to the anode 31 and are partly impinged upon the grid 30 where they cause secondary electrons to be emitted. A portion of the latter will be drawn to the anode 31 due to its higher positive potential, thus decreasing the current flow through the grid circuit. With the proper adjustment of the positive potential at the grid 30 and the potential at the anode 31, it is possible in this manner to secure a decreasing grid current with increasing grid potential (negative grid current-voltage characteristic) in such a manner that oscillations will be sustained in the circuit 32, 33 having a frequency equal to the natural or resonant frequency of this circuit. Numeral 34 represents a shunting capacity to prevent the local oscillating currents from flowing through the battery 9. The remaining parts of the circuit are identical to Figure 1 and the function and operation in producing a combination or intermediate frequency are substantially the same.

Referring to Figure 3, this shows a similar mixer circuit arrangement differing from the previous figures in that two separate electron tubes are provided connected in parallel so that the discharge stream of one tube is modulated by the discharge of the other in a substantially similar manner as described. The first or input tube 35 has a cathode 36, input grid 37 and anode 38. Numeral 39 represents a grid biasing resistance connected in the cathode lead in a known manner and shunted by a decoupling condenser 40. The second or local oscillator tube 41 comprises a cathode 42, a control grid 43, oscillating grid 44 and an anode 45. The anodes of the two tubes are connected together and to the positive pole of the high potential source 9 through the intermediate tuned circuit 19, 20 similar as shown in the previous figures. Heterodyning or local oscillations are produced in the local oscillating circuit composed of inductance 46 and condenser 47 by the proper connection to the grids 43 and 44. The grid 44 is connected to a positive point of the high potential source through a choke coil 18 similar as shown in Figure 1. The feed back or regenerative oscillating action of the circuit is obtained by the connection of the cathode 43 to a suitable tap point on the inductance 46 whose terminals are connected to the grid 44 on the one hand and to the grid 43 on the other hand through a grid biasing resistance 48 shunted by grid condenser 49 in a manner well known in the art.

Referring to Figure 4, this shows a different application of an electron coupled circuit according to the invention adapted for stabilizing the feed back operation in a regenerative radio receiving circuit to secure increased receiving signal strength and selectivity. I have again shown an input transformer for applying the high frequency oscillating signals having a primary 6 and a secondary 7 being shunted by a tuning condenser 8, similar as described hereinbefore. The composite regenerative tube is similar to the tube described before and has a first discharge section comprised of a cathode 3, input grid 5, screen grid 26, suppressor grid 50, and a common anode 2. This discharge section serves for applying and

amplifying the incoming signal oscillations. The second discharge section isolated from the first section by a suitable screen shown at 11' is comprised of a cathode 4, control grid 11, positive grid 12 and common anode 2. This latter section serves for providing and applying a stabilizing feed back potential to act purely electronically on the primary or input discharge section for obtaining a fine and accurate regulation of the degree of regeneration and stabilizing the regenerative function of the tube. Regeneration may be secured in many well known ways by feeding back amplified output energy from the anode or output circuit into the input or grid circuit, such as by an inductive feed back or capacitative feed back arrangement as shown in the drawings by means of a feed back condenser 51 in series with a variable resistance 52 serving for adjusting the degree of regeneration and connected between the input grid 5 and the anode 2. The provision of such feed back or regenerative circuit as is well known causes the signal strength and the selectivity of the receiving circuit to be considerably increased. However, systems of this type as heretofore known in the art are highly unstable and liable to break into self-oscillation and subject to substantial distortion of the output signals.

In order to overcome these disadvantages and to stabilize the operation of such a system, I have shown an additional neutralizing or stabilizing feed back arrangement associated with the second discharge section 4, 2 and adapted to react upon the primary or receiving discharge section in such a manner as to stabilize the operation within a desired frequency and intensity operating range of the receiving signals. The neutralizing feed back in the example illustrated is comprised of a feed back condenser 53 in series with a resistance 54 connected between the output circuit and the grid 11 of the tube as shown. The screen grids 12 and 26 are shown connected to the positive pole of the high potential source 9 through voltage drop resistors 55 and 56 shunted to ground through condensers 57 and 58, respectively, in a manner well known. The suppressor grid 50 is directly connected to the cathode 3 in a well known manner. The condenser 53 or resistance 54 may be made variable to adjust the proper phase of the neutralizing feed back potential or alternatively the condenser 51 or resistance 52, as shown, may be variable for regulating the phase of the regenerative potential applied to the input grid 5 in such a manner as to secure the proper relationship between the separate feed back potentials applied to the two electron streams to insure efficient and most stable operation of the system. The amplified output current variations may be utilized in any well known manner and applied to a further amplifier or detector as may be desired through a tuned transformer having a primary 59 and secondary 60 and tuning condenser 61 as shown. Item 40 represents a cathode lead resistor shunted by a decoupling condenser 39 for securing proper grid operating bias for the discharge section 3, 2. Item 61' is a grid leak resistance connected between grid 11 and cathode 4.

Figure 5 illustrates a further stabilized feed back system according to the invention. This arrangement principally comprises an amplifier having input and output circuits and a separate electron stream controlled by signals derived from the output circuit to produce current variations impressed on or combined electronically with the input or amplifying electron stream in such a manner as to strengthen the original incoming signaling variations. The reacting or regenerating electron discharge section is preferably provided with suitable means for preventing self-oscillations and means for securing a substantially constant regeneration to prevent additive or cumulative reaction and oscillation of the entire system as will be described in more detail in connection with the circuit arrangement shown. The latter comprises the usual input circuit formed by the coupling inductance 6, tuning condenser 8 and inductance 7, a composite electron tube of the type described having at least two discharge sections, the first section being comprised of the cathode 3, control grid 5 and common anode 2, and the second section comprising cathode 4, control grid 11, and an anode 12 in substantially the same manner as described hereinbefore. The input section 3, 2 may comprise additional screen and suppressor elements as is obvious. The input grid 5 is suitably biased by means of the cathode lead resistance 39 shunted by an equalizing condenser 40 as shown before. Input high frequency signals applied to the grid 5 are amplified in the ordinary manner and corresponding current variations set up in the output circuit of the tube which includes a parallel tuned circuit comprising an inductance 65 and a tuning condenser 66 tuned to the frequency of the incoming signaling oscillations.

The amplified signaling current variations may be utilized and applied to either a further amplifier or a detector or the like through a coupling condenser 67 or any other well known coupling element. The anode voltage is supplied from a high potential source indicated by the plus sign in the drawings with a choke coil 68 placed in the supply lead to prevent high frequency currents from entering the supply circuits. In the embodiment shown, signaling output currents are fed back through a coupling condenser 69 to the grid 11 of the second discharge section 4, 2 of the tube. In this manner the electron stream of this section is varied in accordance with the signaling frequency. In order to prevent self-oscillations in the circuit 65, 66, due to inter-electrode capacity between the anode 2 and the grid 11, I have provided a screen grid 12 connected to a suitable positive biasing potential as indicated by the plus sign in the drawings. The screen grid 12 acts as an output electrode forming an ordinary three-electrode tube together with the control grid 11 and cathode 4. In order to prevent self-oscillations in the circuit 65, 66 due to inter-electrode capacity between the screen or anode grid 12 and the control grid 11, I have shown an opposing feed back or tickler coil 70 in the screen grid lead coupled with the coil 65 of the tuned circuit in such a manner as to oppose and suppress any inherent tendency of the circuits to produce self-sustained oscillations. In a system of the type as described, the screen grid 12 besides preventing the production of self-oscillations serves for performing a further function in stabilizing and maintaining substantially steady regenerating conditions over an extended operating frequency and intensity range for the receiving signals. The connections of the control grid 11 and anode grid 12 are such that the potentials of these electrodes caused by variations of the signaling currents in the tuned circuit 65, 66 vary in the same sense in order to suppress the tendency of self-oscillations as described. Supposing that the grids 11 and 12

become more positive due to an increase or decrease of the signaling oscillations, the grid 12 acting as a screen will draw a larger current resulting in a decrease of the current to the anode 2. From this it follows that the function of the screen grid is to counter-act excessive increase of the regenerating oscillations produced in the tube section 4, 2 thereby insuring a substantially constant relative strength of the regenerative signaling variations in the sections 4, 2 super-imposed upon the input signal variations in the section 3, 2.

Referring to Figure 6, this shows a further embodiment of an electron coupled circuit according to the invention as applied to a filter system for modifying or regulating the shape of the frequency response characteristic of the system with regard to a pre-determined band of component frequencies such as the side bands of modulated high frequency signals. The incoming frequency signals are again applied through the transformer 6, 7 tuned by the condenser 8 as described before and the output signals are supplied by means of a similar transformer having a primary 75 and secondary 76, the primary being tuned by means of a condenser 77 and the secondary being tuned by means of a condenser 78. The composite electron tube for securing the electron coupling is similar to the construction as previously described and has a first electron discharge path comprising a cathode 3, input grid 5, screen grid 26, and common anode 2. The input signals are applied to the grid 5 and cathode 2, the grid being negatively biased by means of a resistance 39 inserted in the cathode return lead and shunted by a condenser 40 in the usual manner as described before. The second electron discharge path comprises cathode 4, control grid 11, positive or anode grid 12, and the common anode 2. Both streams are again preferably isolated such as by means of an insulating screen 11'. The grid 11 is shown to be suitably biased such as by means of a grid leak resistance 79 as shown. High frequency signals comprising a pre-determined band of frequencies applied to the control grid 5 are amplified in the output circuit 75, 77 of the tube connected to the high potential source 9. In order to modify the frequency response characteristic of the path between the input and output circuits of the tube, I have shown a tuned circuit comprising a self-inductance 80 and parallel condenser 81 connected between the positive lead of the potential source and the screen grid 12 of the second discharge section in series with a suitable drop resistance 82 to secure the proper steady operating bias for the grid 12. This circuit is tuned to a frequency differing from the tuning of the input or output circuits, and serves to absorb energy from the discharge stream between the cathode 4 and the anode 2 thus reacting upon the primary stream between the cathode 3 and 2. This results in a modification of the frequency response characteristic with regard to the energy transmitted from the input to the output circuit. Thus if the circuit 80, 81, is slightly tuned above the resonance frequency of the circuit 7, 8 or the circuit 75, 77 currents of a frequency slightly above the resonance frequency are absorbed by the electron stream of section 4, 2 reacting upon the primary section 3, 2 resulting in a sharp cut-off above the resonance frequency.

In order to prevent the generation of self-sustained oscillations in the tuned circuit 80, 81 due to inter-electrode feed back, any one of the known neutralizing or similar arrangements may be provided. In the example shown the tendency to oscillate is suppressed by applying a proper neutralizing potential from the tuned circuit to the control grid 11 through a neutralizing condenser 84 connected between the lower end of the coil 80 and the grid 11 while the positive or screen grid 12 is connected to a proper tap point on the inductance coil. Item 79 represents a grid leak resistance for securing the proper steady operating biasing potential on the grid 11.

Items 83 represents a de-coupling condenser for the screen grid voltages, while the remaining parts are similar as shown in the preceding figure. The operation of the circuit according to Figure 6 in modifying the frequency response characteristic is further explained as follows: Input signaling oscillations applied to the grid 5 cause corresponding variations in the output or anode circuit and corresponding potential variations at the anode 2. These latter in turn will result in a variation of the distribution of the discharge current of the section 4, 2 between the anode 6 and the positive or screen electrode 12. Thus for instance if the anode 2 becomes more positive during one half cycle of the signaling frequency oscillations its current will increase while the current to the screen 12 will decrease. Since the latter current is determined by the frequency response characteristic of the circuit 80, 81 it will react through the electron stream upon the anode 2 and in turn upon the primary discharge path 3, 2, in such a manner as to modify resultant frequency response with regard to the energy transfer from the input to the output circuit.

If it is desired to secure a frequency response curve with a sharp cut-off at both sides of the resonant frequency known as a flat top resonance characteristic for selectively passing a predetermined band of signaling frequencies such as the 10 kilocycle broadcast modulation band an additional electron coupled circuit may be provided in accordance with the invention also slightly detuned relative to the resonance frequency.

Referring to Figure 7, I have shown a system of this character employing a composite electron coupled tube comprising three separate discharge sections one of which serves for amplifying and translating the input oscillations while the other sections are used for producing the required reaction through electron coupling to secure a sharp cut-off of the resonance curve both above and below the resonant frequency.

In Figure 7, item 1 represents the tube having three separate discharge sections. The first discharge section comprises the cathode 90, control grid 91, positive or screen grid 92 and common anode 2; the second or input section comprises cathode 3, control grid 5, positive or screen grid 26 and anode 2; and the third section comprises the cathode 4, control grid 11, positive or screen grid 12 and common anode 2. The sections are preferably isolated from each other as by means of the screens 11' and 11'' as shown. The input currents are applied in a manner as described before to the grid 5 and cathode 3 through the tuned input transformer 6, 7. The grid 5 is suitably biased with respect to the cathode 3 by means of the biasing resistance 39 inserted in the cathode return lead and shunted by the condenser 40. The amplified output current variations are supplied through the trans-

former 75, 76 tuned by primary and secondary condensers 77 and 78 similar as shown in Figure 6. The circuit according to Figure 7 differs from the circuit shown by Figure 6 by the provision of an additional tuned circuit comprised of an inductance 93 and condenser 94 connected to the screen grid 92 and the control grid 91 of the additional discharge section 90, 2 through the coupling condenser 96 and grid leak 95. Otherwise the circuit is substantially identical to the arrangement according to Figure 6. The input and output circuits associated with the section 3, 2 are tuned to the frequency F of the signaling currents. Preferably a broad tuning is chosen such as shown in Figure 9 by the resonance curve *a*. By de-tuning the absorption circuits 80, 81 and 93, 94 associated with the additional discharge sections of the tube in such a manner that one circuit is tuned to a frequency F′ above resonance frequency and the other circuit is tuned to a frequency F″ below the resonance frequency, a sharp cut-off of the resultant resonance characteristic is obtained comprising a narrow band width *b* which may be equal to 10 kilocycles for passing the modulation frequency band in ordinary broadcasting transmitting or receiving circuits. In order to secure a sharp cut-off and a substantially square or flat top shaped resultant curve, it is advisable to design the circuits 80, 81 and 93, 94 with low damping as compared to the damping of the input and output circuits. The latter may be obtained by proper design of the circuit constants or by a regenerative or de-damping action by either properly choosing the neutralizing condensers 84 and 96, respectively, or the connection of the screen grids 12 or 92 to a proper tap point of the induction coils 80 or 93 respectively in such a manner as to obtain a certain degree of regeneration and corresponding damping reduction. As pointed out previously, the separate circuits should be carefully shielded to prevent outside or stray couplings such as by the provision of the proper biasing and blocking elements and metallic shields surrounding the separate circuits elements as indicated by items 85, 86 and 87, 97. Circuits of this type are well suited for use as intermediate amplifying stages in superheterodyne receiving systems, and insure great selectivity and stability and in turn high fidelity of the signals in the associated reproducer such as a loud speaker or the like.

Referring to Figure 8, this illustrates schematically a preferred type of a composite tube construction to be used in the different circuits as heretofore described. There is shown at 100 an evacuated envelope such as a glass bulb for housing the electrodes of the tube mounted to a base 101. The electrode structure comprises a common cathode sleeve 102 of oblong cylindrical shape enclosing a non-inductive heater winding 103 connected to pins or prongs 104 and 105 mounted on the bottom of the base 101. The sleeve 102 is covered with two coatings 106 and 107 of electron emissive material covering adjacent sections thereof and separated from each other by an insulating shield such as a mica disc 108. The coatings 106 and 107 serve as the cathodes for the two separate discharge sections while the common cathode terminal is formed by the sleeve 102 connected to the prong 109. I have furthermore shown a common cylindrical shaped anode 110 concentrically surrounding both discharge systems. The first discharge system which may serve for producing the local oscillations in a converter or mixer tube for super-heterodyne circuits furthermore comprises a control grid 111 preferably of spiral shape concentrically surrounding the cathode 106 and a positive or oscillating grid 112 which may consist of two or more single rods mounted between the grid 111 and the anode 110 as shown. The second discharge path which in the case of a mixer tube serves for applying the incoming oscillations comprises the input or control grid 116 which has been shown connected to a cap terminal 113 mounted at the top of the tube in a known manner through a lead 114. The positive or oscillating grid 112 may be connected to a separate prong 117 on the base 101. The anode 110 is connected to prong 118 and the grid 111 of the oscillating section to prong 119. The electrodes may be mechanically mounted in any suitable manner and not shown in the drawings for the sake of simplicity.

Although I have described the invention with reference to the embodiments shown in the drawings, it is understood that many modifications and variations suggest themselves coming within the broad scope and spirit of the invention as set forth and expressed in the appended claims.

I claim:

1. An electrical system comprising a space discharge device, said device including a pair of cathodes and a common anode to provide separate discharge paths, means for shielding said discharge paths from each other, controlling elements associated with each of said discharge paths, a resonant input circuit connected to the control electrode of one of said discharge paths, a resonant output circuit connected to said common anode, said input and output circuits being tuned to the frequency of a signal applied to said input circuit, and a further resonant circuit connected to the control electrode of the other discharge path, said further resonant circuit being detuned relative to the resonant frequency of said input and output circuits.

2. A frequency converter system comprising a discharge device; means for producing a pair of discharge streams therein; a common output electrode for said streams; means for varying one of said streams in accordance with a first predetermined frequency; means for varying the other of said streams in accordance with a different predetermined frequency; and a utilization circuit connected to said output electrode for deriving combination frequency currents obtained from said first and second frequencies.

3. A frequency converter system comprising a discharge device; means for producing a pair of space discharge streams therein; a common output electrode for said streams; means for varying one of said streams in accordance with a first predetermined frequency; means for varying said other stream in accordance with a different pre-determined frequency; and a common output circuit including a circuit tuned to a frequency equal to the difference of said first and second frequencies.

4. In combination with an electrical system comprising a discharge device; a first discharge path therein having a cathode; an anode and a control electrode; a second discharge path comprising a cathode, said anode and a control electrode; a common output circuit connected to said anode; means for controlling said first stream in accordance with a pre-determined function; further means for controlling said second stream in accordance with a different function;

and means for deriving currents in said output circuit varying in accordance with a resultant function obtained from combination of said first and second functions.

5. A frequency converter system comprising a space discharge device; a pair of cathodes therein; a common anode operatively associated with said cathodes to provide two separate discharge paths; a common output circuit connected to said anode; means for varying the impedance of one of said discharge paths according to a predetermined first frequency; means for varying the impedance of said other discharge path in accordance with a different frequency; and a circuit connected in said output circuit and tuned to a frequency equal to the difference of said first and second frequencies.

6. A frequency converter system comprising an electron discharge device; a pair of cathodes and a common anode therein to provide two separate discharge paths; screening means between said discharge paths; controlling elements associated with each of said discharge paths; an input circuit carrying currents of a predetermined frequency connected to the controlling element of one of said discharge paths; means for applying potential variations of different frequency to the controlling element of said other discharge path and circuit tuned to a frequency equal to the difference of said first frequencies connected in said output circuit.

7. An electrical system comprising a space discharge device; a pair of cathodes and a common anode therein to provide two separate discharge paths; means for shielding said discharge paths from each other; controlling elements associated with each of said discharge paths; means for applying input signals to the control element of one of said discharge paths; means for applying potential variations to the control element of said other discharge path to react and modify the variations of said first discharge path and a translating device in said output circuit for utilizing modified output current variations of predetermined characteristic.

8. A frequency converter system comprising a space discharge device; a pair of electron emitters and a common anode therein to provide two separate discharge paths; means for screening said paths from each other; a control element in one of said discharge paths; an input circuit connected to said control element for applying input potential variations, said other discharge path including a control element and a positively biased grid electrode close to said anode; means for applying local potential variations to said second control element; and a tuned circuit in said output circuit for utilizing combination currents resulting from said incoming and local potential variations.

9. A frequency converter system comprising a space discharge device; a pair of electron emitters and a common anode therein to provide two separate discharge paths; a control element for said first discharge path and an input circuit connected therewith for applying controlling potential in accordance with incoming oscillations; a control grid and a screen grid for said second discharge path; a tuned circuit associated with said control and screen grids in regenerative connection for producing local oscillations of different frequency from said incoming oscillations and a tuned circuit connected in said output circuit for receiving beat frequencies obtained from combination of said incoming and said local oscillations.

10. A frequency converter system comprising a space discharge device; a pair of electron emitters and a common anode therein to provide two separate discharge paths; an output circuit connected to said anode; a control element for said first discharge path; an input circuit for receiving incoming oscillations connected to said control element; at least one positive grid electrode for said second discharge path and a tuned circuit associated therewith; means for sustaining local oscillations in said tuned circuit of different frequency from said incoming oscillations; and a tuned circuit inserted in said output circuit for receiving beat frequency currents obtained from combination of said incoming and local oscillations.

11. A frequency converter system comprising a space discharge device; a pair of electron emitters and a common anode therein to provide two separate discharge paths; an output circuit connected to said anode; a control element for said first discharge path; an input circuit for applying incoming frequency oscillations to said control element and a grid electrode for said second discharge path having a positive potential applied to it to secure a negative resistance characteristic; a tuned circuit connected to said grid electrode for generating sustained local oscillations having a frequency different from the frequency of the incoming oscillations and a further tuned circuit inserted in said output circuit for receiving beat frequency currents obtained from combination of said incoming frequency and local frequency oscillations.

12. An electrical circuit comprising means for producing a first space discharge path; means for producing a second space discharge path, a common output electrode for said discharge paths; means for shielding said discharge paths from each other; a control element for said first discharge path; an input circuit connected to said control element for applying input potential variations; an output circuit for said discharge path; said input and output circuits having a pre-determined frequency response characteristic; a control element for said second discharge path and a tuned circuit connected thereto having a different frequency response characteristic from said input and output circuits for modifying the impedance of said second discharge path to react upon the first discharge to modify the frequency response characteristic of said input and output circuits.

13. An electrical system comprising a space discharge device, said device including a pair of cathodes and a common anode to provide separate discharge paths, means for shielding said discharge paths from each other, a control element for one of said discharge paths, a resonant input circuit connected to said control element, an output circuit connected to said anode, said input and output circuits being tuned to the frequency of incoming signal oscillations, a screen grid for said second discharge path, a resonant circuit connected to said screen grid, said last resonant circuit being detuned relatively to the tuning frequency of said input and output circuits, means for maintaining said screen grid at a high positive potential and means for preventing the production of self-excited oscillations in said last mentioned resonant circuit.

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