Fig. 1

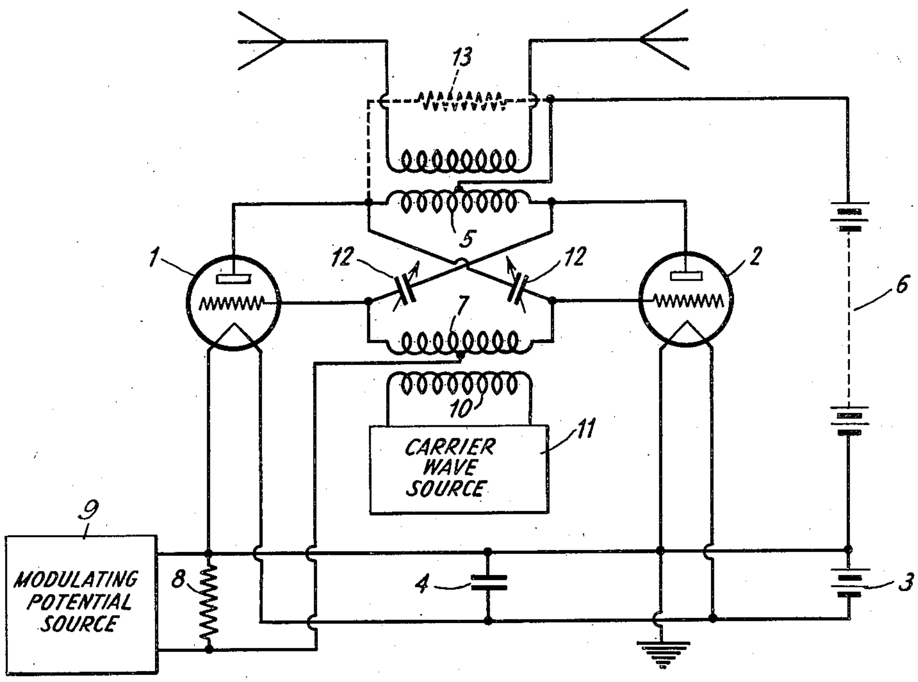
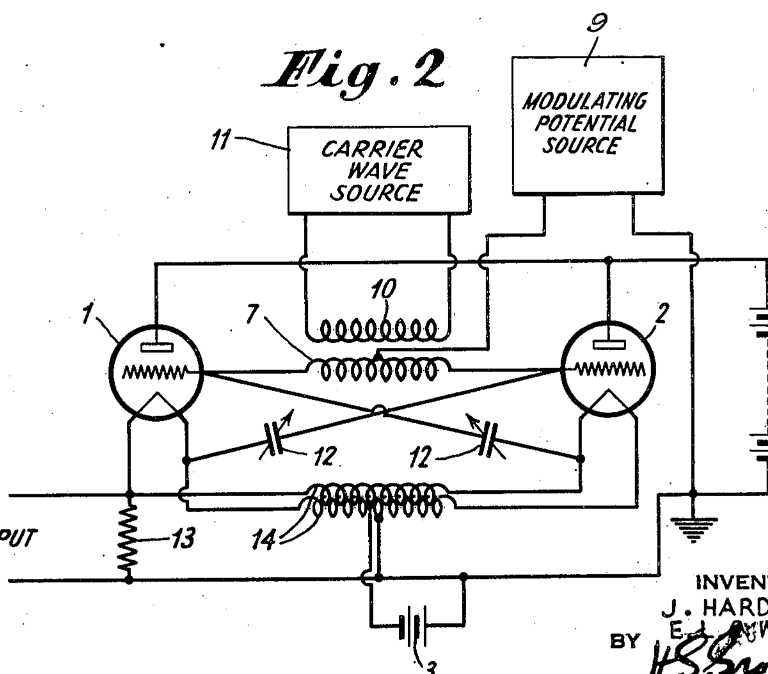



Fig. 2

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THERMIONIC TUBE MODULATOR

Filed Oct. 10, 1936 3 Sheets-Sheet 2

Fig. 2a.

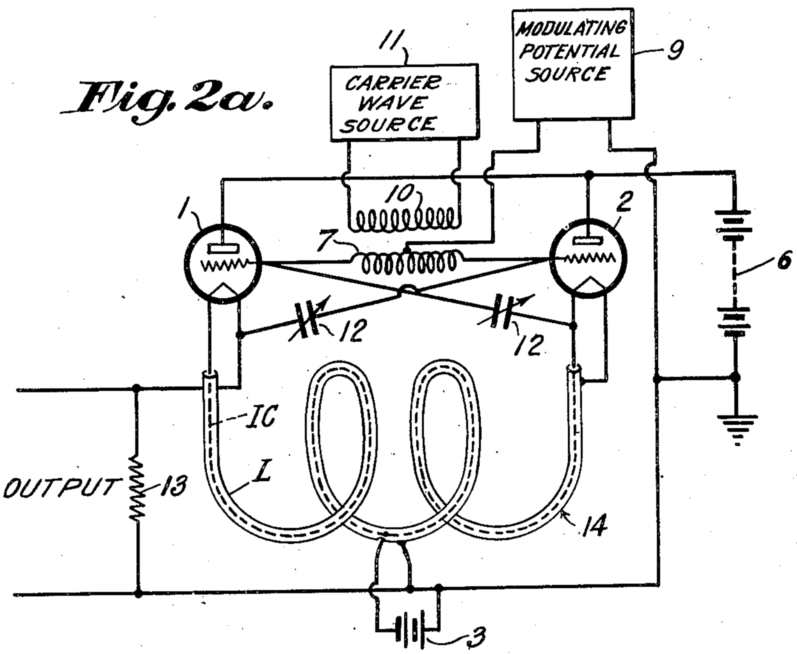


Fig. 3a.

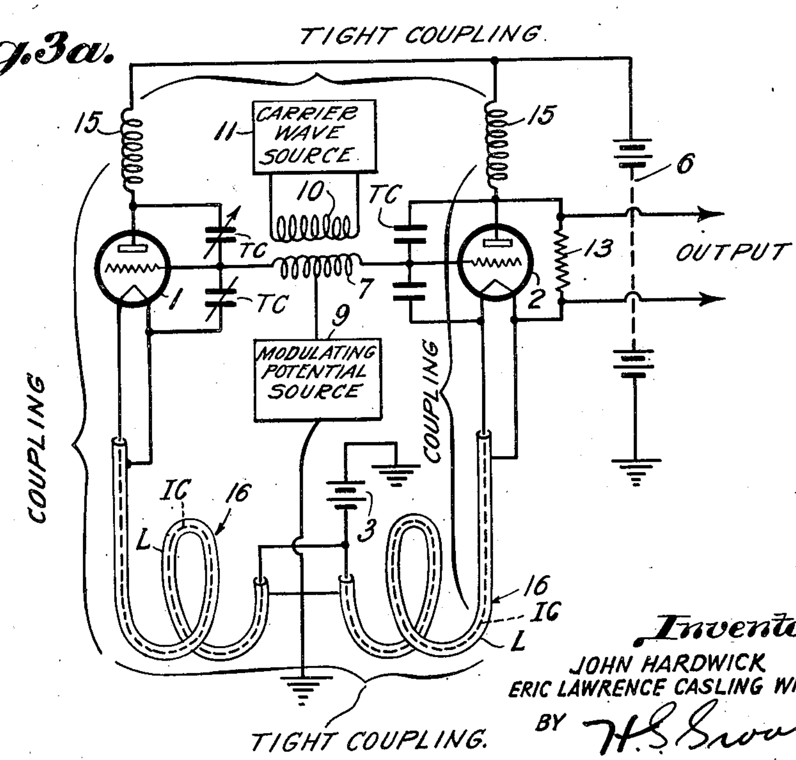


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Fig. 3

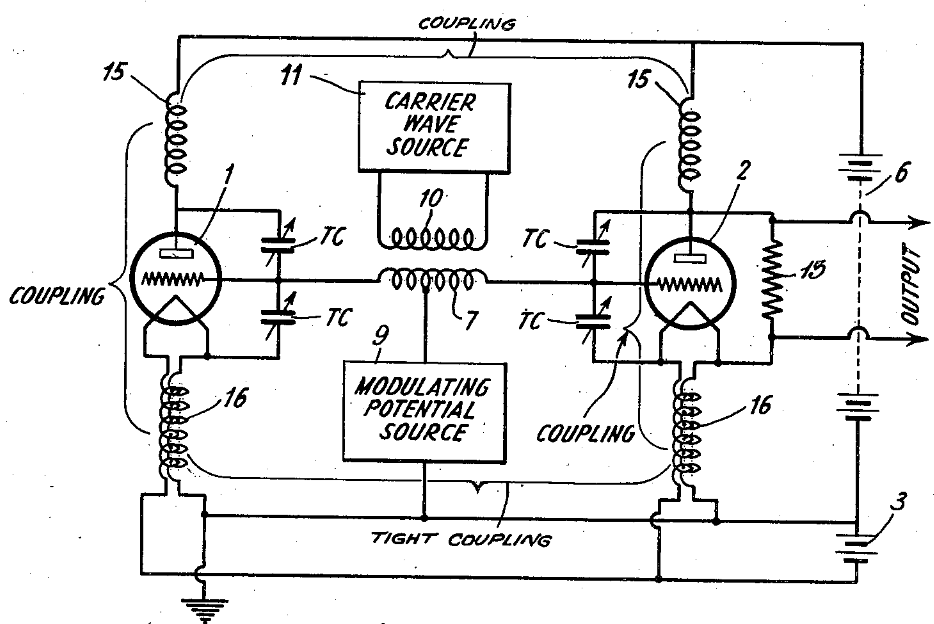
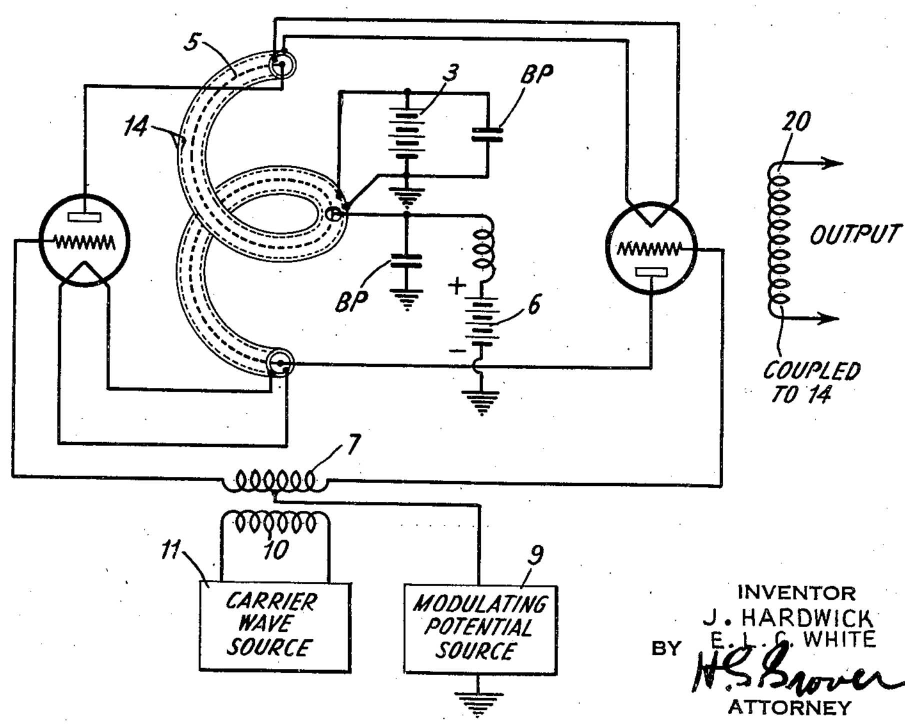



Fig. 4





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## THERMIONIC TUBE MODULATOR

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Application October 10, 1936, Serial No. 104,930
In Great Britain October 15, 1935

11 Claims. (Cl. 179—171.5)

The present invention relates to thermionic valve modulators, and is particularly concerned with amplifiers and modulators which may be required to handle modulation frequencies extending over a wide band of frequency such, for example, as may arise in television systems.

It is an object of the present invention to provide a modulator which, for a given power output, will handle without substantial distortion frequencies considerably higher than can be handled by known modulators.

It is found that the frequency above which many known thermionic tube modulators commence to introduce distortion is determined in part by the capacity of the neutralizing condensers which it is found necessary to employ, and it is a further object of the present invention to provide a modulator in which the necessity for the use of neutralizing condensers is avoided.

According to the present invention, in a thermionic tube modulator comprising a thermionic tube having a cathode, an anode and a control grid, and a source of anode current associated with said tube, an impedance element is connected between said cathode and the negative terminal of said source, said impedance element forming part of both the anode-cathode and the control grid-cathode circuits of said tube, and a load circuit to which modulated carrier frequency oscillations are to be fed is so associated with said impedance element that the whole or a part of the impedance of said load circuit lies effectively between the cathode of said tube and the negative terminal of said source.

In a preferred arrangement, there are employed two tubes having their anode circuits connected in parallel with respect to the anode current source, and having a carrier frequency applied to their control grids in push-pull and modulation frequencies in parallel. The impedance of the load circuit is preferably arranged to lie effectively both in the cathode circuit of the tube or tubes and in the anode circuit thereof, the distribution of the load impedance between the two circuits being made such that the use of neutralizing condensers is rendered unnecessary.

Reference will now be made to the accompanying drawings, in which

Figure 1 shows diagrammatically a known form of modulator which will be referred to for purposes of explanation,

Figures 2 and 2*a* show modulators arranged in accordance with the invention, and

Figures 3, 3*a* and 4 show modifications of the arrangement of Figure 2.

Like parts in the several figures are given the same references.

Referring to Figure 1, two similar thermionic tubes 1 and 2 have their filaments connected in parallel to a source of filament current indicated by battery 3; the latter is shunted by condenser 4. The anodes of the two tubes are connected to the opposite ends of a coil 5, such as the primary winding of an output transformer, the center point of which is connected to the positive terminal of an anode current source 6, the negative terminal of which is earthed.

The control grids of tubes 1 and 2 are connected to the ends of the secondary winding 7 of an input transformer, the center point of which winding is connected to one end of a resistance 8, the other end of which is grounded, across which modulation frequency potential differences are established from source 9. A primary winding 10 is coupled to 7 and 10 is connected at its terminals to a source of wave energy 11 of carrier frequency.

In order to prevent coupling between the anode circuits and the grid circuits of tubes 1 and 2, due to the anode-to-grid capacity (referred to hereinafter as $C_{AG}$) of each tube, neutralizing condensers 12 are provided as shown. The capacity of each of condensers 12, which will be referred to as $C_N$, is made equal to $C_{AG}$. The impedance of the load circuit to which the modulated oscillations are fed is represented by resistance 13, the value of which will be referred to as R. In practice the load may comprise an antenna coupled as shown to 5. It is assumed that the frequency discrimination introduced by the circuits represented by R, up to and including the aerial, is small compared to that occurring in the anode circuit of the tubes, so that R may be regarded as not varying with frequency; this is substantially the case in practice.

Now in Figure 1, since the anode to grid capacity is neutralized, i. e., $C_{AG}=C_N$, the minimum total capacity considered in shunt across resistance 13, i. e., across one half of the coil 5 is $4(\frac{1}{2}C_{AG}+\frac{1}{2}C_N+\frac{1}{2}C_{AF})$ where $C_{AF}$ is the anode to filament capacity of one tube. To be added to this in practice are the stray capacities which can be kept down to the order of $C_{AF}$. Therefore, the modulation frequency ($f$) at which the frequency curve of the modulator is 3 descibels down is given by:

$$f=\frac{1}{2\pi R\times 2\text{ (capacity across }R)}$$

$$=\frac{1}{2\pi R\times 4(C_{AG}+C_N+C_{AF}+2C_{stray})}$$

(where $C_{stray}$ is the stray capacity across the whole coil) and it will be seen that this frequency can be increased not only by decreasing the value of the capacity in shunt with coil 5, but also by decreasing the value of R, the load resistance. In practice, the value of R for a given power output is fixed and hence R cannot be reduced without sacrificing the power output, but in accordance with one feature of the invention the effective value of R is reduced as will hereinafter be apparent.

Reference will now be made to Figure 2, in which there is shown an arrangement wherein the load impedance is given the desired value for maximum power output, but wherein the effective resistance for damping is reduced (and hence the frequency $f$ is increased) by the use of negative, or anti-regenerative feedback. In the arrangement of Figure 2, the coil 5 of Figure 1 is omitted, and the filaments of tubes 1 and 2 are connected to their associated current source 3 through the two tubes of a double wound inductance coil 14, connections being made to battery 3 from tapping points in the two windings of coil 14.

The load resistance 13 is connected between the cathode of tube 1 and ground, and the load impedance thus lies wholly in the cathode circuit. Coil 14 provides negative feedback from the anode circuits of tubes 1 and 2 to the grid circuits thereof. Neutralizing condensers 12 are provided as shown, and the capacity of each is made equal to the grid-to-filament capacity of tube 1 or 2.

More in detail, since the load 13 is connected across one half of the coil 14 the latter acts as a step-down transformer and hence can absorb no load. The condensers 12 are employed to neutralize the grid-filament capacity of the tubes 1 and 2, while coil 14 provides negative feedback since it is common to the anode and the grid circuits. The resistance 13, which is shown in the circuits, is, of course, not a physical part thereof and merely represents the load on the tubes. In practice, in a modulator, the impedance represented by resistance 13 may comprise the impedance of the aerial and feeder which would be coupled to the output circuit shown in Figure 1 through, for example, the medium of a coil coupled to coil 5.

With tubes in the circuit of Figure 2 similar to those employed in the arrangement of Figure 1, the effective tuning capacity, that is to say, the total capacty which takes part in determining the frequency at which the modulation characteristic is 3 dbs. down, is substantially the same as in the arrangement of Figure 1, but the effect of the negative feed-back due to coil 14 is that the load 13 is effectively shunted by a resistance equal approximately to

$$\frac{1}{g}$$

where $g$ is the mutual conductance of the tubes 1 and 2. Thus the load may be given the desired value for maximum power output, but its effective damping value is less than this, and hence the frequency range of the apparatus is increased.

The method of coupling the aerial to the modulators of Figure 2 is not germane to the invention, and is not described; any desired suitable circuit arrangement may be employed.

In the arrangement of Figure 3, the load 13 is associated with both the anode and cathode circuits of tubes 1 and 2, and the arrangement is made such that proportion of the load associated with the anode circuit to the load associated with the cathode circuit is such that the use of neutralizing condensers is unnecessary.

In Figure 3, the anodes of tubes 1 and 2 are connected to the positive terminal of source 6 through coils 15 which are tightly coupled, and the cathodes thereof are connected to the source 3 through double-wound coils 16, respectively which coils are also tightly coupled. The load 13 is connected between the anode of tube 2 and the cathode thereof, and coils 15 and coils 16 respectively are coupled together, said latter coupling also preferably being tight. The output may also be impressed from both tubes on windings differentially coupled to the two windings 16.

The values of the inductances of coils 15 and 16 are made such that

$$\frac{L_{15}}{L_{16}}=\frac{C_{GF}}{C_{AG}}$$

where $L_{15}$ and $L_{16}$ are the inductances of coils 15 and 16, and $C_{GF}$ and $C_{AG}$ are the grid-to-filament and anode-to-grid capacities of tubes 1 and 2. In these circumstances, the high-frequency potential differences set up across coils 15 and 16 are in the same ratio as those set up across $C_{GF}$ and $C_{AG}$. There is thus no coupling between the tube anodes and grids. Adjustable trimming condensers TC may be connected between the anode and grid and between the grid and filament of each tube so that the relation give above may be readily realized, it being inconvenient to adjust $L_{15}$ or $L_{16}$.

The total effective tuning capacity in this case is made up of

$$2\left(\frac{C_{AG}.C_{GF}}{C_{AG}+C_{GF}}+C_{AF}\right)$$

together with the stray capacities, and is less than in the arrangement of Figure 1 owing to the absence of neutralizing condensers.

For a tube of the water-cooled anode type, the following inter-electrode capacities are typical:

$C_{AG}$=20 micro-microfarads
$C_{AF}$=15 micro-microfarads
$C_{GF}$=30 micro-microfarads

So that if stray capacities amount of 10 micro-microfarads, the total tuning capacity in the case of Figure 1 is 130 mmfds., while in the case of Figure 3 it is 64 mmfds., this represents an increase in frequency range of approximately 100%.

Furthermore, on account of the negative feedback due to coils 16, a damping resistance of a valve equal to approximately

$$\frac{1}{g}$$

is effectively introduced across coils 16. For a tube such as has been considered,

$$\frac{1}{g}$$

may be 100 ohms, and the optimum value for R, 400 ohms. The effective value of

$$\frac{1}{g}$$

transferred to the load, is

$$100\times\left(\frac{C_{AG}+C_{GF}}{C_{AG}}\right)^2=625 \text{ ohms}$$

Hence, due to the use of negative feedback, the frequency range is further increased

$$\frac{625+400}{625}$$

or 1.6 times.

Thus in the arrangement of Figure 3, the frequency range is about 3 times that of the arrangement of Figure 1. Further, the capacity across the modulation frequency input terminals is reduced by the omission of the neutralizing condensers.

The double-wound coils 14 and 16 of Figures 2 and 3 may be wound of double wire, or may be constituted by a copper pipe forming one lead L, and having an insulated conductor IC within it which serves as the other lead as shown in Figures 2*a* and 3*a* respectively.

In the arrangement of Figure 4 the filament heating windings 14 comprise two concentric tubes which also enclose the anode winding 5. The winding 5 is symmetrically grounded through a source of anode potential 6. The concentric tubes 14 are also symmetrically tapped and connected to a source 3 and to ground. Here, as in Figure 3 the need of neutralizing condensers is eliminated by proportioning the load in the anode circuits relative to the load in the cathode so that the relation

$$\frac{L \text{ anode}}{L \text{ cathode}}=\frac{C_{GF}}{C_{GA}}=1$$

If necessary, a small capacity may be connected between the grid and anode or grid and filament to insure the above relation. In this manner coupling between the grids and anodes is eliminated. Negative feedback is produced in the windings 14 to thereby introduce damping in the circuits and broaden the frequency band which may be handled uniformly. In the arrangement of Figure 4 the load or output 20 is coupled to the entire winding 14, in this respect differing from Figure 3, to utilize the output of both tubes fully.

It is found that in arrangements according to the invention, it may be necessary to arrange that the amplitudes of the applied carrier and modulation frequency oscillations are greater than are necessary in known arrangements such as that of Figure 1. A further important feature of transmitters embodying modulators according to the invention is that they have characteristics which are more nearly rectilinear than those of transmitters embodying known modulators.

I claim:

1. In a signalling system, a pair of electron discharge tubes each having an anode, a cathode and control grid, said cathodes being of the filamentary types, an input circuit on which wave energy may be impressed connected with said control grids, parallel inductances connecting the terminals of said filamentary cathodes together and to a source of heating current, other parallel inductances connecting said anodes to the positive terminal of a source of potential the negative terminal of which is connected to said source of heating current, the ratio of said last named parallel inductances to said first named parallel inductances being equal to the ratio of the capacity between the grid and filament of said tubes and the capacity between the anode and grid of said tubes to inherently neutralize said tubes and a load circuit connected between the anode and cathodes of said tubes.

2. A system as recited in claim 1 wherein said grids are connected in push-pull relation by said input circuit and wherein modulating potentials are applied in phase to like electrodes in said tubes.

3. In a signalling system, a pair of electron discharge tubes each having an anode, a control grid and a filamentary cathode, parallel inductively coupled conductors connecting said filamentary cathodes together, connections between points on said conductors and a source of heating current for said filamentary cathodes, a connection between one of said points and ground, inductances connecting the anodes of said tubes together and to the positive terminal of a source of potential the negative terminal of which is grounded, the ratio of the inductance in the anode to ground circuit relative to the inductance in the cathode to ground circuit being equal to the ratio of the capacity between the control grid and filament and the capacity between the anode and grid to thereby neutralize said tubes and circuits, means including said parallel conductors connecting said control grids to said cathodes thereby insuring degeneration in said tubes and circuits, means for applying wave energy to the control grids of said tubes, and means for impressing voltages appearing between said anodes and cathodes on a load circuit.

4. A system as recited in claim 3 wherein said first named means connects said control grids in push-pull relation and wherein modulating potentials are applied in phase to said grids.

5. In a signalling system, a pair of electron discharge tubes each having an anode, a control grid, and a filamentary cathode, inductances connecting said filamentary cathodes together, connections between points of symmetry of said inductances and a source of filament heating current, a connection between a point on said inductances and the negative terminal of a source of potentials, means connecting the anodes of said tubes directly together and to the positive terminal of said source of potential, a load circuit connected between the cathodes of said tubes and the negative terminal of said source of potential, a source of wave energy to be relayed, a reactance connected between the control grids of said tubes, means for impressing wave energy from said source on said reactance, and a connection between a point on one of said inductances and the control grids of said discharge tubes whereby said one of said inductances is in the circuit between said control grids and cathodes and the circuit between said anodes and cathodes to insure degeneration in said tubes and circuits, and neutralizing condensers connecting the control grid of one of said tubes to the cathode of the other of said tubes and cathode of the latter tube to the control grid of the former.

6. An electron discharge tube amplifier comprising an electron discharge tube having an input grid and cathode on which oscillations to be amplified are impressed and an output electrode, an output circuit from which the amplified oscillations may be applied to a load connected between said output electrode and cathode, an inductance in said output circuit tuned by an associated shunt capacity including the capacity of said tube and circuits to resonate at a predetermined frequency and a connection between a point on said output circuit and ground such that

a substantial amount of said output circuit is effectively arranged between the cathode of said tube and ground whereby negative or anti-regenerative feedback at the frequency of the oscillations to be supplied to the load occurs in said circuit so that the load is effectively shunted by a resistance and its effective damping is increased.

7. An electron discharge tube modulator comprising two electron discharge tubes having grid, anode and cathode electrodes arranged in push-pull, means for impressing oscillations to be modulated on the grids of said tubes, a neutralizing condenser connected between the grid of each tube and the cathode of the other tube, an output circuit including an inductance tuned by an associated capacity including the capacity of said tubes and circuits to resonate at a predetermined frequency connected between said anodes and said cathodes, a connection between a point on said output circuit and ground such that substantially the entire output circuit is effectively arranged between the cathodes of said tubes and ground whereby negative or anti-regenerative feedback occurs and the load is effectively shunted by a resistance so that its effective damping is increased.

8. An electron discharge tube modulator comprising an electron discharge tube having a control grid on which oscillations to be modulated are impressed, said tube having an anode and a cathode, an output circuit comprising an inductance tuned by a shunting capacity including the tube capacity to resonate at a predetermined frequency connected between said anode and cathode, means for grounding a point on said output circuit to divide the same in two portions, the ratio between which are equal to the ratio between the tube capacities between the grid and cathode and grid and anode, and means for coupling a load circuit to the anode and cathode ends of said output circuit.

9. A system as recited in claim 5 wherein said inductance connecting said filamentary cathodes together comprise concentric members in the form of a tubular conductor, and a conductor within said tubular conductor.

10. In an electron discharge amplifying system for delivering to a resonant load circuit carrier waves modulated to produce sidebands comprising a channel wider than the band of uniform transmission of the said resonant load circuit per se, an electron discharge tube having electrodes connected with said resonant load circuit, means including an input circuit connected with the electrodes of said tube for causing to flow in said tube modulated wave energy, means in said circuits for reducing the coupling inherent in the tube between said resonant load circuit and said input circuit, and means for degeneratively feeding a sufficient voltage from said load circuit to said input circuit to make the apparent impedance of said tube to which said load circuit is connected so low that the said channel of sidebands is substantially uniformly transmitted by said resonant load circuit.

11. In a signalling system a pair of electron discharge devices each having electrodes including a filamentary cathode, a control grid, and an anode, means for impressing wave energy to be modulated in push-pull relation on the control grids of said tubes, means for impressing modulating potentials in phase on the control grids of said tubes, parallel conductors interconnecting the filamentary cathodes of said tubes, said parallel conductors being coupled together, a source of filament heating potentials connected between points on said conductors, an output circuit connecting the anodes of said tubes in parallel and to a point on one of said conductors, said output circuit having a portion in common with the control grid to cathode circuits of said tubes to produce in said tubes degenerative effects to thereby reduce the impedances of the tubes, and means in said circuits for neutralizing the capacity between the tube electrodes.

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